Temporal comparison of mussel (Mytilus californianus) shell thickness determined from shells collected from six study sites along the west coast of North America from 2000 to 2019

Website: https://www.bco-dmo.org/dataset/908647
Data Type: Other Field Results
Version: 1
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Project
» Coastal mosaics of local adaptation and the eco-evolutionary dynamics of a marine predator-prey interaction (Coastal Adaptation)

Contributors	Affiliation	Role
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Abstract
Climate change, specifically ocean acidification, is impacting calcification of marine organisms. A reduction in pH has been shown to affect mussel growth and shell thickness along the Pacific coast of North America. Mussels, Mytilus californianus, are a foundation species in rocky shore ecosystems and are prey for a number of taxa, including the Channeled Dogwhelk, Nucella canaliculata, which feeds by drilling a hole through the shell of their prey. Previous research has documented geographic variation in N. canaliculata predator drilling phenotype on Mytilus californianus. However, few studies have assessed how variation in mussel shell traits shape the evolution of this co-evolving predator. Thus, we analyzed M. californianus shell thickness over two decades (2000-2001, 2008-2009, and 2019) and across ~1,000 kilometers of coastline to quantify the prey-driven selection landscape. We analyzed mussel shell thickness at 1/3 the length of the mussel shell as this is the most commonly drilled region. Mussel shells from the central Oregon coast were thicker than those from California. This pattern is associated with geographic variation in predator drilling phenotypes. However, the selective landscape appears to be changing, with recent mussel shells being thinner than a decade prior, particularly on the central Oregon coast. This research highlights the importance of studying species interactions across broad spatial and temporal scales.

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Coverage

Spatial Extent: **N**:44.8378 **E**:-121.929 **S**:36.4472 **W**:-124.402
Temporal Extent: 2000-07-01 - 2019-06-09

Methods & Sampling

Shell collection took place at rocky shore ecosystems spanning ~1,000 kilometers (km) of coastline along the west coast of North America. Shell collections occurred at three wave-exposed rocky headlands in California (Soberanes Point (36°26'50" N, 121°55'44" W), Bodega Marine Reserve (38°19'09" N, 123°04'28" W), Van Damme State Park (39°16'43" N, 123°48'12" W)) and at three wave-exposed rocky headlands in Oregon (Cape Arago (43°18'13" N, 124°24'07" W), Strawberry Hill (44°15'00" N, 124°06'55" W), and Fogarty Creek (44°50'16" N, 124°03'33" W)).

At each of the six study sites, mussels were collected from wave-exposed, mid-intertidal mussel beds. Mussels from 2000-2001 and 2008-2009 were originally collected for different projects. As a result, the sample size and range of mussel shell lengths for each site and time period varied somewhat. The mussel shells from the 2000-2001 time period came from three surveys. First, in 2000, 100 empty/dead mussel shells from Soberanes Point were collected; subsequently, live mussels from a similar range in shell lengths were collected from Strawberry Hill and Fogarty Creek. Second, in 2001, 25 live mussels from a limited size range (55-73 millimeters (mm)) were collected from each site (except for Cape Arago where 50 mussels were collected). Third, in 2001, quadrat surveys of drilled mussels were completed at a subset of the sites. The mussel shells from the 2008-2009 period were originally collected to survey predation in mussel beds (Sanford & Worth 2009). At each site, mussels from ten 0.25-square meter (m^2) quadrats were removed, measured, and assessed for drill holes. For the mussel shells from 2019, approximately 100 live mussels were collected from each site. For all collections containing live mussels, the tissue was removed, and the shells were rinsed in fresh water and then air dried.

Mussel shells were cut on a bandsaw at 1/3 the length of the left valve from the anterior end. The mussel shell cross sections were scanned (model: CanoScan LiDE 110) and photos of the anterior section were used to calculate thickness via imaging software (ImageJ; Java 1.8.0_172). Maximum and minimum thickness along each cross section was measured, disregarding the dorsal hinge for maximum thickness and growing lip for minimum thickness, as these regions are known to be significantly thicker and thinner, respectively. Subsequently, average thickness was calculated using these two measurements. Due to the historical nature of the 2000-2001 and 2008-2009 mussel shells, there was some variation in how they were processed. First, some of the archived mussels were drilled/empty shells. Second, some of the 2008-2009 mussels only had the right valve remaining. Third, some of the 2000-2001 and 2008-2009 shells were analyzed on the posterior cross section since these shells were cut for a previous experiment and some shell pieces were missing.

We used the 2019 mussel shells to test the validity of our measurement of thickness to alternate metrics for shell thickness. For all 2019 shells, indirect shell thickness across the entire left valve was calculated as:

1000* valve dry weight / surface area

(where surface area = length x ($height^2$ + $width^2$)^0.5 x pi/2) (Freeman & Byers 2006).

We also used 2019 mussels from two sites (Soberanes Point and Strawberry Hill) to determine the integrated thickness of the cross section, measured as the area of the polygon of the scanned image divided by the length of the curved mussel shell.

Data Processing Description

To control for the effect of mussel length on mussel shell thickness, we used the ratio of mean thickness at 1/3 the length of the mussel to mussel length as our response variable.

BCO-DMO Processing Description

- Imported original file "M.californianus_shell_thickness_2000:01_2008:09_2019.xls" into the BCO-DMO system.
- Flagged 'NA' as a missing data value (missing values are blank/empty in the final file).
- Created Latitude and Longitude columns and added the values for each site as provided in the metadata.
- Converted the latitude and longitude values to decimal degrees and rounded to 5 decimal places.
- Renamed columns/fields to comply with BCO-DMO naming conventions.
- Rounded the 'Average_Thickness' column to 3 decimal places to match formatting that had been applied in the original Excel file.
- Rounded the 'Inegrated_Segment_Thickness' column to 3 decimal places.
- Saved the final file as "908647_v1_shell_thickness.csv".

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Data Files

File
908647_v1_shell_thickness.csv(Comma Separated Values (.csv), 239.30 KB) MD5:789fbf96d8708ce91b5162a814d91be1 Primary data file for dataset ID 908647, version 1.

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Related Publications

Freeman, A. S., & Byers, J. E. (2006). Divergent Induced Responses to an Invasive Predator in Marine Mussel Populations. In Science (Vol. 313, Issue 5788, pp. 831–833). American Association for the Advancement of Science (AAAS). https://doi.org/10.1126/science.1125485
Methods

Sanford, E., & Worth, D. J. (2009). Genetic differences among populations of a marine snail drive geographic variation in predation. Ecology, 90(11), 3108–3118. https://doi.org/10.1890/08-2055.1
Methods

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Parameters

Parameter	Description	Units
Site	Name of field site	unitless
Site_Code	Code of field site	unitless
State	State - California or Oregon	unitless
Latitude	Latitude of field site	decimal degrees
Longitude	Longitude of field site; negative values = West	decimal degrees
Date_Collected	Date when mussel shells were collected; may include year, month, and day (yyyy-mm-dd); year and month (yyyy-mm); or only year (yyyy) depending on the site.	unitless
Year_Collected	Year mussel shells were collected	unitless
Time_Period	Year(s) mussel shells were collected. 2000 and 2001 are grouped together and 2008 and 2009 are grouped together.	unitless
Quadrat_num	Quadrat number, if applicable; some of the mussels from 2001 and 2008-2009 were collected during quadrat surveys for prior experiments	unitless
Mussel_num	Identification number of each mussel for each site, year and quadrat (if applicable)	unitless
Shell_Length	Length of valve along the anterior-posterior axis	millimeters (mm)
Height	Height of valve along the ventral-dorsal axis	millimeters (mm)
Width	Width of valve along the left-right axis	millimeters (mm)
Shell_Weight	Dry weight of valve	grams (g)
Surface_Area	Surface area = length x (height^2 + width^2)^0.5 * pi/2	square millimeters (mm^2)
Indirect_Shell_thickness_of_Valve	Indirect shell thickness across the entire valve = 1000 * valve dry weight / surface area	grams per square millimeter (g/mm^2)
Drilled	Inidcates if mussel was drilled - "Drilled" or "Not Drilled"	unitless
R_vs_L	Right (R) or left (L) valve	unitless
A_vs_P	Anterior (A) or posterior (P) section scanned	unitless
Max_Thickness	Maximum thickness of cross section measured using image analysis, disregarding dorsal hinge	millimeters (mm)
Min_Thickness	Minimum thickness of cross section measured using image analysis, disregarding ventral lip	millimeters (mm)
Average_Thickness	Average thickness calculated from max and min thickness measurements	millimeters (mm)
Integrated_Segment_Thickness	Thickness calculated as the total area of the cross section divided by the length of the cross section	millimeters (mm)

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Instruments

Dataset-specific Instrument Name	CanoScan LiDE 110
Generic Instrument Name	Image scanner
Generic Instrument Description	An electronic device that generates a digital representation of an image for data input to a computer. OR a receiver designed to search for a signal within a specified frequency range. [Definition Source: NCI]

Dataset-specific Instrument Name	bandsaw
Generic Instrument Name	Manual Biota Sampler
Generic Instrument Description	"Manual Biota Sampler" indicates that a sample was collected in situ by a person, possibly using a hand-held collection device such as a jar, a net, or their hands. This term could also refer to a simple tool like a hammer, saw, or other hand-held tool.

Dataset-specific Instrument Name	drill
Generic Instrument Name	Manual Biota Sampler
Generic Instrument Description	"Manual Biota Sampler" indicates that a sample was collected in situ by a person, possibly using a hand-held collection device such as a jar, a net, or their hands. This term could also refer to a simple tool like a hammer, saw, or other hand-held tool.

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Project Information

Coastal mosaics of local adaptation and the eco-evolutionary dynamics of a marine predator-prey interaction (Coastal Adaptation)

Coverage: Northeast Pacific coast; California and Oregon, USA

NSF Award Abstract:
Historically, ecologists regarded evolution as a process that typically acts slowly over very long time scales. However, recent studies suggest that evolution might also shape the way species interact over much shorter timespans, ranging from weeks to years. Are these sorts of rapid feedbacks between evolution and ecology important in marine ecosystems? This project will address this question along the Pacific coast of the United States by studying predatory snails (Channeled Dogwhelks) that feed on California Mussels, an important habitat-forming species on rocky intertidal shores. Prior research shows that some dogwhelk populations are composed of an assortment of individuals that differ genetically in how effectively they can drill through mussel shells. This project will test whether short-term changes in the environment can impose rapid natural selection that favors some of these drilling variants over others, altering the effects that a dogwhelk population has on the surrounding mussel bed. At the same time, this project will examine whether regional differences in mussel

shell thickness have influenced the evolution of drilling ability among dogwhelk populations distributed along >900 kilometers of the California and Oregon coasts. Overall, this study seeks to understand the dynamic feedbacks between evolution and ecology that might influence marine communities in the face of changing ocean conditions. This project will train diverse undergraduate and graduate students and will provide the foundation for a significant public outreach component, including the production of accessible video documentaries.

This project seeks to advance our understanding of eco-evolutionary dynamics in the sea by investigating links among oceanographic variation, natural selection, species interactions, and community succession. This project will use the interaction between the Channeled Dogwhelk (*Nucella canaliculata*) and the California Mussel (*Mytilus californianus*) as a model system to address two central objectives. (1) The research team will explore how spatial mosaics of selection drive adaptive differentiation among populations of consumers. Newly collected and archived mussels will be analyzed to characterize variation in shell thickness along the coasts of California and Oregon, and to evaluate whether this spatial mosaic has been consistent or variable over the past two decades. Laboratory experiments will test whether dogwhelk populations distributed across this mosaic have diverged in the thickness of shell that they can drill successfully. (2) The research team will examine whether temporal variation in selection on consumer phenotypes shapes predator-prey interactions, with cascading effects on ecological dynamics. In particular, the project will test whether short-term variation in prey recruitment and shell thickness can impose rapid selection on the frequency of drilling phenotypes within a dogwhelk population. A field experiment will also test whether selection on these predator phenotypes in turn alters the trajectory of mussel bed succession.

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-1851462

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