Owl limpet growth rates and mussel cover in Northern and Central California collected from eight intertidal sites from Jun 2021 to May 2023

Website: https://www.bco-dmo.org/dataset/1000475
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Project
» Evolutionary and ecological dynamics of a contemporary climate-driven range expansion (LottiaRangeExp)

Contributors	Affiliation	Role
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Abstract
As the climate warms, species distributions are shifting poleward, but we have a limited understanding of how organisms perform in their expanded range and the environmental drivers that modulate performance across latitude during range expansions. The abundant center hypothesis (ACH) predicts that abundance and performance decline towards the edge of a species' range and is the foundation for most predictive theory extended to the eco-evolutionary dynamics of range shifts. However, it is unclear how often these predictions are met during actual range shifts and under what contexts deviations are expected. Here, we use a poleward range expansion of an intertidal limpet (Lottia gigantea) to test predictions regarding patterns of performance and environmental drivers across the geographic range. We monitored the growth of individual L. gigantea across eight sites spanning 650 km of the California coast to quantify variation in performance. In this dataset, to relate growth to environmental variation, we surveyed the density of conspecifics and coverage of space-holding species (mussels) in limpet microenvironments. Included for each tagged focal limpet: a plot identifier, limpet count, mussel cover, initial and final shell length and width, initial and final sampling dates and location, and relative growth rate. Abundance declined towards the poleward edge, but mussel cover varied as a mosaic. Stepwise forward model selection showed that growth declined weakly with increasing mussel cover and increased slightly with warmer body temperatures. Overall growth did not fit an ACH pattern, as growth in expanded sites was as high, if not higher than growth in range core sites. In contrast to predictions derived from the ACH, we observed rapid growth near the poleward range edge.

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Coverage

Location: Northern and Central California rocky intertidal zone
Spatial Extent: **N**:38.5101 **E**:-120.6201 **S**:34.7357 **W**:-123.2422

Temporal Extent: 2021-06-28 - 2023-05-15

Methods & Sampling

This dataset contains growth measurements of tagged *Lottia gigantea* individuals collected as part of a long-term monitoring effort. Growth rates were calculated from repeated shell measurements collected during annual resurveys. The dataset includes mussel cover measured at the time of the surveys. The related dataset (found in the Related Dataset section) includes the 2023–2024 survey period separately and includes co-occurring grazer species counts and densities.

Variation in biotic communities:

We surveyed *L. gigantea* habitats to test whether the biotic environment differed among the four range core sites and four expanding edge sites, and whether variation in *L. gigantea* performance was associated with the biotic environment. We considered Dillon Beach, Bodega Marine Reserve, Fort Ross, and Kruse Ranch to be in the expanded range (Sanford et al., 2019), and Vandenberg, Seal Beach, Soberanes Point, and Hopkins Marine Station to be in the range core. Given that *L. gigantea* have a patchy distribution (Fenberg & Rivadeneira, 2011), we haphazardly established 50-100 $1m^2$ plots with limpets present at each site, across approximately 300 m of intertidal habitat. Each plot was marked with marine epoxy (Zspar splash zone compound) in its center. Within each plot, we tagged a single focal *L. gigantea* using a small (< 6 mm) Floy Tag fixed to the anterior end of the shell using a small dab of marine epoxy (Zspar splash zone compound). For each tagged focal limpet, we recorded growth rate using calipers to relate performance to variation in environmental factors.

Within each plot, we recorded co-occurring grazing species and sessile space occupying species (see Related Datasets for co-occurring grazer species counts and densities). In summer 2021, we surveyed conspecific density and mussel cover in each plot. To record conspecific density, we counted all *L. gigantea* individuals within each $1m^2$ plot. To determine mussel cover, we photographed each plot using a digital camera (Olympus Touch), and measured mussel cover for the full plot in imageJ (Schneider, 2012).

To quantify performance across the range in response to biotic drivers, we recorded organismal growth rate as a function the environmental data collected within each $1m^2$ plot. In *L. gigantea* growth rate is a strong metric for performance and fitness, as shell length scales with gonad mass (Kido & Murray, 2003). We measured shell length for all tagged limpets from the anterior to posterior end of the shell using calipers. Each focal limpet was measured annually between 2021 and 2023, and because limpet starting size differed, we calculated relative growth rate (RGR) as $\ln(SL_{Final}/SL_{Initial}/\Delta t)$, where SL is shell length and t is time (Paine et al., 2012).

Data Processing Description

We calculated relative growth rate (RGR) as $\ln(SL_{Final}/SL_{Initial}/\Delta t)$, where SL is shell length and t is time.

BCO-DMO Processing Description

- Loaded tagging_growth2021.2023.csv as table "tagging_growth" with empty string and "nd" treated as missing values
- Renamed columns: Lottia.count to Lottia_count, Mussel.cover to Mussel_cover, Length_i to Length_initial, Width_i to Width_initial, Date_i to Date_initial, Length_f to Length_final, Width_f to Width_final, Date_f to Date_final
- Converted Date_initial from format %m/%d/%y to ISO format %Y-%m-%d (string output)
- Converted Date_final from format %m/%d/%y to ISO format %Y-%m-%d (string output)
- Applied find/replace on Site column: replaced "BMR" with complete name "Bodega Marine Reserve"
- Output to 1000475_v1_limpet_tagging_growth_2021_to_2023.csv

Problem Description

Missing data for limpets that we were unable to collect growth rate from are included, but the RGR column is unfilled.

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Related Publications

Fenberg, P. B., & Rivadeneira, M. M. (2011). Range limits and geographic patterns of abundance of the rocky intertidal owl limpet, Lottia gigantea. Journal of Biogeography, 38(12), 2286–2298. https://doi.org/10.1111/j.1365-2699.2011.02572.x
Methods

Kido, J., & Murray, S. (2003). Variation in owl limpet Lottia gigantea population structures, growth rates, and gonadal production on southern California rocky shores. Marine Ecology Progress Series, 257, 111–124. https://doi.org/10.3354/meps257111
Methods

Paine, C. E. T., Marthews, T. R., Vogt, D. R., Purves, D., Rees, M., Hector, A., & Turnbull, L. A. (2012). How to fit nonlinear plant growth models and calculate growth rates: an update for ecologists. Methods in Ecology and Evolution, 3(2), 245–256. Portico. https://doi.org/10.1111/j.2041-210x.2011.00155.x
Methods

Sanford, E., Sones, J. L., García-Reyes, M., Goddard, J. H. R., & Largier, J. L. (2019). Widespread shifts in the coastal biota of northern California during the 2014–2016 marine heatwaves. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-019-40784-3
Methods

Schneider, C. A., Rasband, W. S., & Eliceiri, K. W. (2012). NIH Image to ImageJ: 25 years of image analysis. Nature Methods, 9(7), 671–675. https://doi.org/10.1038/nmeth.2089
Software

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Related Datasets

IsRelatedTo

Walkes, S., Bay, R., Sanford, E. (2026) **Owl limpet growth rates and density in Northern and Central California collected from eight intertidal sites from May 2023 to Nov 2024.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-06-09 http://lod.bco-dmo.org/id/dataset/1000468 [view at BCO-DMO]
Relationship Description: Data collected from the same sample sites.

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Parameters

Parameter	Description	Units
Plot	Unique identifier for each 1 m^2 plot in which microenvironmental data and focal limpet growth were recorded	unitless
Lottia_count	Number of Lottia gigantea counted within each 1m^2 plot	unitless
Mussel_cover	Area of plot substrate covered by mussels	cm^2
Length_initial	Initial length measurement for the focal owl limpet	mm
Width_initial	Initial width measurement for the focal owl limpet	mm
Date_initial	Initial date of sampling	unitless
Site	Location name; Bodega Marine Reserve, Dillon Beach, Hopkins, Kruse Ranch, Seal Beach, Soberanes, or Vandenberg	unitless
Length_final	Final length measurement for the focal owl limpet	mm
Width_final	Final width measurement of the focal owl limpet	mm
dt	Length of sampling period	days
Date_final	Final date of sampling period	unitless
RGR	Relative growth rate across sampling period for the focal owl limpet	mm/mm/day
Latitude	Latitude of study site, positive is North	decimal degrees
Longitude	Longitude of study site, negative is West	decimal degrees

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Instruments

Dataset-specific Instrument Name	calipers
Generic Instrument Name	calipers
Dataset-specific Description	For each tagged focal limpet, we recorded growth rate using calipers to relate performance to variation in environmental factors.
Generic Instrument Description	A caliper (or "pair of calipers") is a device used to measure the distance between two opposite sides of an object. Many types of calipers permit reading out a measurement on a ruled scale, a dial, or a digital display.

Dataset-specific Instrument Name	Olympus Touch digital camera
Generic Instrument Name	Camera
Dataset-specific Description	Camera: Olympus Touch digital camera
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	Floy Tag
Generic Instrument Name	labeling tag
Dataset-specific Description	Within each plot, we tagged a single focal L. gigantea using a small (< 6 mm) Floy Tag fixed to the anterior end of the shell using a small dab of marine epoxy (Zspar splash zone compound).
Generic Instrument Description	Passive devices attached to captured organisms to specifically identify them when recaptured after release.

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Project Information

Evolutionary and ecological dynamics of a contemporary climate-driven range expansion (LottiaRangeExp)

Coverage: Coastal California intertidal

NSF abstract:
Anthropogenic climate change is shifting the distributions of species across the globe. Such contemporary shifts in species' ranges may have cascading effects on entire ecosystems. This project disentangles the mechanisms underlying climate-driven species range shifts in marine systems using the intertidal owl limpet as a case study. During the recent marine heatwaves off the Pacific coast of North America, populations at the northern range limit in northern California have expanded, with ongoing reproduction even after termination of the heatwave events. This is therefore an ideal system to explore the dynamics of natural selection that occur as species occupy new regions. Broadly, this project deepens understanding of how range shifts occur in marine systems and furthers the ability to predict future species distributions in response to climate change. The project provides research experiences for high school and undergraduate students from historically

underrepresented groups by engaging with existing, demonstrably-effective programs. The investigators host leadership and skill-building workshops for senior female graduate students and engage the public in partnership with the California Academy of Sciences, Bodega Marine Lab, and San Francisco Exploratorium. Finally, the project provides training for a postdoctoral scholar and two graduate students.

Although phenomenological studies suggest that climate-associated range shifts are common in marine systems, to date, mechanistic studies of the climate-organism interactions that alter geographic distributions have largely focused on terrestrial systems. However, dispersal dynamics greatly differ in many marine systems, as currents may frequently transport planktonic larvae into new environmental regimes. This project integrates detailed demographic observations of the recent range expansion of the intertidal owl limpet, Lottia gigantea, with ecological, phenotypic, and genomic measurements of divergence across its range. Specifically, the work 1) documents phenotypic divergence in larval and juvenile traits across the zone of range expansion, 2) uses whole genome sequencing to estimate gene flow across the entire range, 3) identifies genomic patterns of selection across the zone of range expansion and through time, and 4) identifies drivers of variation in performance over latitudinal and microgeographic scales. The ability to monitor this range shift in real time, along with the suitability of this system for tracking individuals across multiple years, allows the investigators to examine the impact of selection in novel range-edge conditions at the phenotypic and genomic levels, and scale from individuals to species-level responses to ongoing environmental 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.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023297

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