Arctic cod growth and condition in a warming Alaska Arctic

Comparing thermal responses of fish in laboratory and wild settings

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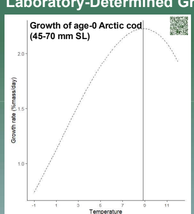
Arctic cod is an integral component of Arctic food web as it is remarkably efficient at assimilating and transferring energy to higher trophic levels

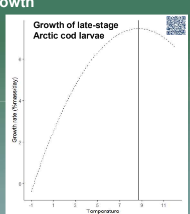
Background

Rapidly changing conditions in the region have made it increasingly important to expand what is known of Arctic cod ecology in the context of climate change. Survival of juveniles through their first winter is likely a crucial bottleneck for Arctic cod population dynamics. Both **larger size and increased lipid storage in the fall have previously been demonstrated to increase successful overwintering in juveniles**. Summer temperatures in the Northern Bering and Chukchi Sea regions are rapidly approaching laboratory-determined upper thermal limits for juvenile Arctic cod growth and energy storage. Yet it remains unclear if laboratory measurements of thermal stress translate to the same degree of stress in wild fish. **To fully realize the value of these laboratory studies, it is important to compare the growth and condition of laboratory fish to that of wild fish under comparable thermal conditions.**

Laboratory-Determined Growth

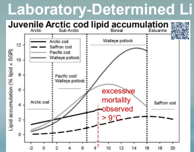


Adapted from Laurel et al. 2017

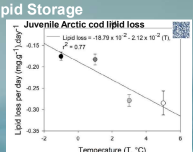


Adapted from Koenker et al. 2018

Laboratory-Determined Lipid Storage



Copeman et al. 2017, Figure 5



Copeman et al. 2022a, Fig. 7d

Question: Do laboratory measurements of thermal stress (i.e. reduced growth and lipid storage) manifest similarly in wild Arctic cod?

1. **This study aims to compare the growth rates and lipid storage of age-0 Arctic cod caught in the Northern Bering and Chukchi Sea regions during three thermally distinct years.**
2. **These results will then be compared to laboratory thermal responses to clarify the predictive potential such laboratory findings provide for wild Arctic cod populations moving forward.**

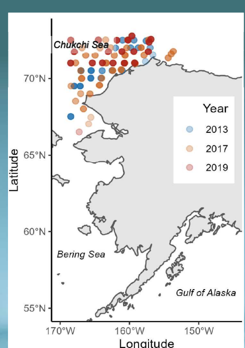
Methods

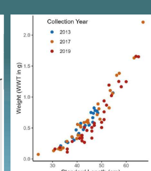
Collection

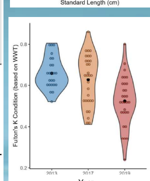
Age-0 Arctic cod were collected in midwater and surface trawls during the 2013 Arctic Ecosystem Integrated Survey (EIS) and the 2017 & 2019 Arctic Integrated Ecosystem Research Program (AIERP) surveys using a variety of gear types.

Temperatures at time of capture (CTD surface and bottom temp)

Year	Average Temperature (°C)	Temperature Range (°C)
2013	4.74	0.27-8.28
2017	5.49	2.06-7.87
2019	6.67	3.58-10.4



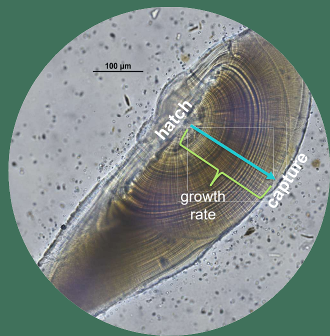




In Progress

Otoliths to estimate growth rate and daily age

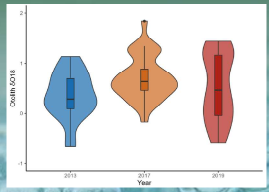
Growth rate = # daily increments/fish length (mm)



- Age-0 otoliths thin-sectioned transversely through the core to expose daily increment patterns via hand polishing (n ≈ 20+ otoliths/year)
- All otoliths imaged at 90x (oil immersion)
- Daily increments enumerated twice by the same age reader, each time using a new image.
- Subset of otoliths will be aged by more experienced age reader for quality control
- Hatch dates will also be estimated as growth rates vary with ontogeny

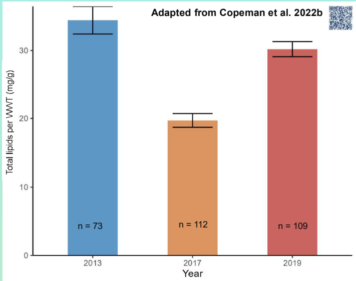
Characterize Thermal History

- CTD temperature values at time of capture do not reflect entire thermal experience
- Estimate average water temperatures fish experienced during first year of life using otolith stable oxygen isotope signatures and recently developed fractionation equations for Arctic cod (Kastelle et al. 2022).

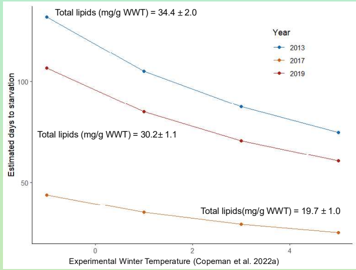


Next Steps

1. **Examine age and growth outcomes alongside lipid and condition outcomes (completed and published by Copeman et al. 2022b).**



Annual difference in the lipid storage of age-0 Arctic cod (*Boreogadus saida*) collected on ecosystem surveys during 2013, 2017, and 2019. Otoliths used for growth calculations in this study are a smaller subset of this specimen pool.



Average tissue concentrations of lipids in Arctic cod examined in this study were used with the rate of loss equation (mg g^{-1} WWT) $day^{-1} = -18.79 \times 10^{-2} - 2.12 \times 10^{-2} * (T, °C)$, $r^2 = 0.77$ to calculate survival times. Specifically, we calculated the time for lipids to decline from observed field values to experimentally-determined starvation levels (12.4 mg g^{-1}) as was done in Copeman et al. 2022a for this range of temperature treatments. This demonstrates the importance of lipid content for winter survival potential.

2. **Compare responses of wild Arctic cod in the context of their thermal experience to laboratory findings regarding growth and lipid storage.**

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Photos by: Erling Svensen, Peter Leopold, Kali Stone