Mussel respiration data from experiments with mussels sourced in WA conducted at University of Washington Friday Harbor Laboratories, Friday Harbor, WA from 2020 to 2023

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Data Type: experimental
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Project
» Collaborative Research: Microscale interactions of foundation species with their fluid environment: biological feedbacks alter ecological interactions of mussels (Microscale Mussels)

Contributors	Affiliation	Role
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Abstract
From 2021 to 2023, we measured aquatic respiration rates of three species of mytilid mussels (Mytilus trossulus Gould, M. galloprovincialis (L.), and M. californianus Conrad) under a range of water temperatures and velocities. M. californianus was obtained from the intertidal zone at Cattle Point, WA, USA (48.449966, -122.964350) and shipped in chilled coolers to the University of Washington Friday Harbor Laboratories (48.545998, -123.013046). M. trossulus and M. galloprovinicialis were obtained from a commercial supplier (Penn Cove Shellfish, Coupeville, WA, USA). Mussels were acclimated in a recirculating seawater. We conducted lab experiments to investigate the effects of multiple environmental stressors (e.g., water temperature and velocity) on physiological responses in three closely-related mytilid mussel species. In closed respirometry chambers (15 cm × 5 cm × 5 cm, L × W × H), we measured oxygen use by individual mussels under a combination of five temperatures (e.g., 5, 11, 17, 23, and 29°C) and five velocities (2, 4, 6, 10, and 20 cm s-1) in a fully crossed design. Oxygen concentrations were measured with non-intrusive fiber-optic O2 sensors (Pyroscience, Aachen, DEU). Samples were recorded at a rate of 1 Hz and drift of the O2 probe was negligible (e.g., <0.1% over 2 h at 20°C). Trials were run for 2 h, ensuring that a stable rate of decline could be identified. After each trial, all soft tissues were dried for 72 hours at 60°C (Lindeberg/Blue M Vacuum Oven; ThermoScientific Inc., Waltham, MA, USA) and weighed using an analytical balance (0.001 g; PA153 Pioneer Analytical Balance; Ohaus Corp., Pine Brook, NJ, USA). Data were analyzed to estimate respiration rates using the R package respR (Harianto, 2019).

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Coverage

Location: Experiments were conducted at the University of Washington's Friday Harbor Labs on San Juan Island, WA, USA with mussels sourced in WA.
Spatial Extent: **N**:48.545998 **E**:-122.7070647 **S**:48.2184883 **W**:-123.013046
Temporal Extent: 2021-06-14 - 2023-09-01

Methods & Sampling

M. californianus Conrad, 1837 were obtained from Cattle Point on San Juan Island, WA (48°26'59.6811"N, 122°57'51.9358"W). *M. trossulus* and *M. galloprovincialis* were obtained from a commercial supplier (Penn Cove Shellfish, Coupeville, WA, USA; 48°13'06.5579" N, 122°42'25.4331"W). The mussels were maintained in seatables (66 × 135 × 32 cm) with a constant flow of seawater at the Friday Harbor Laboratories (48°32'45.7249" N, 123°00'46.9262"W). Mussels were fed twice daily with a total of approximately 10 mL of Shellfish Diet 1800 TM (Reed Mariculture, Campbell, CA, USA).

Aquatic respiration rates were measured in a closed, recirculating flow chamber of 1-liter capacity. The transparent acrylic test chamber (15 cm × 5 cm × 5 cm, L × W × H) was connected to a submersible pump (360 GPH, Model 25D, Rule Industries, Gloucester, MA, USA) via PVC pipe (25.4 mm i.d.) and custom machined high-density polyethylene connector fittings. The water-tight test chamber was filled with artificial seawater (32 PSU; Instant Ocean; Spectrum Brands, Blacksburg, VA) and submersed in a temperature-controlled water bath (50 L). The water bath's temperature was maintained using a programmable, recirculating water heater/chiller (±0.005°C; AP07R-20-A11B, Polyscience, Niles, IL, USA). Trials were run at water velocities were estimated along the centerline of the testing chamber by tracking the displacement of glass microbeads at each flow setting (mean particle diameter 9 µm, density 2.0 g cm^{-3}; Potters Industries, Malvern, PA, USA).

Oxygen concentrations were measured with non-intrusive fiber-optic fluorescence-based optodes and sensor spots on the inner surface of the chamber (FireSting Pro; OXSP5 and TPSP5 spots, Pyroscience, Aachen, DEU). Samples were recorded at a rate of 1 Hz and drift of the O2 probe was negligible (e.g., <0.1% over 2 h at 20°C).

Each trial involved positioning individual mussels along the centerline of the chamber and subsequently measuring the organism's oxygen usage at stable temperatures of 5, 11, 17, 23, and 29°C. Trials were run for 2 h, ensuring that a stable rate of decline could be identified. After each trial, all soft tissues were dried for 72 hours at 60°C (Lindeberg/Blue M Vacuum Oven; ThermoScientific Inc., Waltham, MA, USA), and weighed using an analytical balance (0.001 g; PA153 Pioneer Analytical Balance; Ohaus Corp., Pine Brook, NJ, USA).

Data Processing Description

All analyses were conducted in R (ver. 4.4.2; RStudio 2024.12.0 (build 467). The R package respR was used to analyze the respiration data (Harianto, 2019). Respiration rates were standardized by the dry biomass of the mussels.

BCO-DMO Processing Description

* Data table within submitted file "Mussel_respiration_data.csv" was imported into the BCO-DMO data system for this dataset. Table will appear as Data File: 953833_v1_mussel-respiration-rates.csv (along with other download format options).

* Metadata extracted from methodology and added to table mussel_collection_information.csv including geospaital bounds (in decimal degrees), site information, and a lookup table for the species code used in the dataset matched to the full Scientific Name (authority) and LSID.

* LSIDs added for taxonomic names used in the metadata using the world register of marine species on 2025-02-20.

Problem Description

N/A

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Related Publications

Harianto, J., Carey, N., & Byrne, M. (2019). respR—An R package for the manipulation and analysis of respirometry data. Methods in Ecology and Evolution, 10(6), 912–920. Portico. https://doi.org/10.1111/2041-210x.13162 https://doi.org/10.1111/2041-210X.13162
Software

RStudio Team (2024) RStudio: Integrated Development for R. Version 4.2.2 (build 467) 2024.12.0. RStudio, Inc., Boston, MA. http://www.rstudio.com/
Software

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Parameters

Parameter	Description	Units
Species	species names of mussels used in experiments. M_trossulus = Mytilus trossulus;M_gallo = Mytilus galloprovincialis;M_cali = Mytilus californianus (see Supplemental File mussel_collection_information.csv for more information about names and collection information).	unitless
Temperature	water temperatures in degrees celsius	degrees Celsius (deg C)
Velocity	water velocities	centimeters per second (cm s-1)
Respiration	respiration rate	micromoles of O2 per gram per hour (umol O2 g-1 h-1)

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Instruments

Dataset-specific Instrument Name	Lindeberg/Blue M Vacuum Oven; ThermoScientific Inc., Waltham, MA, USA
Generic Instrument Name	Drying Oven
Generic Instrument Description	a heated chamber for drying

Dataset-specific Instrument Name	recirculating water heater/chiller (±0.005°C; AP07R-20-A11B, Polyscience, Niles, IL, USA)
Generic Instrument Name	Immersion heater
Dataset-specific Description	The water bath's temperature was maintained using a programmable, recirculating water heater/chiller (±0.005°C; AP07R-20-A11B, Polyscience, Niles, IL, USA).
Generic Instrument Description	Submersible heating element for water tanks and aquaria.

Dataset-specific Instrument Name	non-intrusive fiber-optic fluorescence-based optodes and sensor spots (FireSting Pro; OXSP5 and TPSP5 spots, Pyroscience, Aachen, DEU)
Generic Instrument Name	Optode
Generic Instrument Description	An optode or optrode is an optical sensor device that optically measures a specific substance usually with the aid of a chemical transducer.

Dataset-specific Instrument Name	O2 sensors (Pyroscience, Aachen, DEU)
Generic Instrument Name	Oxygen Sensor
Dataset-specific Description	Oxygen concentrations were measured with non-intrusive fiber-optic O2 sensors (Pyroscience, Aachen, DEU). Samples were recorded at a rate of 1 Hz and drift of the O2 probe was negligible (e.g.,
Generic Instrument Description	An electronic device that measures the proportion of oxygen (O2) in the gas or liquid being analyzed

Dataset-specific Instrument Name	submersible pump (360 GPH, Model 25D, Rule Industries, Gloucester, MA, USA)
Generic Instrument Name	Pump
Generic Instrument Description	A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps

Dataset-specific Instrument Name	PA153 Pioneer Analytical Balance; Ohaus Corp., Pine Brook, NJ, USA
Generic Instrument Name	scale
Dataset-specific Description	analytical balance (0.001 g; PA153 Pioneer Analytical Balance; Ohaus Corp., Pine Brook, NJ, USA)
Generic Instrument Description	An instrument used to measure weight or mass.

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Project Information

Collaborative Research: Microscale interactions of foundation species with their fluid environment: biological feedbacks alter ecological interactions of mussels (Microscale Mussels)

Coverage: University of Washington Friday Harbor Laboratories

NSF Award Abstract:
The project investigates how the metabolic activity of dense aggregations of marine organisms alter the water chemistry of their interstitial spaces, and how these microscale alterations feedback to affect the organisms' interactions in coastal ecosystems. The research team focuses on bivalve mussels, foundation species that form dense 'beds' typically known for facilitating other species by ameliorating harsh flow conditions. This ability can become a liability, however, if flow is not sufficient to flush the interstitial spaces and steep, metabolically-driven concentration gradients develop. The research evaluates whether corrosive chemical microclimates (such as low oxygen or low pH) are most extreme in low flow, high temperature conditions, especially for dense aggregations of mussels with large biomass and/or high respiration rates, and if they negatively impact mussel beds and the diverse biological communities they support. The research addresses a global societal concern, the impact of anthropogenic climate change on coastal marine ecosystems, and has potential applications to aquaculture and biofouling industries by informing adaptation strategies to "future-proof" mussel farms in the face of climate change and improved antifouling practices for ships, moorings, and industrial cooling systems. The project forges new collaborations with investigators from three campuses and integrates research and education through interdisciplinary training of a diverse group of graduate, undergraduate and high school students. STEM education and environmental stewardship is promoted by the development of a K-12 level science curriculum module and a hand's-on public exhibit of bivalve biology at a local shellfish farm. Research findings are disseminated in a variety of forums, including peer-reviewed scientific publications and research presentations at regional, national and international meetings.

The research team develops a framework that links environmental conditions measured at a coarse scale (100m-100km; e.g., most environmental observatories) and ecological processes at the organismal scale (1 cm – 10 m). Specifically, the project investigates how aggregations of foundation species impact flow through interstitial spaces, and how this ultimately impacts water chemistry immediately adjacent to the organisms. The research focuses on mytilid mussels, with the expectation that the aggregation alters the flow and chemical transport in two ways, one by creating a physical resistance, which reduces the exchange, and the other by enhancing the exchange due to their incurrent/excurrent pumping. These metabolically-driven feedbacks are expected to be strongest in densely packed, high biomass aggregations and under certain ambient environmental conditions, namely low flow and elevated temperature, and can lead to a range of negative ecological impacts that could not be predicted directly from coarse scale measures of ambient seawater chemistry or temperature. The team develops computational fluid dynamic (CFD) models to predict interstitial flows and concentration gradients of dissolved oxygen and pH within mussel beds. The CFD model incorporates mussel behavior and physiological activity (filtration, gaping, respiration) based on published values as well as new empirical work. Model predictions are compared to flow and concentration gradients measured in mussel aggregations in the laboratory and field. Finally, the team conducts several short-term experiments to quantify some of the potential negative ecological impacts of corrosive interstitial water chemistry on mussel aggregations, such as reduced growth, increased dislodgement, increased predation risk, and reduced biodiversity. Because the model is based on fluid dynamic principles and functional traits, the framework is readily adaptable to other species that form dense assemblages, thereby providing a useful tool for predicting the ability of foundation species to persist and provide desirable ecosystem services under current and future multidimensional climate scenarios.

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-2050129

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