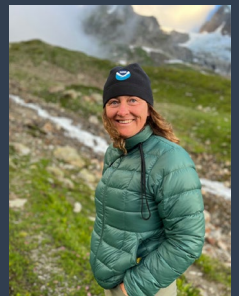
Crab Plan Team
Research update:

Process and ecosystem studies on the early life history of crab at the Hatfield Marine Science Center

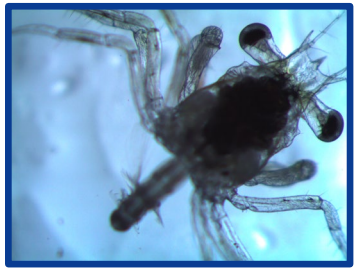


Louise Copeman, Marine Ecologist

Fisheries Behavioral Ecology Program, Newport, OR

Outline

- **Facilities for crab research at HMSC**
  - Wet lab facilities
  - Marine lipid ecology lab
- **Laboratory experiments on temperature-dependent vital rates of early juvenile crab stages**
- **Field studies focused on juvenile crab energetic condition**
- **Future/ongoing research: addressing knowledge gaps in the warming-starvation hypothesis for Bering Sea snow crab**



Fisheries Behavioral Ecology Program

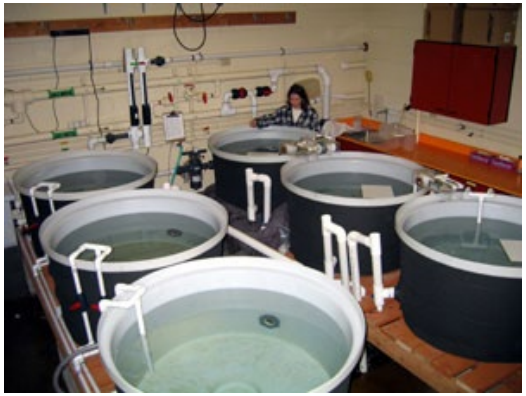
Laboratory and field-based approaches to understanding physiology and energetic condition of Arctic species in Newport, Oregon

Facilities: Arctic wet lab space

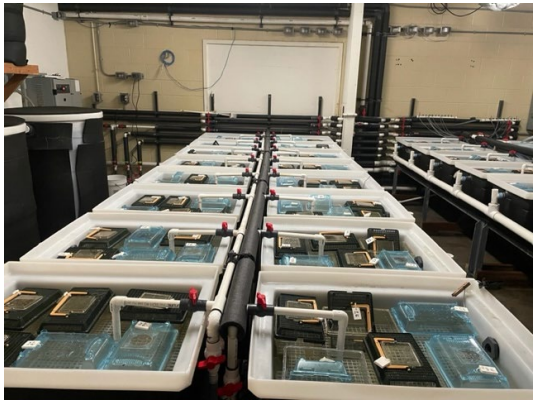
- High flow through good quality sea water
- Over 20,000 sq. ft. of wet laboratory
- Centralized chilling system & local heating systems
- Quarantine facilities
- Staff trained in the culture of larvae to broodstock
- Long term thermal growth experiments

10-foot “Arena” tanks, n=6

“medium” round tanks, n=15



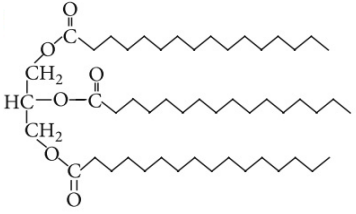
“crab individual cell in Arctic lab”

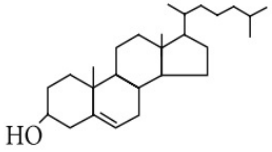


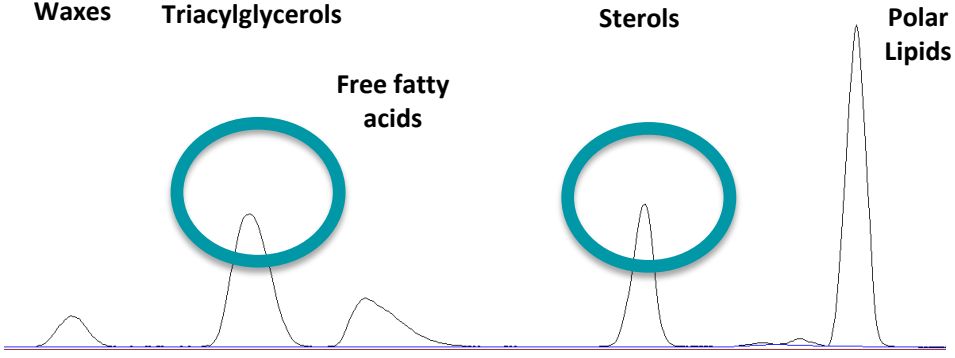
100L larval tanks, three labs of n=16

Facilities: Marine Lipid Ecology Lab

- Extensive dry labs for dissections and chemical analyses
- Four different chromatography instruments for measuring lipid-based condition and trophic biomarkers



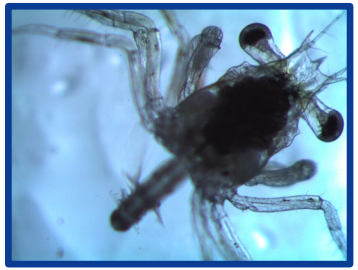




Outline

- **Facilities for crab research at HMSC**
  - Wet lab facilities
  - Marine lipid ecology lab

- **Laboratory experiments on temperature-dependent vital rates of early juvenile crab**



Comparative temperature-dependent vital rates of early juvenile snow and Tanner crab

Tanner crab, *Chionoecetes bairdi*

Snow crab, Chionoecetes opilio

Louise Copeman[1], Michele Ottmar[1], Clifford Ryer[1], Trond Kristiansen[2]

[1]Fisheries Behavioral Ecology Program, AFSC, NOAA

[2]Farallon Institute

Objectives

- Based on realized species distributions we hypothesized that snow crab would have a narrow thermal range (0 to 3 °C) whereas Tanner crab would have a wider thermal range (4 to 9 °C) for optimal survival and growth

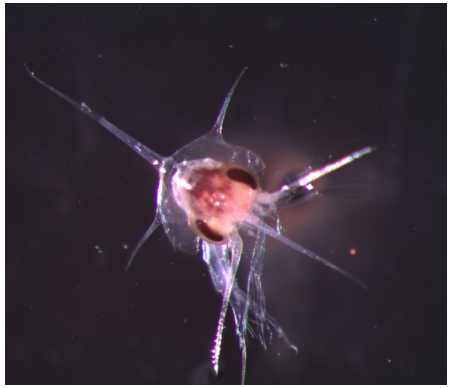
Objectives:

- to explicitly measure temperature-dependent growth and survival for the early benthic stages of Bering Sea snow and Tanner crab across a wider range of temperatures (-0.5 to 16 °C) than previously investigated in the laboratory

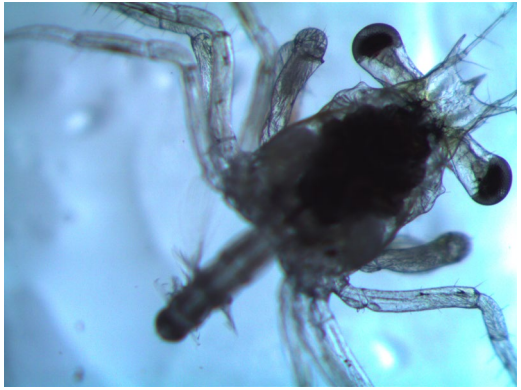
- to couple vital rates to statistically down-scaled bottom temperature data in order to understand available thermal habitat and growth potential both now and at end of the century

Small juvenile snow crabs are difficult to source!

Broodstock from Bering Sea BTS

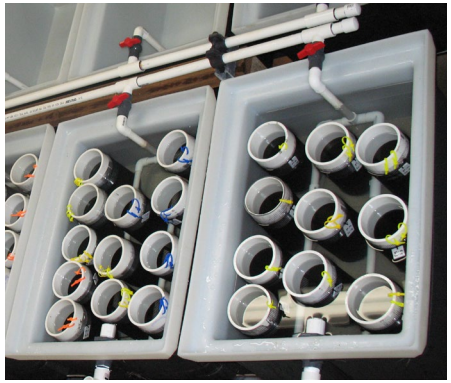


Zoea



Megalopa

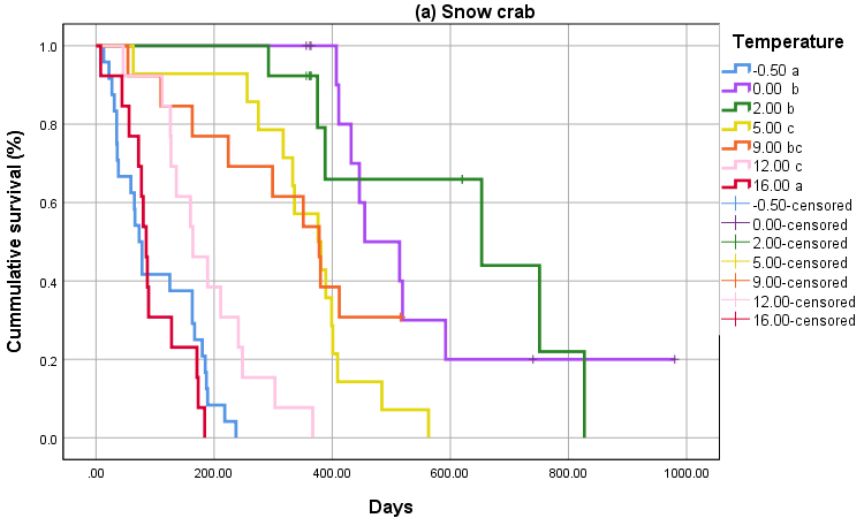
Experiments lasted over 2 years:
Snow crab 0 ℃ - 712 days
Tanner crab 0 ℃ - 623 days

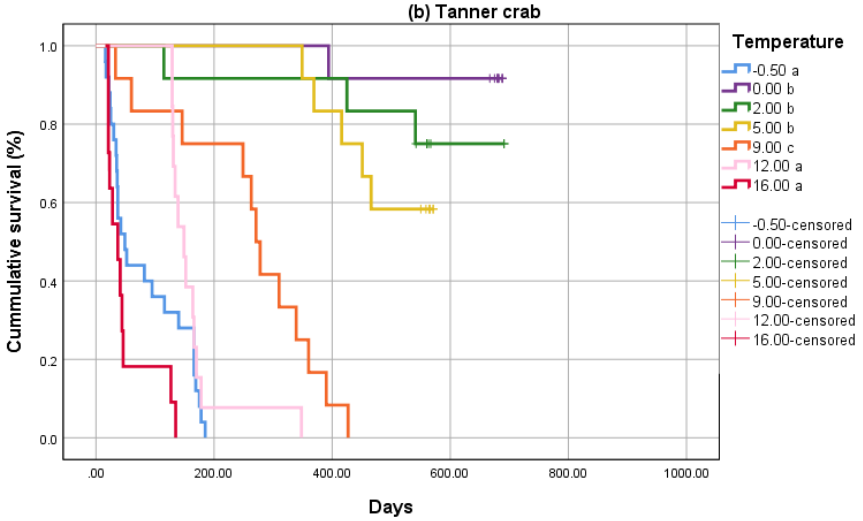


Individual growth cells

C1 benthic crab

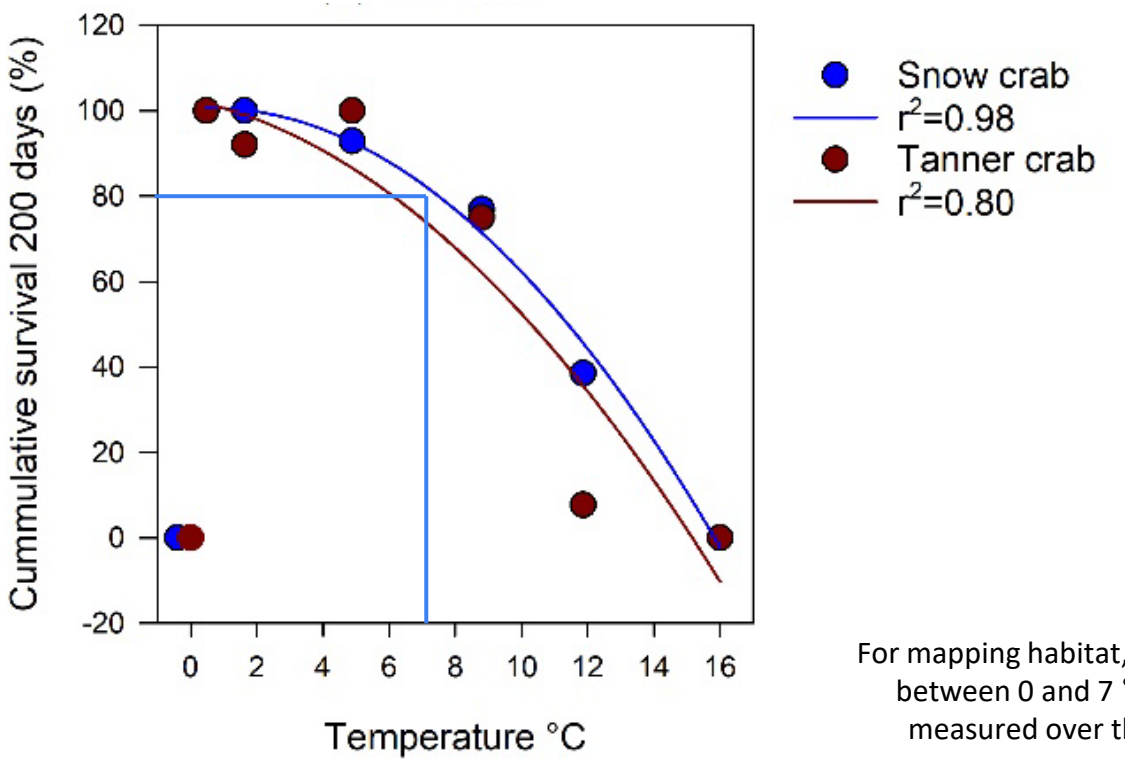
Temperature-dependent survival was similar across species!





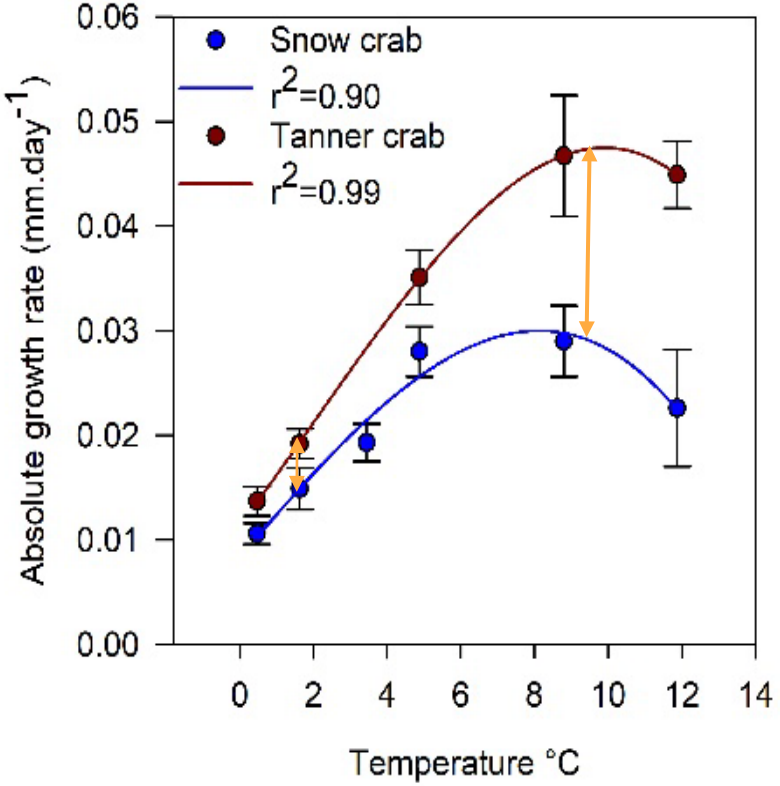
- Similar temperature-dependent survival for both species.
- High survival between 0 and 5 °C.
- Lower survival at temperatures below 0 and above 9°C.

Survival over first 200 days



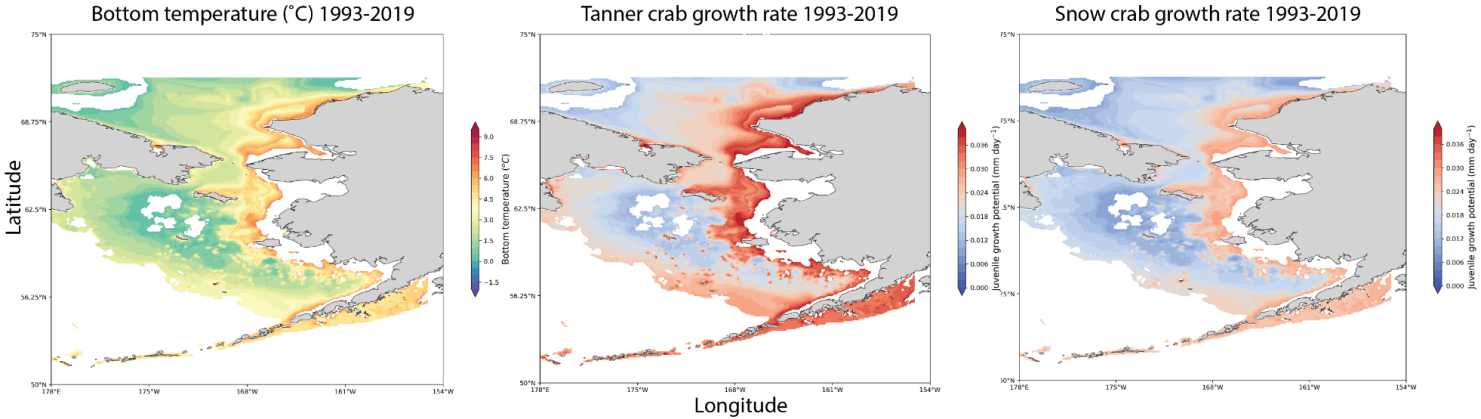
For mapping habitat, we limited available habitat to between 0 and 7 °C where > 80% survival was measured over the first 200 days of growth.

Growth rates (mean C1 to C4 stages)



Growth rates increased up to 9 °C
Growth rates diverged between the species >2 °C.

Spatial trends in crab thermal habitat and growth rates



Thermal habitat was limited to temperatures between 0 and 7 ˚C where we measured > 80% survival over the first 200 days of juvenile growth.

Conclusions

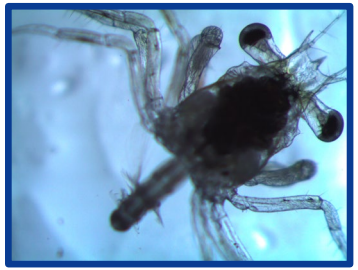
- Snow and Tanner crab had similar thermal tolerances with high survival (>80%) across a wide range of temperatures (0 to 7 °C)

- Realized juvenile snow crab distributions (concentrated in the cold-pool, <2 °C) are likely due to interactive effects such as predator avoidance or food quality but not solely due to a direct physiological thermal limitation

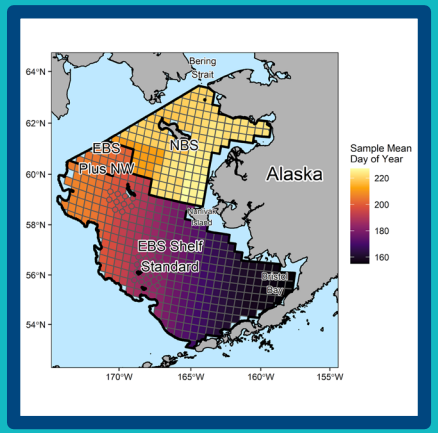
- Thermal habitat available for juvenile snow and Tanner crab will dramatically contract to the western Bering Sea and Chukchi Sea by the end of the century

Outline

- **Facilities for crab research at HMSC**
  - Wet lab facilities
  - Marine lipid ecology lab
- **Laboratory experiments on temperature-dependent vital rates**
  - optimal snow crab habitat is not exclusively defined by temperature
- **Field studies focused on juvenile crab nutrition in a rapidly warming Bering Sea**



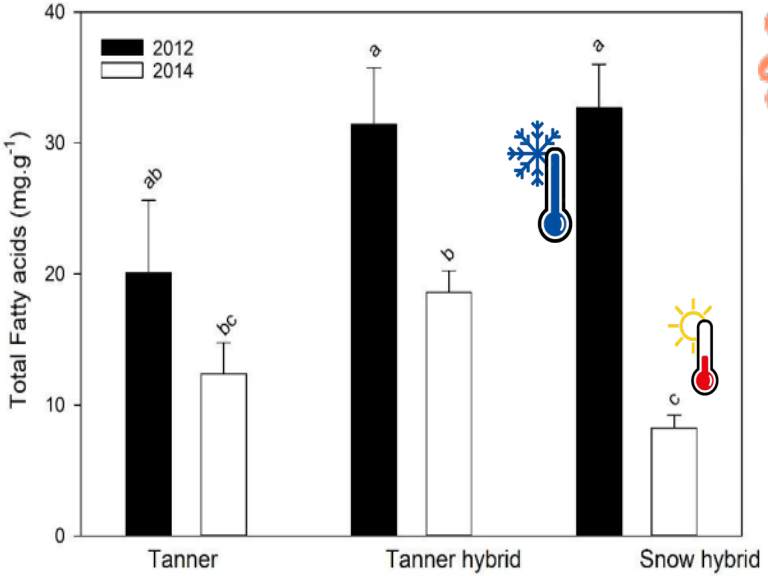
The importance of temperature and diatom flux in defining juvenile Alaskan crab energetic condition

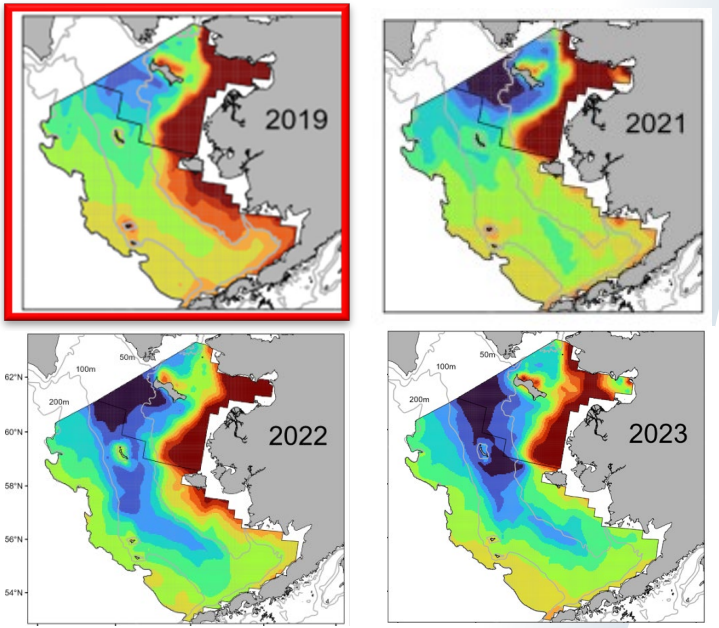


Louise Copeman[1], Erin Fedewa[1], Michelle Stowell[2], Samantha Mundorff[2], Jens Nielsen[1,3]

[1]Alaska Fisheries Science Center, NOAA, [2] CIMERS, Oregon State University, [3] CICOES, University of Washington

Oscillations in the Bering Sea cold-pool are extreme habitat change for juvenile crab





Copeman et al. 2021
On-going small mesh beam trawls 2021- 2023

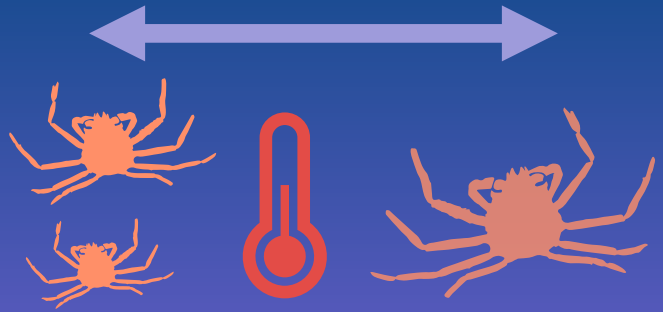
Figures courtesy of Sean Rohan, NOAA

NOAA FISHERIES

Warming and reduced sea ice can impact energetic condition of juvenile crabs

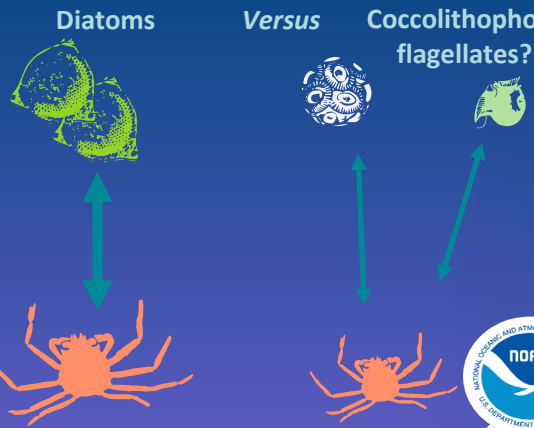
DIRECT THERMAL EFFECTS:

Fast growth but low fat storage and higher mortality



INDIRECT FOOD WEB EFFECTS:

Absence of ice-edge blooms and smaller phytoplankton size reduce benthic food quality



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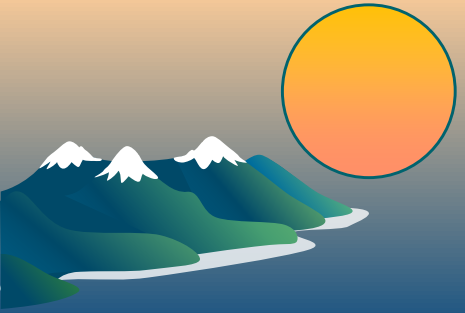
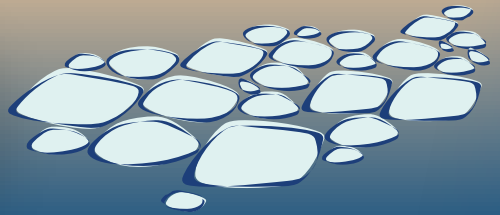
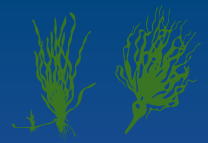
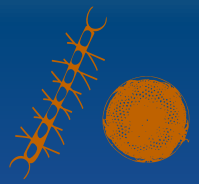
Tracing food web effects: Fatty acid biomarker approach







Macrophytes



Diatoms

Dinoflagellates

Bacteria

copepods

Carnivory

18:3n-3, 18:2n-6
20:4n-6

20:5n-3
16:1n-7/16:0

22:6n-3
$\sum C_{18}$ PUFA

Odd & branched chains

$\sum$20:1+22:1

18:1n-9/18:1n-7

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Goals

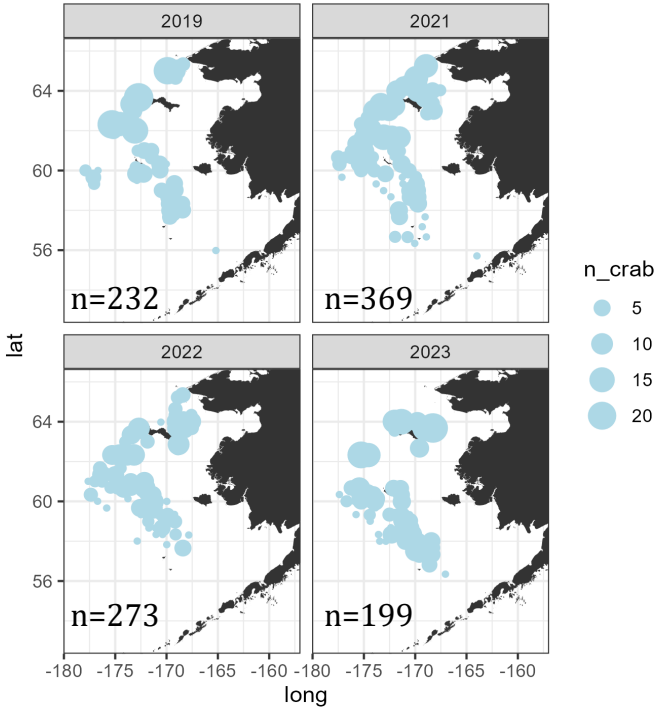
- To develop a simple condition metric for juvenile snow crab based on water and lipid content of the **hepatopancreas**

- To use fatty acid biomarkers to understand changes in trophic relationships during and following the 2018-2019 marine heat wave

- To link changes in crab biomarkers to spring bloom dynamics with the aim of developing a predictive ecosystem indicator for juvenile crab condition

NOAA FISHERIES

Methods: Crab collections from annual GAP/SAP surveys



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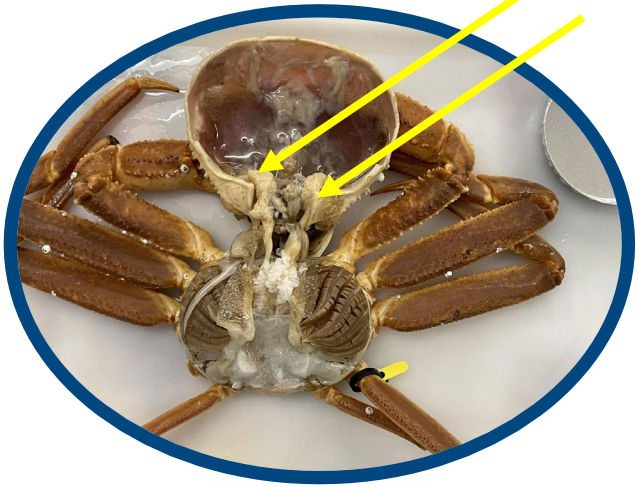
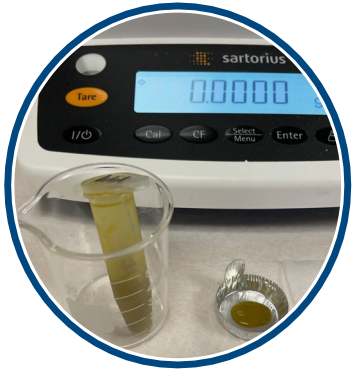
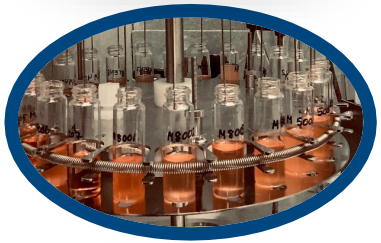
Methods: Laboratory



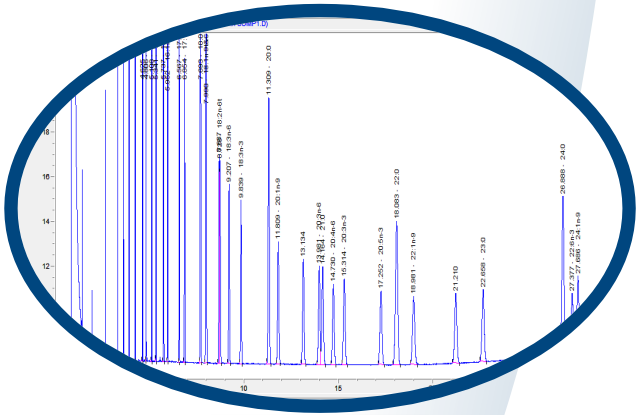
Back deck field dissections of lipid-rich hepatopancreas



Wet weight to dry weight ratios



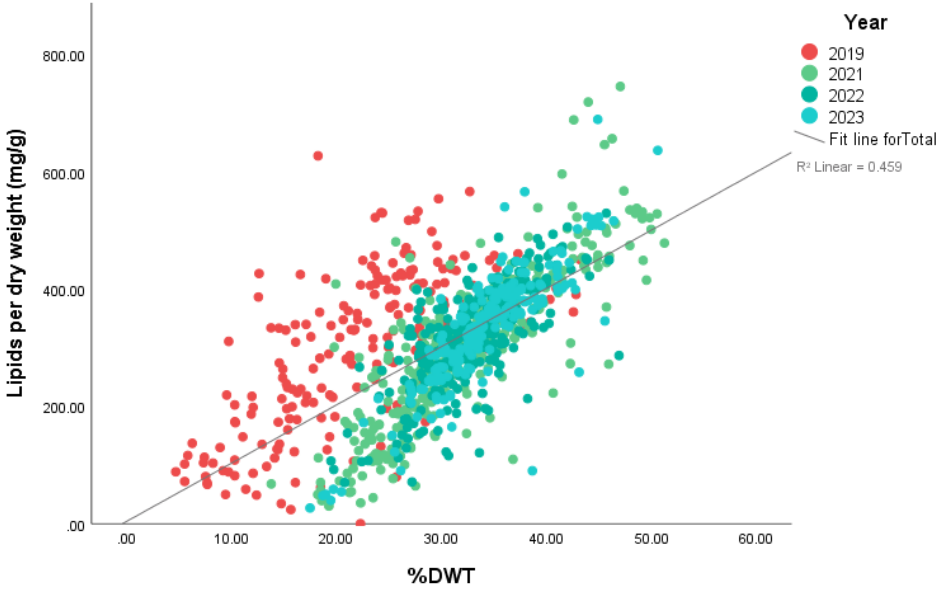
Chemical extraction and derivatization of lipids



Integration of fatty acid methyl esters

NOAA FISHERIES

Water content of the hepatopancreas is a rapidly determined proxy for fat storage in juvenile crab



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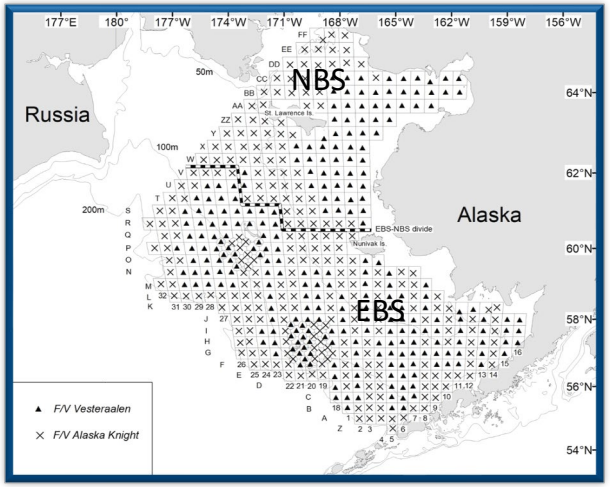
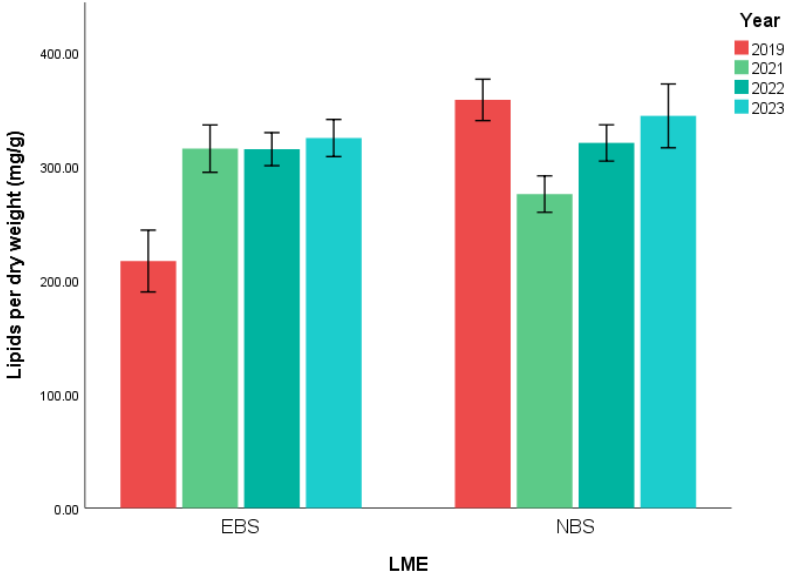
Crab condition was anomalously low in 2019 during the marine heat wave on the EBS shelf





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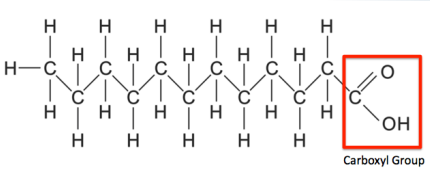
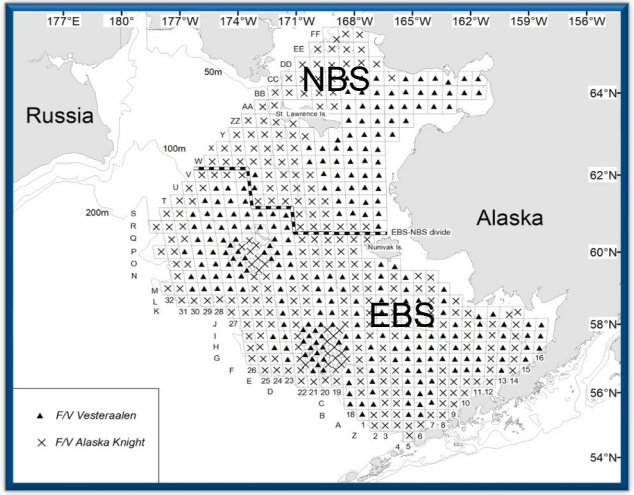
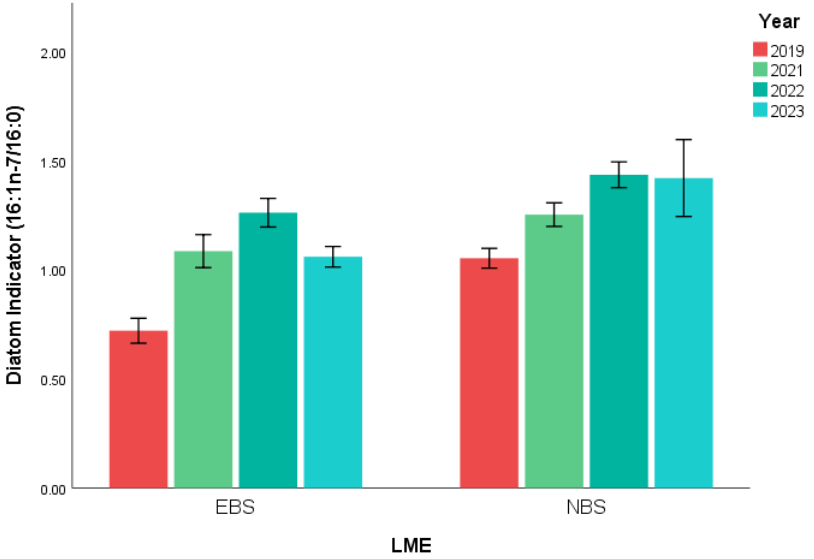
Diatom fatty acid biomarkers stored in crab tissues declined during the marine heat wave







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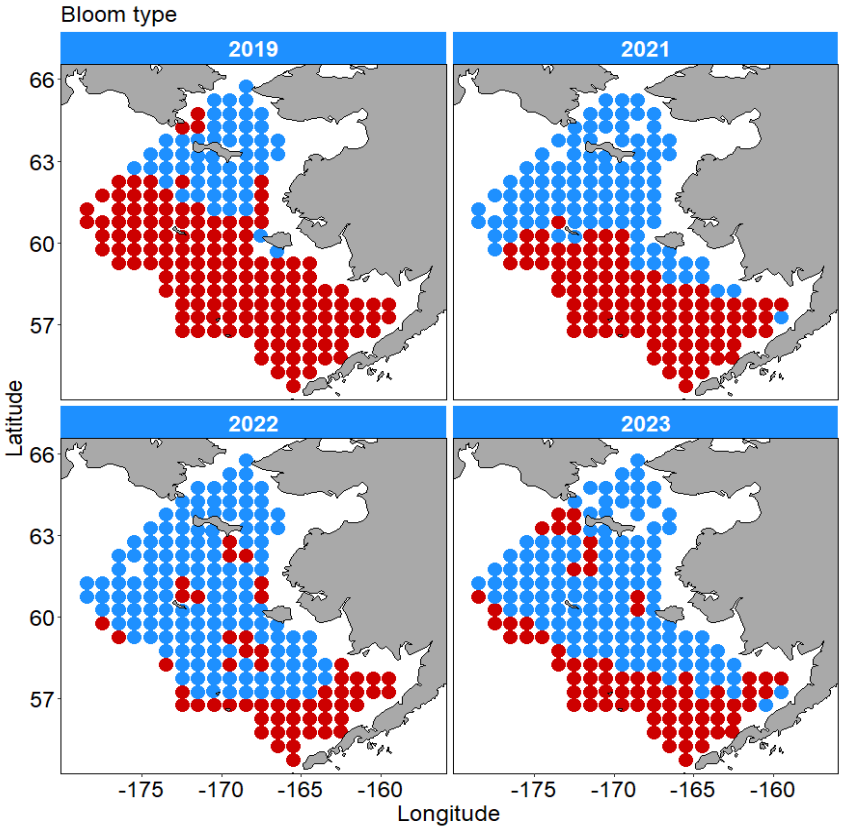
Can we link crab lipids to spring bloom dynamics?

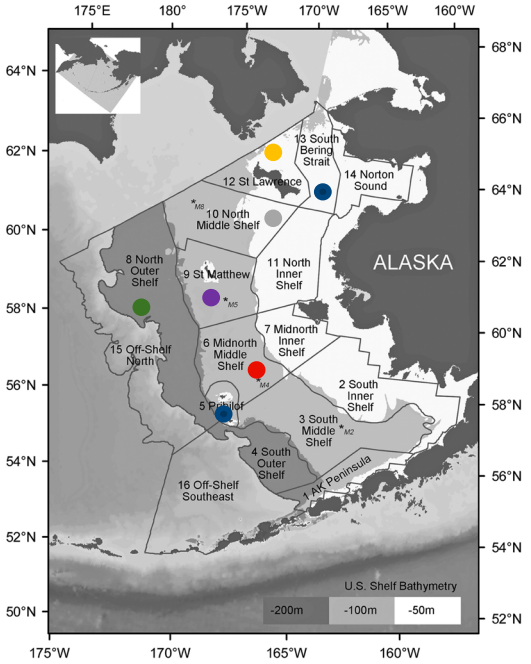


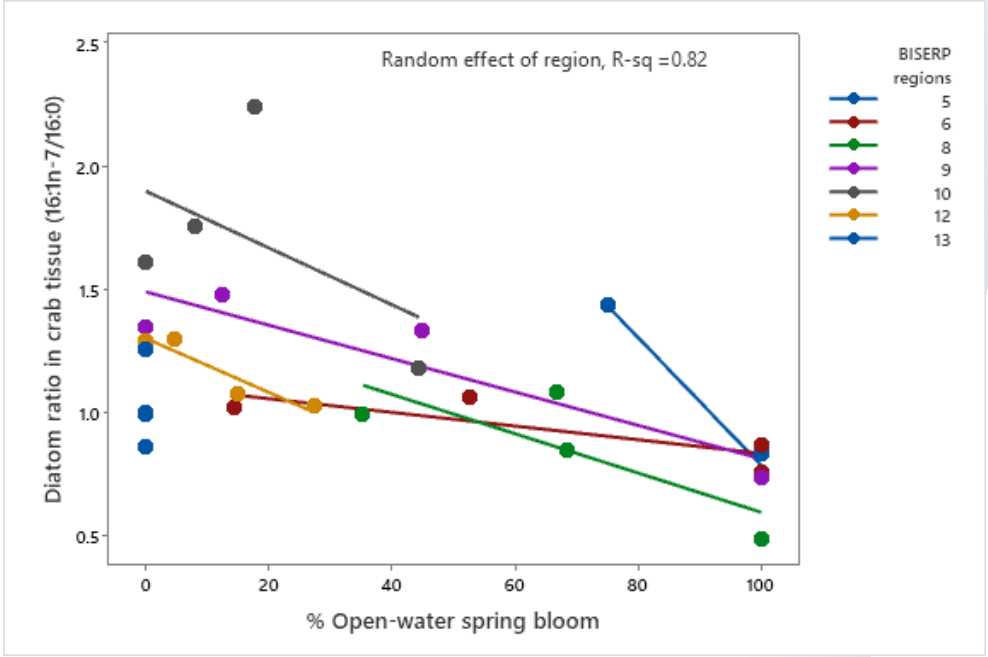
Bloom formation
Red: Open water
Blue Ice-assoc.

Nielsen et al. 2024,
Progress in Oceanography

NOAA FISHERIES

Open water spring blooms were associated with lower diatom-sourced lipids in juvenile crabs





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Conclusions

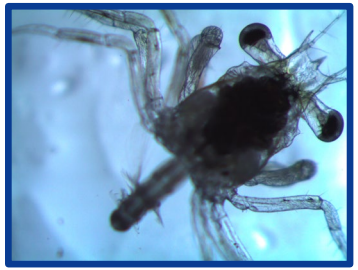
- Moisture-based hepatopancreas metrics can rapidly predict energetic condition in snow crab.
- Low lipid storage was measured in crab during the recent heat wave but energetic recovery was evident from 2021 to 2023, when normal conditions returned to the Bering Sea.
- Elevated lipid storage was positively associated with diatom-sourced fatty acids.
- Spring bloom characteristics, derived from satellite and mooring data, helped explained most of the variation in crab diatom-sourced lipid storage.
- Spring bloom metrics (ice or open water) may provide earlier spring indicators that can allow us to predict crab conditions on an annual basis.

NOAA FISHERIES

Outline

- **Facilities for crab research at HMSC**
  - Wet lab facilities
  - Marine lipid ecology lab

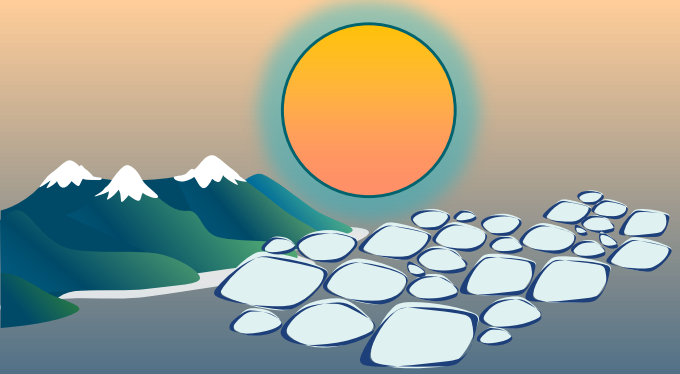
- **Laboratory experiments on temperature-dependent vital rates**
  - Optimal snow crab habitat is not solely defined by temperature



- **Field studies focused on juvenile crab nutrition in a rapidly warming Bering Sea**
  - Ice-associated spring blooms are important in defining food quality and resulting energetic condition of juvenile snow crab

- **Future/ongoing research: addressing knowledge gaps surrounding the starvation hypothesis of snow crab**

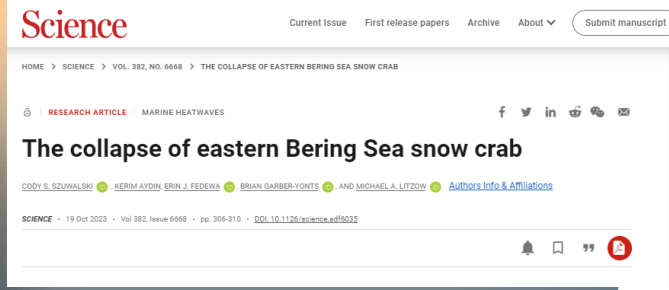
A working hypothesis for the snow crab collapse



Reduction in sea ice extent leads to a smaller cold pool and reduced pelagic flux to the benthos

The spatial footprint of snow crab shrinks as high densities concentrate in cold water habitats

Temperature-driven increases in metabolic demand coupled with a small area to forage results in starvation



NOAA FISHERIES

Are crabs in hot water?

Marine heat waves challenge sustainable fisheries management

GORDON H. KRUSE Authors Info & Affiliations

SCIENCE • 19 Oct 2023 • Vol 382, Issue 6668 • pp. 260-261 • DOI: 10.1126/science.adk7565

Starvation study in progress

Two size classes of snow crab

- 2, 5 and 8°C treatments
- Responses: Survival, morphometric condition, lipid-based condition
- Laboratory validation of a rapid non-lethal condition metric: The Brix Index

Metabolic scope (planned for 2024)

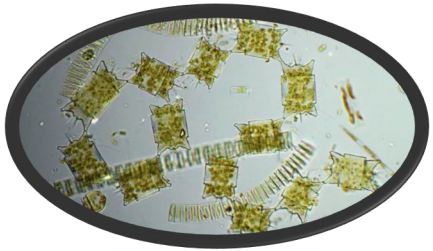
- Food ration and temperature treatments
- Responses: Respiration, survival and multiple condition metrics

Crab have tober and

We ns.

Acknowledgements

Louise Copeman
Louise.Copeman@noaa.gov



Funding sources: North Pacific Research Board, Essential Fish Habitat and NOAA Fisheries

OSU Marine Lipid Lab Research Assistants: Michelle Stowell and Samantha Mundorff

FBEP NOAA, Research Assistants: Michele Ottmar, Mara Spencer, Paul Iseri, MaryBeth Rew Hicks, Jessica Andrade

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