

Owl limpet growth rates and density in Northern and Central California collected from eight intertidal sites from May 2023 to Nov 2024

Website: <https://www.bco-dmo.org/dataset/1000468>

Data Type: Other Field Results

Version: 1

Version Date: 2026-06-09

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 8 sites spanning 650 km of the California coast to quantify variation in performance. To relate growth to environmental variation, we surveyed the community of competing grazers for each owl limpet. This table contains individual-level records of initial and final shell dimensions, relative growth rates, and co-occurring grazer species counts and densities (including *Lottia scabra*, *L. digitalis*, *L. pelta*, *Nuttallina* spp., and *Tegula funebris*) within focal *L. gigantea* territories across the eight study sites spanning the range core and expanding poleward edge, sampled between May 2023 and November 2024. Stepwise forward model selection showed that competing grazing species had little effect on growth. 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:38.6042 E:-120.5201 S:34.7357 W:-129.6264

Temporal Extent: 2023-05-08 - 2024-11-02

Methods & Sampling

This dataset represents a subset of a longer-term monitoring effort of tagged *Lottia gigantea* individuals conducted across California intertidal sites. The dataset includes annual measurements collected between 2023 and 2024 and associated survey-derived habitat and grazer community metrics. The related dataset (found in the Related Dataset section) contains growth measurements from earlier survey years, but does not include community sampling data.

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 1m² 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.

For each plot in summer 2023, we sampled the community of competing species within the territories of the focal limpet from 8 sites. Owl limpets are sympatric with several other intertidal grazing species across their range, including limpets (*L. scabra*, *L. digitalis*, *L. pelta*), chitons (*Nutallina* spp.), and snails (*Tegula funebris*) (Stimson, 1973). *L. gigantea* territories are clearly recognizable as darker areas on the substrate (Fenberg, 2013), so we counted all individuals of the above mentioned grazing species within the territories of the tagged focal limpets and measured the territory area on imagej to record density (Schneider et al., 2012). In cases which the territory boundary was uncertain, or territories overlapped, we counted all individuals within a 0.25 m² quadrat, placed with the focal owl limpet at its center. We did not count grazers < 5 mm as *Lottia* congeners are often indistinguishable at that size, cryptic, and difficult to count accurately.

Quantifying performance:

To quantify performance across the range in response to biotic drivers, we recorded organismal growth rate as a function of the environmental data collected within each 1m² 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 (see Related Dataset for additional data), 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).

BCO-DMO Processing Description

- Loaded tagging.growth.24.csv as table "res1" with empty string and "nd" treated as missing values
- Renamed 19 columns to replace dots and abbreviations with underscores and full names: Territory.Area -> Territory_Area, L.scabra -> L_scabra, L.scabra.density -> L_scabra_density, L.digitalis -> L_digitalis, L.digitalis.density -> L_digitalis_density, L.pelta -> L_pelta, L.pelta.density -> L_pelta_density, Nutallina.density -> Nutallina_density, Nuttallina.sp -> Nuttallina_sp, Tegula.funebris -> Tegula_funebris, Tegula.funebris.density -> Tegula_funebris_density, Total.grazers -> Total_grazers, Total.grazers.density -> Total_grazers_density, Length_i -> Length_initial, Width_i -> Width_initial, Date_i -> Date_initial, Length_f -> Length_final, Width_f -> Width_final, Date_f -> Date_final
- Stripped leading and trailing whitespace from Date_initial and Date_final columns
- Converted Date_initial from %m/%d/%y format to ISO date format %Y-%m-%d
- Converted Date_final from %m/%d/%y format to ISO date format %Y-%m-%d
- Renamed Nutallina_density to Nuttallina_density (corrected spelling)
- Replaced site code "BMR" with full name "Bodega Marine Reserve" in the Site column
- Output final data to 1000468_v1_limpet_tagging_growth_2023_2024.csv

Related Publications

Fenberg, P. (2013). Intraspecific home range scaling: A case study from the owl limpet (*Lottia gigantea*). *Evolutionary Ecology Research*, 15(1), 103-110. <https://ir.library.oregonstate.edu/concern/articles/3x816s06c>
Methods

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

Stimson, J. (1973). The Role of the Territory in the Ecology of the Intertidal Limpet *Lottia Gigantea* (Gray). *Ecology*, 54(5), 1020-1030. Portico. <https://doi.org/10.2307/1935568>
Methods

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Related Datasets

IsRelatedTo

Walkes, S., Bay, R., Sanford, E. (2026) **Owl limpet growth rates and mussel cover in Northern and Central California collected from eight intertidal sites from Jun 2021 to May 2023**. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-06-09
<http://lod.bco-dmo.org/id/dataset/1000475> [[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
Territory_Area	Area of owl limpet territory	Square centimeters (cm ²)

L_scabra	Count of all <i>Lottia scabra</i> found within territory boundaries	unitless
L_scabra_density	Density of <i>L. scabra</i> within owl limpet territory boundaries. Calculated as L_scabra/Territory_Area	individual/cm ²
L_digitalis	Count of all <i>Lottia digitalis</i> found within territory boundaries	unitless
L_digitalis_density	Density of <i>L. digitalis</i> within owl limpet territory boundaries. Calculated as L_digitalis/Territory_Area	individual/cm ²
L_pelta	Count of all <i>Lottia pelta</i> found within territory boundaries	unitless
L_pelta_density	Density of <i>L. pelta</i> within owl limpet territory boundaries. Calculated as L_pelta/Territory_Area	individual/cm ²
Nuttallina_density	Density of <i>Nuttallina spp.</i> within owl limpet territory boundaries. Calculated as Nuttallina_sp/Territory_Area	individual/cm ²
Nuttallina_sp	Count of all <i>Nuttallina spp.</i> found within territory boundaries	unitless
Tegula_funebris	Count of all <i>Tegula funebris</i> found within territory boundaries	unitless
Tegula_funebris_density	Density of <i>Tegula funebris</i> within owl limpet territory boundaries. Calculated as Tegula_funebris/Territory_Area	individual/cm ²
Total_grazers	Count of all grazers within owl limpet territory. Calculated by summing L_scabra, L_digitalis, L_pelta, Nuttallina_sp, Tegula_funebris	unitless
Total_grazers_density	Density of all grazers within owl limpet territory. Calculated as Total_grazers/Territory_Area	individual/cm ²
Length_initial	Initial length measurement for the focal owl limpet	mm
Width_initial	Initial width measurement for the focal owl limpet	mm
Site	Location name	unitless
Date_initial	Initial date of sampling	unitless
Length_final	Final length measurement for the focal owl limpet	mm

Width_final	Final width measurement	mm
Date_final	Final date of sampling period	unitless
dt	length of sampling period	days
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
Generic Instrument Name	Camera
Dataset-specific Description	Camera: Olympus Touch
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 <i>L. gigantea</i> 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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