Morphological data of Littorina obtusata populations from reciprocal transplant experiments in the Gulf of Maine conducted 20 years apart

Website: https://www.bco-dmo.org/dataset/990830
Version: 1
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Project
» Local adaptation and the evolution of plasticity under predator invasion and warming seas: consequences for individuals, populations and communities (evolution of plasticity)

Contributors	Affiliation	Role
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Abstract
The impact of invasive predators during the early stages of invasion is often variable in space and time. Such variation is expected to initially favor plasticity in prey defenses but fixed defenses as invaders become established. Coincident with the range expansion of the invasive green crab (Carcinus maenas) in the Gulf of Maine we document rapid changes in shell thickness – a key defense against shell crushing predators – of an intertidal snail (Littorina obtusata). These data summarize the results of reciprocal transplant experiments between snail (Littorina obtusata) populations in the northern and southern Gulf of Maine that were conducted 20 years apart. The results revealed that temporal shifts in snail shell thickness were driven by the evolution of increased trait means and erosion of thickness plasticity. The virtual elimination of the trade-off in snail tissue mass that often accompanies thicker shells is consistent with the evolution of fixed defenses under increasingly certain predation risk and are therefore consistent with the predicted impacts of spatiotemporal changes in green crab abundance throughout the Gulf of Maine.

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Coverage

Location: Quoddy Head, Maine and Lobster Cove, Massachusetts
Spatial Extent: **N**:44.82 **E**:-66.97 **S**:42.56 **W**:-70.77
Temporal Extent: 1998 - 2018

Dataset Description

This dataset is part of a broader study conducted in the Gulf of Maine to investigate phenotypic plasticity of prey species in response to predator invasion and warming oceans:

1. Green crab surveys plus historical crab density data (dataset 990378)

2. Green crab density from field studies at rocky intertidal sites from April 2019 to December 2021 (dataset 911365)
3. Latitudinal (clinal) variation in *Littorina obtusata* shell thickness and tissue mass (dataset 990839)
4. Field experiment outplanting *Littorina obtusata* with predators (green crabs) to examine local and regional geographic variation in inducible defenses conducted from April to August 2021 (dataset 911221)
5. Morphological data from reciprocal transplant experiment in the field **(this dataset)**

See Related Datasets section below for links and additional details.

Methods & Sampling

To examine how shell thickness and its plasticity have changed after 20 years (1998-2018), we repeated a reciprocal transplant experiment in 2018 that had previously been conducted in 1998 (Trussell and Smith, 2000). To allow a robust comparison of the two experiments, we carefully replicated all aspects of the 1998 experiment including using the same experimental chambers that were deployed into the field 20 years earlier. In early May 2018, we collected juvenile *Littorina obtusata* (5-6 mm in shell length) from a northern and a southern site in the Gulf of Maine. The northern site was near Quoddy Head in Lubec, Maine (44.82, -66.97) and the southern site was Lobster Cove in Manchester, Massachusetts (42.56, -70.77). All snails were individually tagged with a color-coded dot of permanent ink that was then sealed with cyanoacrylate glue. We measured initial shell length and shell thickness with digital calipers (± 0.01 mm) and shell mass and tissue mass (± 0.001 g) were estimated using a non-destructive weighing technique (Palmer, 1982).

After completing initial measurements, we transported snails from both populations to the northern or southern site in mid-May. At each site, we placed six snails (hereafter, response snails) from a single population and approximately 60 grams of brown algae (*Ascophyllum nodosum*) as food into 24 separate, replicate cylindrical containers (5-cm height x 10-cm diameter) that had mesh windows (mesh size = 3mm) to allow water flow. Hence, at each site 12 replicate containers housed snails from either the northern or southern population and 6 replicates for each population exposed snails to either the presence (Crab) or absence (No Crab) of predation risk. To create these risk treatments, each container stocked with response snails was secured beneath a similar container that was perforated on all sides and housed either (a) a mature male green crab (Crab) and 30 conspecific snails (hereafter, stimulus snails) or (b) just 30 stimulus snails (No Crab) to serve as a control. Each pair of stimulus-response containers was placed inside a large, replicate cylindrical chamber (11-cm height x 28-cm diameter) that had mesh windows (mesh size = 3mm) to permit water flow. These large chambers were anchored haphazardly in the mid-intertidal zone (~1.5 m MLW). Ocean temperature was monitored at 5-minute intervals during the experiment with dataloggers (Tidbits, model UTBI-001, Onset Computer Corp.) that were placed inside three replicate chambers at each site. Every 14 days we replaced stimulus snails in both the Crab and No Crab containers. For appropriate replicates, we also confirmed that crabs were alive; any dead crabs were replaced immediately. Overall, we had to replace 7 crabs at the northern site and 7 crabs at the southern site. At day 45, we replaced the *Ascophyllum* that served as food for response snails in all replicates. After 90 days in the field, all response snails were returned to the Northeastern University Marine Science Center (Nahant, Massachusetts) for measurement of final snail shell length, shell thickness, and tissue mass.

BCO-DMO Processing Description

- Imported original file named "2.Trussell.Corbett.Updated.ReciprocalTransplantExperiment.csv" into the BCO-DMO system.
- Renamed fields/columns to comply with BCO-DMO naming conventions.
- Saved the final file as "990830_v1_morphological_data_reciprocal_transplant.csv"

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Data Files

File	
990830_v1_morphological_data_reciprocal_transplant.csv	(Comma Separated Values (.csv), 38.91 KB) MD5:ca3430b81848cb2731f5a3b15a3405f7
Data summarizing morphological variation in snails (Littorina obtusata) that were raised in the presence and absence of green crab (Carcinus maenas) risk cues at a northern site and southern site in the Gulf of Maine; Primary data file for dataset ID 990830, version 1	

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Related Publications

Corbett, J. J., & Trussell, G. C. (2025). Evolution in changing seas: The loss of plasticity under predator invasion and warming oceans. Science Advances, 11(6). https://doi.org/10.1126/sciadv.adr6947
Results

Palmer, A.R. (1982). Growth in marine gastropods. A non-destructive technique for independently measuring shell and body weight. Malacologia 23: 63-74.
Methods

Trussell, G. C., & Smith, L. D. (2000). Induced defenses in response to an invading crab predator: An explanation of historical and geographic phenotypic change. Proceedings of the National Academy of Sciences, 97(5), 2123–2127. https://doi.org/10.1073/pnas.040423397
Methods

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Related Datasets

IsSupplementedBy

Trussell, G. C., Corbett, J. J. (2023) **Littorina obtusata shell length, shell thickness, and tissue mass measured during a field experiment conducted at 12 sites in the Gulf of Maine from April to August 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2023-10-11 doi:10.26008/1912/bco-dmo.911221.1 [view at BCO-DMO]

IsRelatedTo

Trussell, G. C., Corbett, J. J. (2023) **Green crab (Carcinus maenas) density at rocky intertidal sites determined at 8 sites in the Gulf of Maine from April 2019 to December 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2023-10-12 doi:10.26008/1912/bco-dmo.911365.1 [view at BCO-DMO]

Trussell, G. C., Corbett, J. J. (2025) **Green Crab Density for Multiple Sites in the Gulf of Maine for 1973, 2003, 2017-2018 and 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-12-10 http://lod.bco-dmo.org/id/dataset/990378 [view at BCO-DMO]

Trussell, G. C., Corbett, J. J. (2025) **Latitudinal variation in the shell thickness and tissue mass of Littorina obtusata snails in 1995-1997 and 2017-2018.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-12-30 http://lod.bco-dmo.org/id/dataset/990839 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
Year	Year in which the experiment was conducted	unitless
Population	Source population (North, South) of the snails used in the reciprocal transplant experiment	unitless
Location	Denotes the site (North, South) at which snails were raised as part of the reciprocal transplant experiment	unitless
Risk_Treatment	Treatment exposure; whether snails were raised in the presence (Crab) or absence (No Crab) of green crab risk cues during the reciprocal transplant experiment	unitless
Replicate	Denotes the specific unit that snails were raised in as part of the reciprocal transplant experiment	unitless
Initial_Shell_Thickness	Shell thickness (mm) of snails at the beginning of reciprocal transplant experiment	millimeters (mm)
Initial_Shell_Length	Initial shell length (mm) of snails at the beginning of reciprocal transplant experiment	millimeters (mm)
Initial_Shell_Mass	Initial shell mass (mg) of snails at the beginning of reciprocal transplant experiment	milligrams (mg)
Initial_Tissue_Mass	Initial tissue mass (mg) of snails at the beginning of reciprocal transplant experiment	milligrams (mg)
Final_Shell_Thickness	Shell thickness (mm) of snails at the end of reciprocal transplant experiment	millimeters (mm)
Final_Shell_Length	Final shell length (mm) of snails at the beginning of reciprocal transplant experiment	millimeters (mm)
Final_Shell_Mass	Final shell mass (mg) of snails at the beginning of reciprocal transplant experiment	milligrams (mg)
Final_Tissue_Mass	Final tissue mass (mg) of snails at the beginning of reciprocal transplant experiment	milligrams (mg)

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Instruments

Dataset-specific Instrument Name	digital calipers
Generic Instrument Name	calipers
Dataset-specific Description	We measured initial shell length and shell thickness with digital calipers.
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	Tidbits, model UTBI-001, Onset Computer Corp
Generic Instrument Name	Onset HOBO TidbiT v2 (UTBI-001) temperature logger
Dataset-specific Description	Ocean temperature was monitored at 5-minute intervals during the experiment with dataloggers (Tidbits, model UTBI-001, Onset Computer Corp.)
Generic Instrument Description	A temperature logger that measures temperatures over a wide temperature range. It is designed for outdoor and underwater environments and is waterproof to 300 m. A solar radiation shield is required to obtain accurate air temperature measurements in sunlight (RS1 or M-RSA Solar Radiation Shield). With an operational temperature range between -20 degrees Celsius and +70 degrees Celsius, the TidbiT v2 has an accuracy of +/-0.21 and a resolution of 0.02 degrees Celsius.

Dataset-specific Instrument Name	cylindrical containers with mesh windows
Generic Instrument Name	Test chamber
Dataset-specific Description	The experimental containers were cylindrical (5-cm height x 10-cm diameter) and had mesh windows (mesh size = 3mm) to allow water flow.
Generic Instrument Description	A test chamber is a controlled environment where specific conditions (temperature, humidity, light, etc.) are maintained for testing and research purposes. Also called climatic chamber, environmental chamber, environmental room, or environmental enclosure

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Project Information

Local adaptation and the evolution of plasticity under predator invasion and warming seas: consequences for individuals, populations and communities (evolution of plasticity)

NSF Award Abstract:
Over the past two decades, the Gulf of Maine has experienced unprecedented warming that, among other

things, has further enabled the invasive green crab to expand its range in rocky shore habitats. The adverse ecological impacts of this invasive predator have been documented worldwide. This study examines how geographic variation in the capacity of two common prey species to respond to the combination of this predator and warming ocean temperatures can shape prey feeding and performance and impact community structure and dynamics. Hence, this research enhances understanding of the evolution of phenotypes, their plasticity, and the nature of adaptation and its role in eco-evolutionary dynamics. More broadly, it informs understanding of how organisms and marine communities may respond to future environmental change. In addition, this project makes contributions to the STEM pipeline by providing middle and high school, undergraduate, and graduate students with cross-disciplinary training in evolutionary and community ecology. In collaboration with an institutional outreach program, the investigator is also developing web-based multimedia projects and teacher resource materials based on this research.

A central principle in ecology is that species residing in the middle of food chains must balance the benefits of eating with the risk of being eaten by their predators. Solving this foraging-predation risk trade-off often involves plasticity in prey traits with consequences for the evolution of adaptation and species interactions that drive community-level processes. Hence, the foraging-predation risk trade-off provides a powerful conceptual framework that links evolutionary and community ecology. Yet at the same time, other environmental stressors like temperature can shape this trade-off, adding complexity that makes it difficult to predict the capacity of organisms to adapt to environmental change and the consequences for communities. The investigator is conducting this study in rocky shore habitats of the Gulf of Maine (GOM) which have long been influenced by strong latitudinal temperature gradients and non-native species invasions. The overarching hypothesis is that predation risk and temperature are factors shaping geographic variation in plasticity and adaptation, with consequences for individuals, populations, and communities. First, the investigator is conducting field experiments to document geographic variation in the trait plasticity of two common prey species in the green crab's diet. Second, he is using reciprocal transplant experiments to examine trait plasticity in response to risk and water temperature, generating data to compare with similar experiments conducted in the late 90s prior to recent ocean warming and expansion in range of green crabs. Third, he is conducting a laboratory common garden experiment to evaluate the effects of risk and water temperature on trait plasticity. Finally, he is using reciprocal transplant experiments in the field to understand the interactive effects of risk and water temperature on prey foraging rates and the abundance of a species that plays an important role in intertidal community structure and dynamics.

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-2017626

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