Impacts of climate change on productivity of Arctic marine food-chains

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and

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Climate change, *Calanus* size, and productivity of Arctic marine food chains

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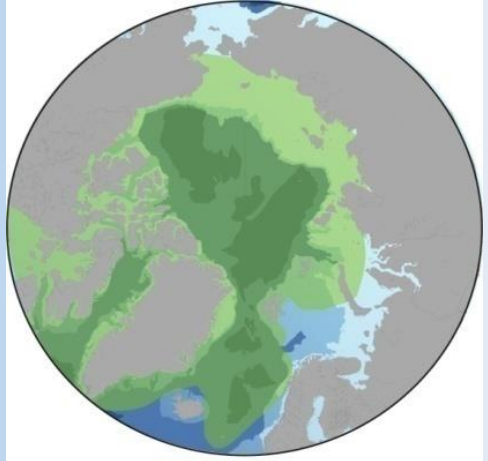
Arctic *Calanus (C. glacialis, C. hyperboreus)*

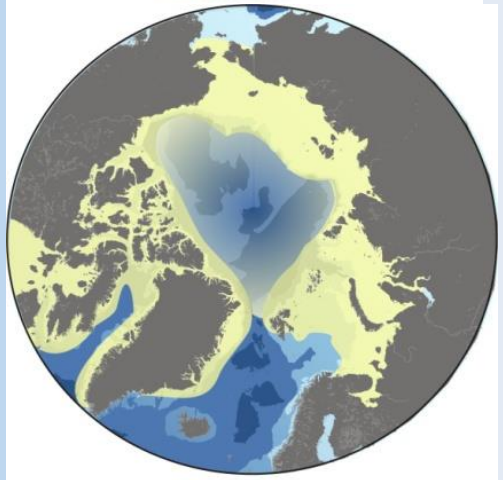
- Efficient herbivores
- Multi-year life-cycles, slow growth, large body size
- High total lipid (50-70%) and energy rich wax esters (70-90%)
- Seasonal vertical migrations

➢Presumed adaptations to seasonality of Arctic ecosystems

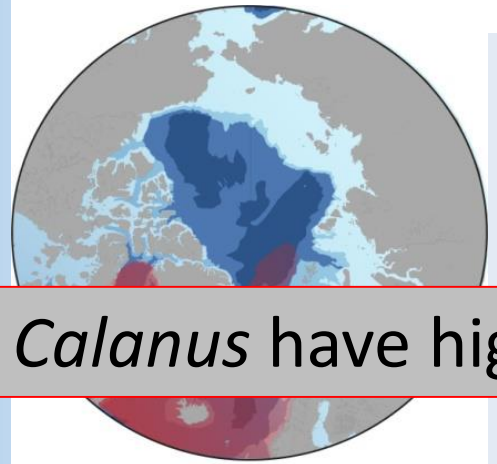
Arctic and North Atlantic *Calanus* species



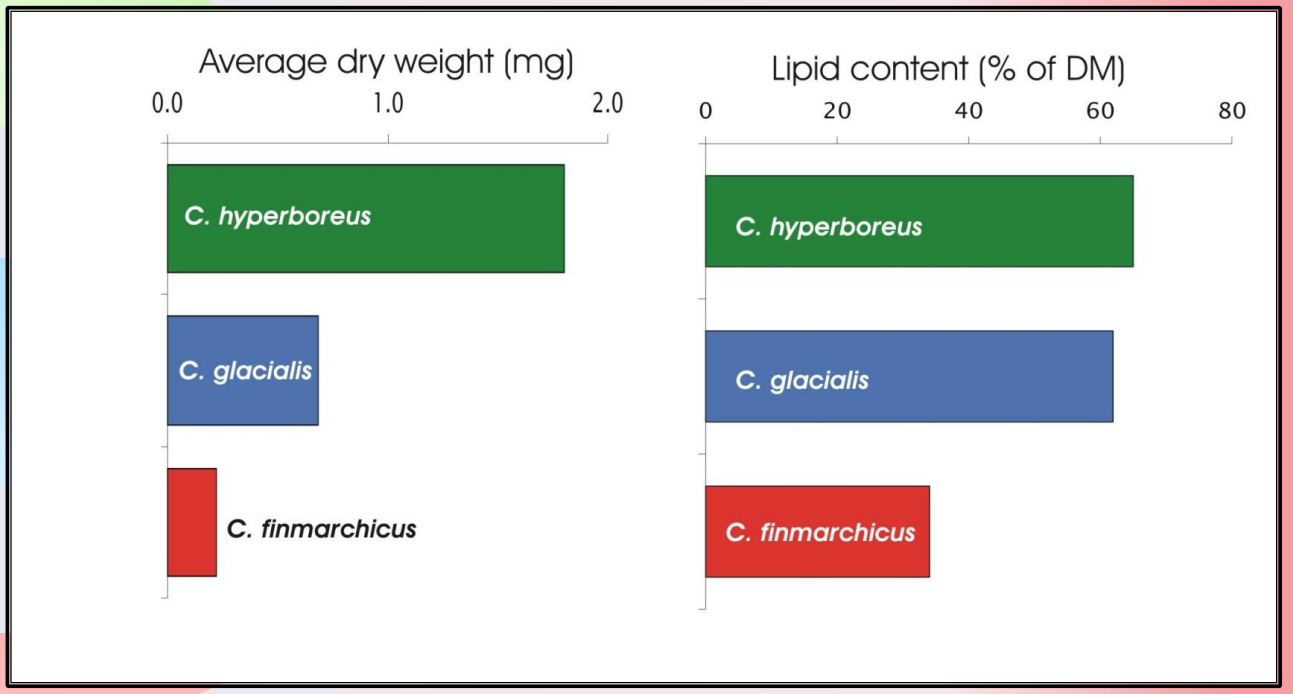
Arctic, deep water
C. hyperboreus
4.5-7 mm
1-1.8 mg lipids



Arctic, shelf
C. glacialis
3-4.6 mm
0.4-0.45 mg lipids



Atlantic
C. finmarchicus
2-3.2 mm
0.04-0.08 mg lipids

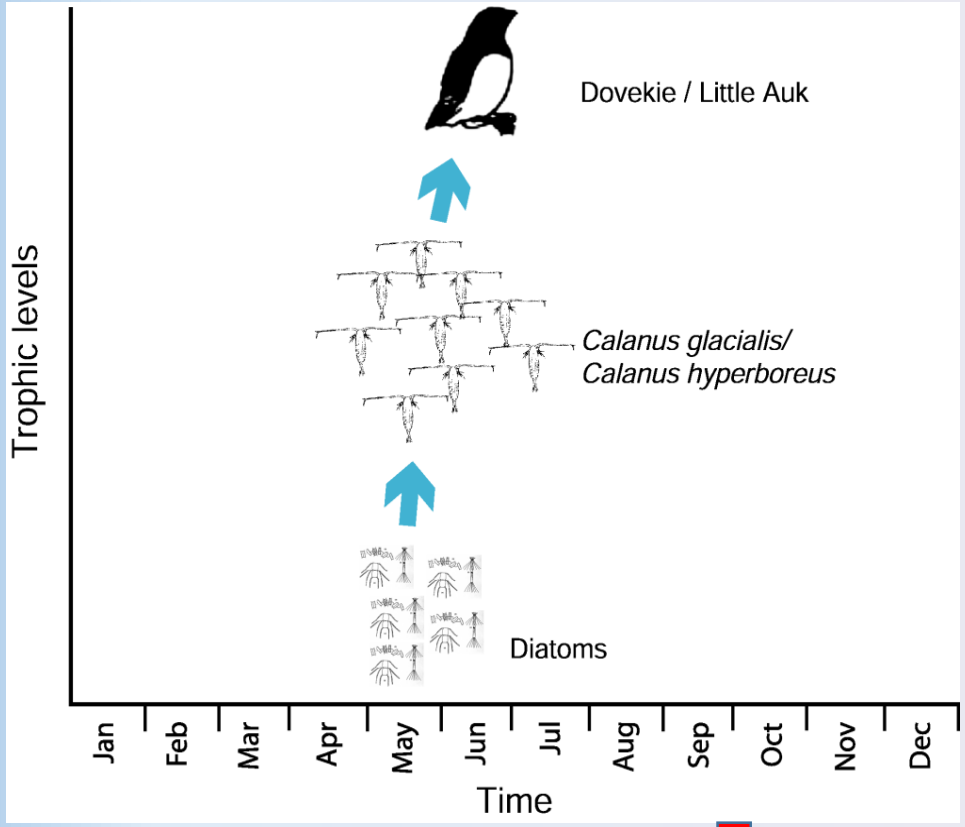


After Falk-Petersen et al. 2007, 2009

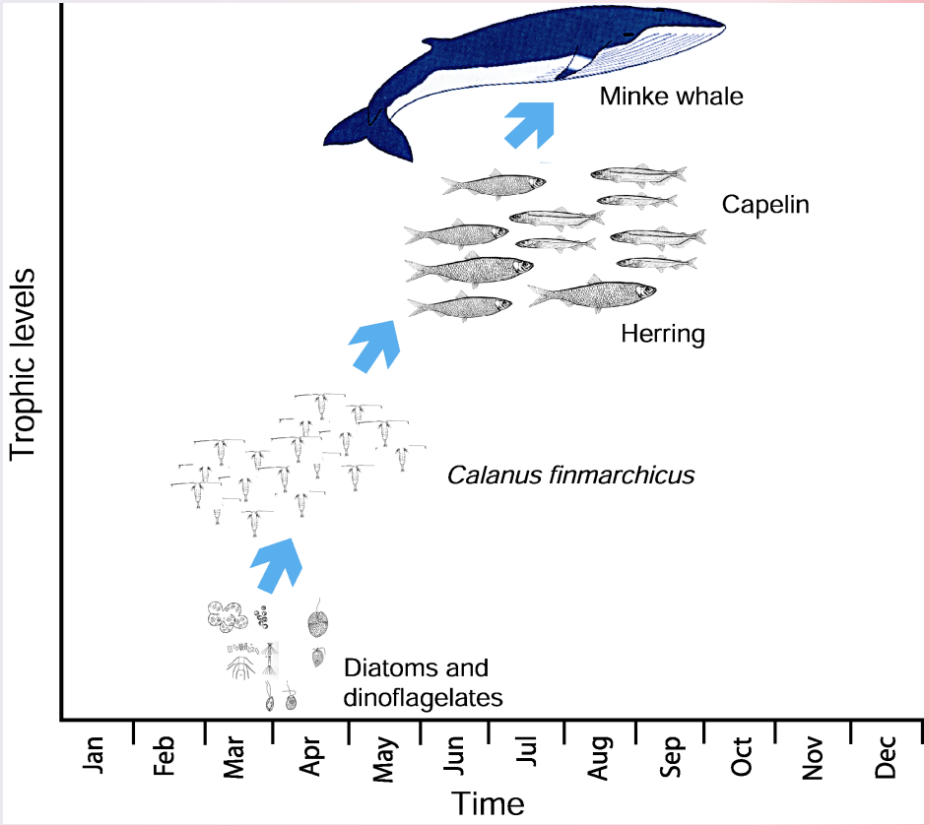
Arctic *Calanus* have higher species-specific lipid content than boreal species

Calanus species and the Arctic pelagic food web

Cold periods



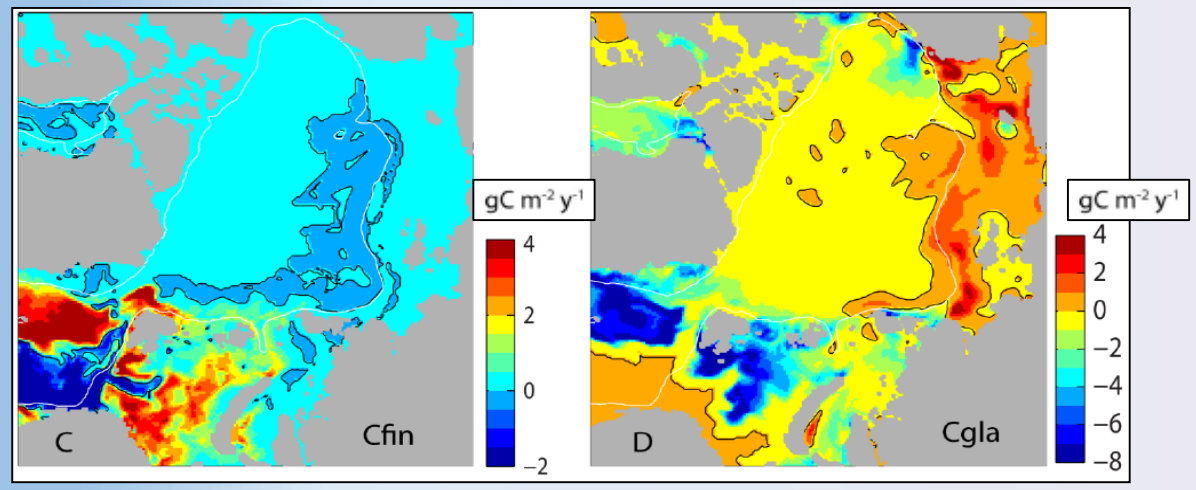
Warm period (warmer future?)



More energy to higher trophic levels

Falk-Petersen et al. 2007

Calanus in a future Arctic



Slagstad et al. 2015 Front Mar Sci

<u>Lab experiment changing temp and food: feeding, reproduction, lipids</u>:

'Our results suggest that a future warmer ocean will reduce the advantage of early spawning by *C. glacialis* and that *C. finmarchicus* will become increasingly prevalent.'

Kjellerup et al. 2012 MEPS

Modeling and experimental studies predict replacement of *C. glacialis* with *C. finmarchicus*

The Paradigm: Consequences (?) of changes in *Calanus* community

The ‘warmer Arctic’ scenarios also forecast a switch in the Arctic marine food web from large, lipid-rich Arctic herbivores to boreal grazers, which could mean that primary production will be utilised by smaller, faster-growing and less lipid-rich species (Søreide et al. 2010) and consequently, the food resources available to the top Arctic predators such as seabirds, seals, and whales would be reduced (Weslawski et al. 2009).

Weydmann et al. 2014 MEPS

Observations from that modeling study indicate declining trends for the Arctic species *C. glacialis* and *C. hyperboreus* in the western BS, especially since 2004 and onwards. This is potentially serious because the BS ecosystem is home to one of the largest concentrations of seabirds in the world, and it holds an abundant and diverse assemblage of marine mammals.

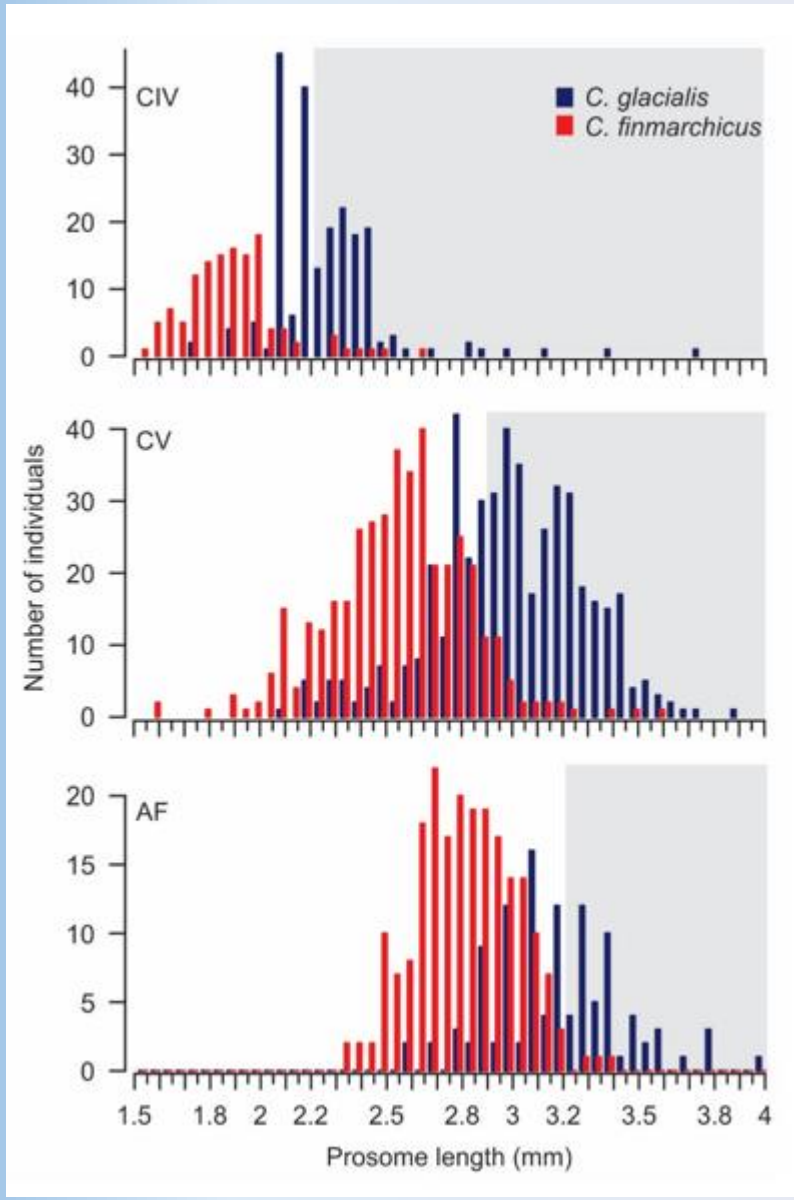
Dalpadado et al. 2012 ICES J Mar Syst

But…

- Foundation of paradigm (species- specific lipid content) based on limited data
- *Calanus* identification may not be so straightforward
- *C. finmarchicus* has dominated in the Barents Sea in the last 10+ years and we see record high cod stocks and whale population recovery

So maybe the future is not so bleak (at least based on *Calanus*)

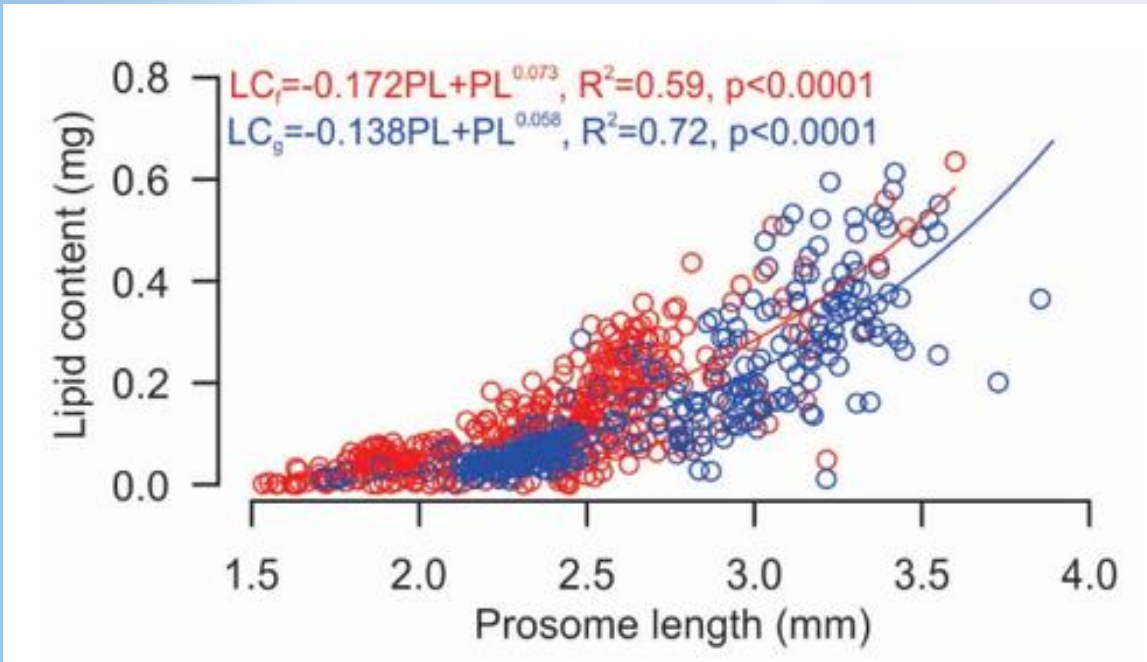
Insights from molecular taxonomy



- Misidentification of *Calanus* spp. based on morphology
- Broad overlap in size between Arctic and boreal *Calanus,* and both species exhibit considerable heterogeneity in size
- *C. glacialis* can be considerably smaller than believed

Renaud et al. submitted

Size, species identity, and lipid content

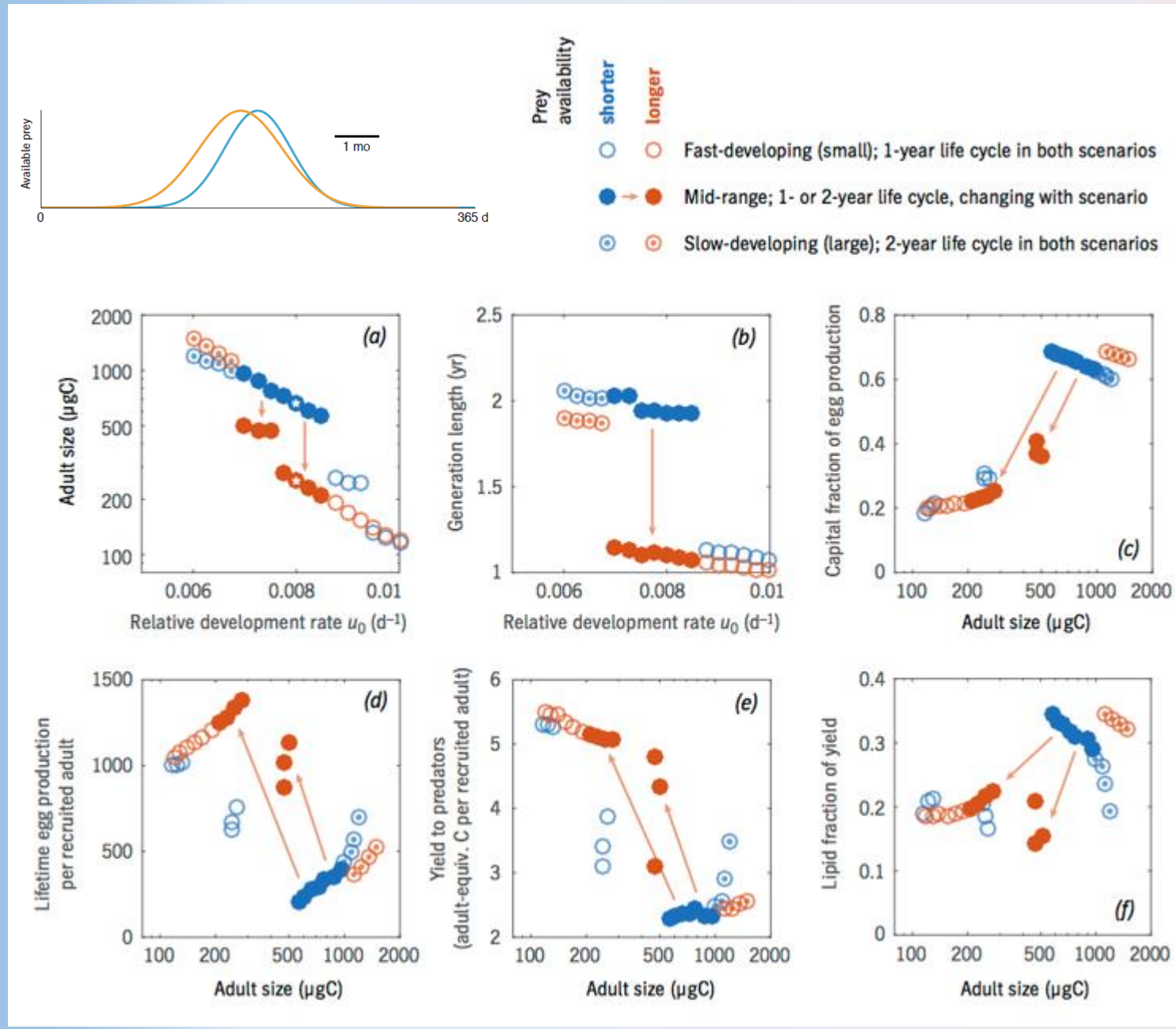


- Size alone determines lipid content, not species
- Slightly greater lipid-body size relationship for *C. finmarchicus*

➢ *No evidence to support species-specific lipid content!*

So how will shrinking individual sizes and potential species shifts affect the available nutrition for predators of *Calanus*?

Renaud et al. submitted

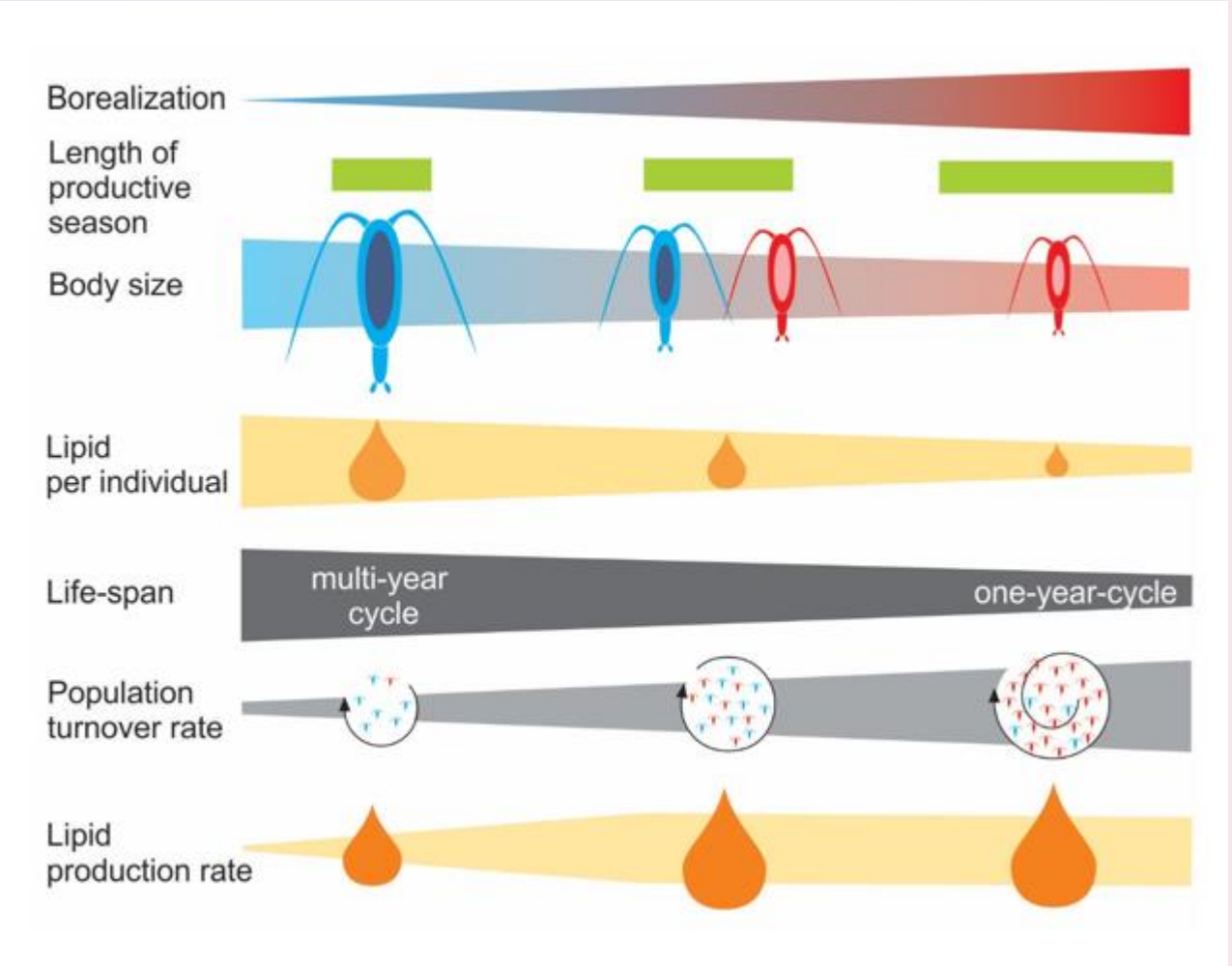


- 2y to 1 y life cycle (b)
- 30% lower individual lipid yield (f)
- But higher yield to predators per adult (e)
- And increased lifetime egg production (d)

➢ Much greater population-level lipid production

Renaud et al. submitted

Ecosystem resilience to shifts in *Calanus* communities

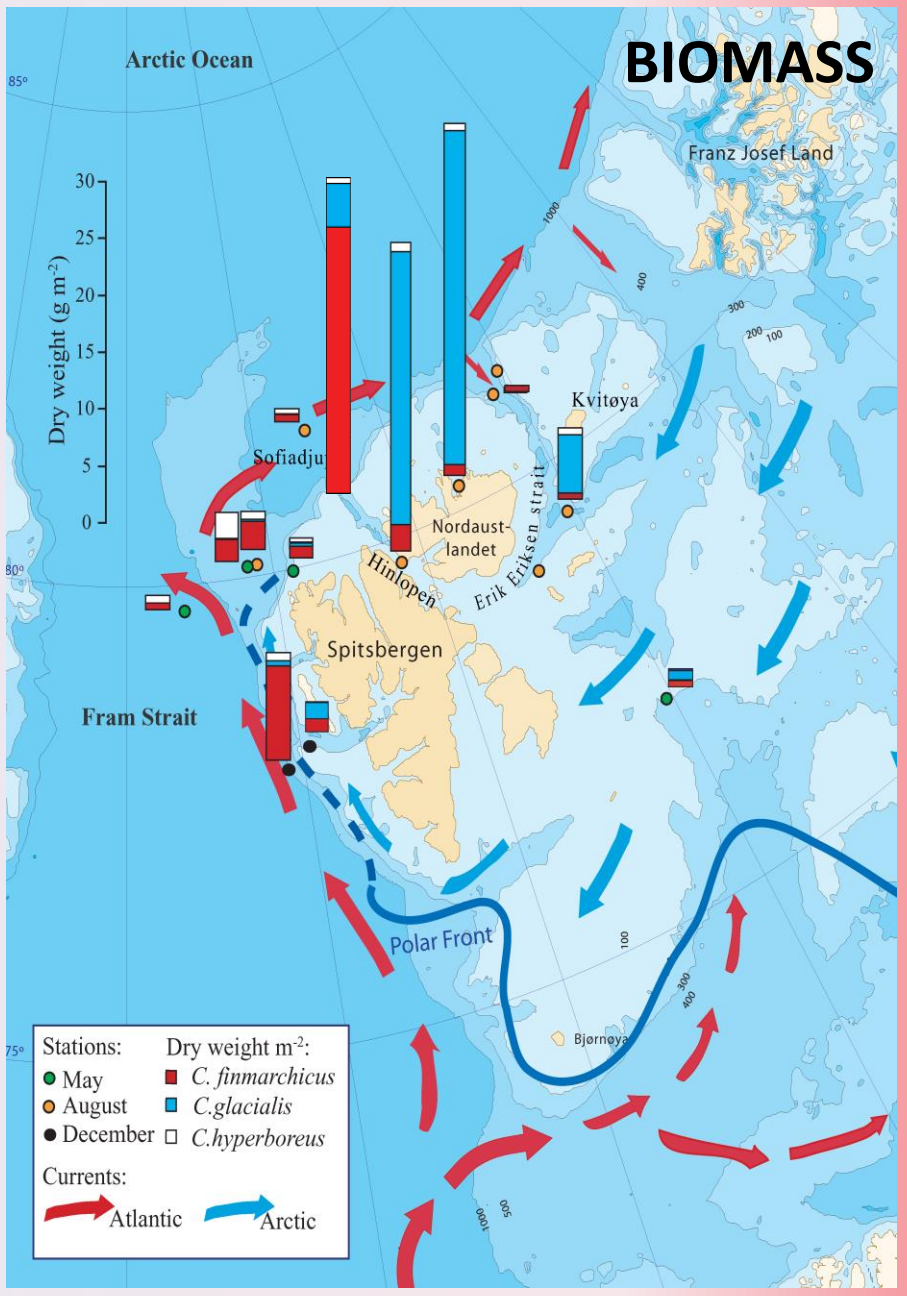


Central basin/shelves → Advective areas

Calanus in Svalbard waters

C. hyperboreus
C. glacialis
C. finmarchicus

Søreide et al. (2008)



Calanus size and temperature

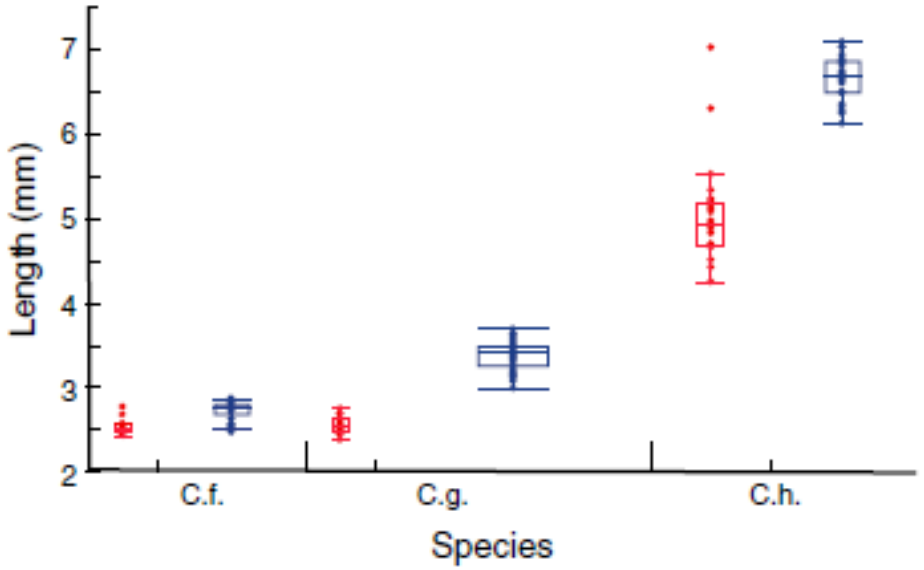


Figure 3. Box plots of median length of the three *Calanus* species from their temperate (red) and arctic (blue) sampling sites. C.f.: *Calanus finmarchicus*; C.g.: *Calanus glacialis*; C. g.: *Calanus hyperboreus*. Width of boxes scales with samples sizes. Horizontal extensions of boxes and lines represents the 25% and 75% quantiles, respectively. Observations outside this range are represented by dots.

Leinaas et al. 2016 Ecol Evol