Freeze tolerance and ecological responses of the intertidal gastropod *Tegula funebralis* under varying subaerial cold regimes



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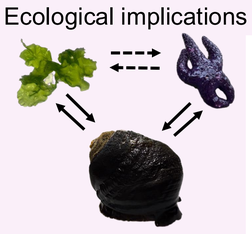
Background

Extreme cold exposure in the intertidal zone

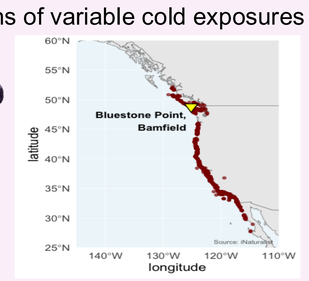


Cold snap can expose intertidal organisms to low air temperatures during low tide, with variation in both the intensity and number of cold-exposure events.

Ecological implications of variable cold exposures

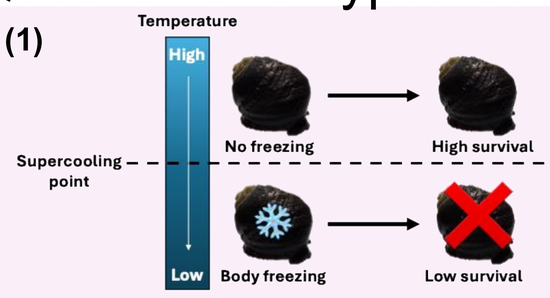


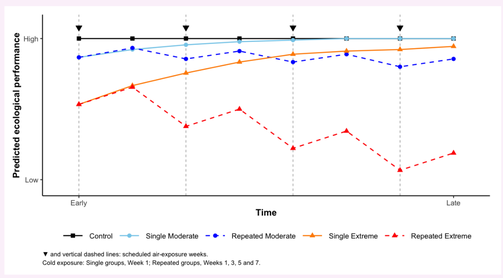
The black turban snail (*Tegula funebralis*)



Studying how an abundant grazer responds to variable cold exposures may help predict its performance and distribution changes.

Question and hypothesis





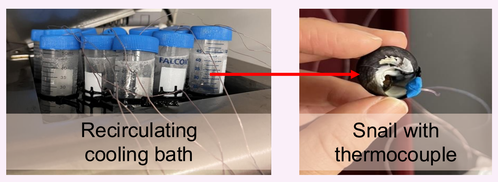
(1) T. *funebralis* will exhibit substantial mortality near the onset of internal body freezing.
(2) Ecological performance of *T. funebralis* will decline with successive cold exposures, with partial recovery between exposures and greater declines under more intense cold conditions.

(1) Freeze tolerance assay

Methods

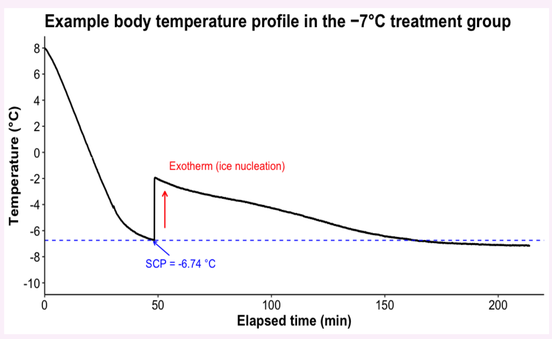
Temperature exposures

-8 °C | -5 °C | -4 °C | -6 °C | -9 °C | -7 °C



12 snails per each temperature group;
cooling from 8 °C to target minimum air temperatures;
cooling rate: -0.5°C/min;
exposure duration: 3 hours

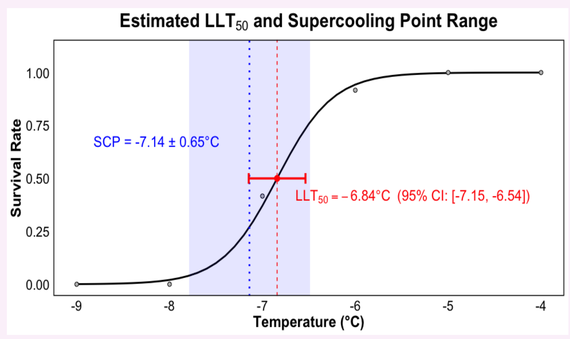
Measurements



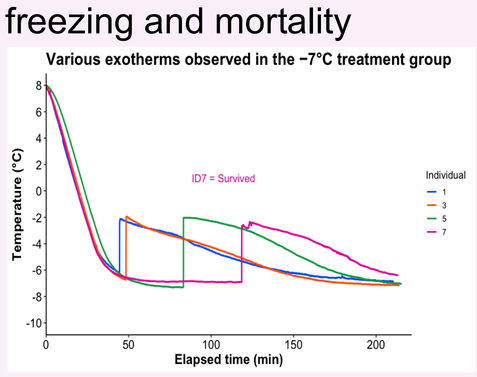
Supercooling points (SCPs) → Mean ± SD
72-hour survivals → LLT_{50}

Results

Evidence of association between freezing and mortality



Substantial mortality occurred near the onset of internal ice formation.



Some individuals showed delayed exotherms and survived internal freezing.

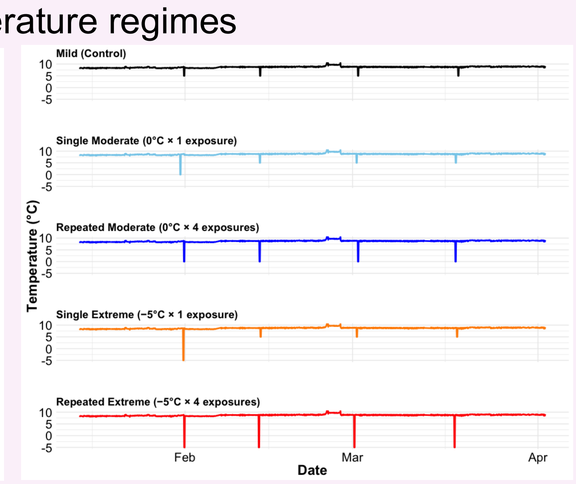
(2) Repeated-exposure experiment: ecological performance with two-week recovery periods

Methods

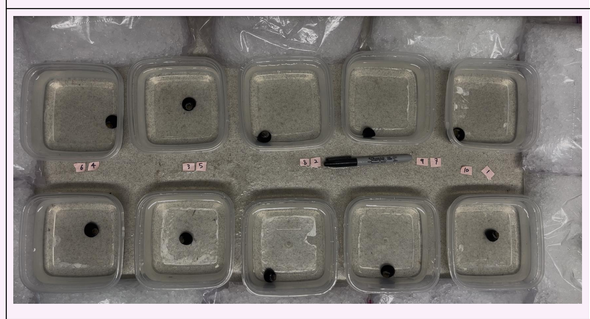
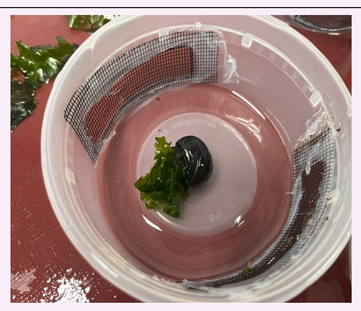
Sublethal temperature regimes

	Week 1	Week 3	Week 5	Week 7
Mild (Control)	5°C	5°C	5°C	5°C
Single Moderate	0°C	5°C	5°C	5°C
Repeated Moderate	0°C	0°C	0°C	0°C
Single Extreme	−5°C	5°C	5°C	5°C
Repeated Extreme	−5°C	−5°C	−5°C	−5°C

62-day experiment | n = 10 snails per group | 3 h per air exposure
Air exposures every two weeks; tiles show air-exposure temperatures.
Before and after each exposure: seawater at 8°C with continuous access to seaweed.

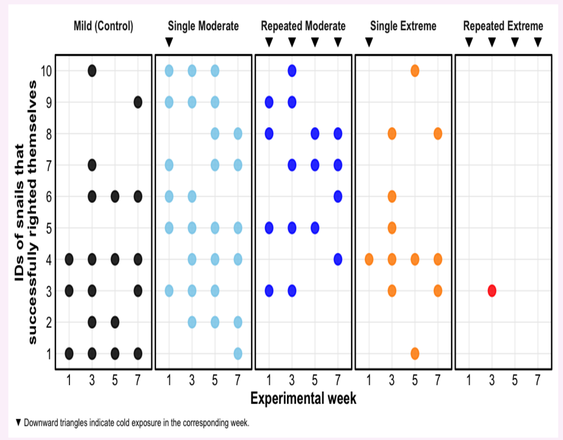


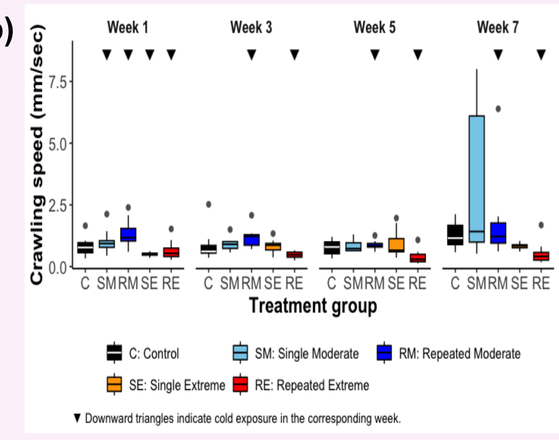
Ecological Performance

Locomotion	Grazing
Immediately after cold exposure	Weekly feeding with *Ulva* sp.
	
• **Righting success (o/x):** upright in 30 min • **Crawling speed (mm/sec.):** mean horizontal crawling speed ≤ 30 min	• **Grazing rates**: proportion of seaweed mass consumed • **Total consumption (g):** cumulative consumption

Results

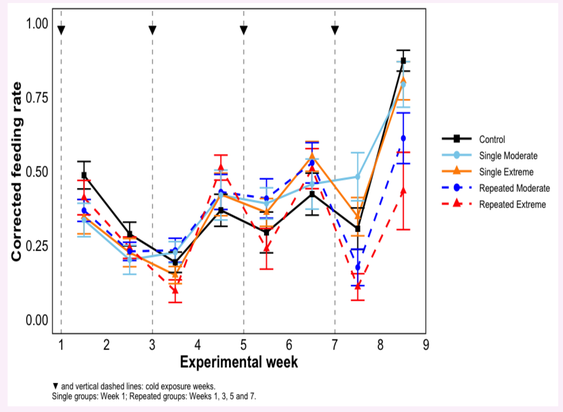
Extreme exposure reduced locomotor performance

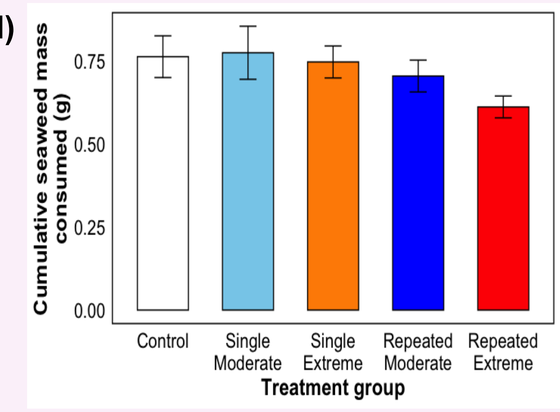




(a) Righting success: Lower in extreme or repeated exposure (Binomial GLMM; $p < 0.001$)
(b) Crawling speed: Slower under extreme exposure (LMM; $p < 0.001$)

Repeated and extreme suppressed grazing





(c) Grazing rate: Lower in extreme (Beta GLMM; $p = 0.03$) and repeated exposure ($p < 0.001$). Recovery failures in repeated groups after the last exposure ($p < 0.05$)
(d) Total consumption: Lower under repeated exposure (ANCOVA, $p < 0.05$; no interaction)

Discussion

- *T. funebralis* may have a tolerance strategy to cope with freezing temperature regimes that are not severe in terms of duration and intensity (partial freeze tolerance).
- Even a single extreme cold exposure caused prolonged locomotor impairment in *T. funebralis*, whereas repeated cold exposures suppressed the late-experiment increase in grazing performance, potentially reflecting persistent impairment, stress accumulation, and insufficient recovery between exposures.
- Ongoing and future studies will investigate the factors linking freezing to mortality, changes in energy reserves and cryoprotectant accumulation under repeated cold exposures, the effects of impaired locomotion on predator avoidance under short-term cold extremes, and latitudinal variation in cold tolerance in *T. funebralis* (see QR code below for details).

Acknowledgement

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This study was conducted at the UBC Point Grey campus in Vancouver, which is located on the ancestral and unceded territory of the xʷməθkʷəy̓əm (Musqueam) First Nation.

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