Body size variations between temperate and arctic populations of marine and terrestrial ectotherms; Calanoid Copepods and Collembola as model organisms

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Two ecological "rules"

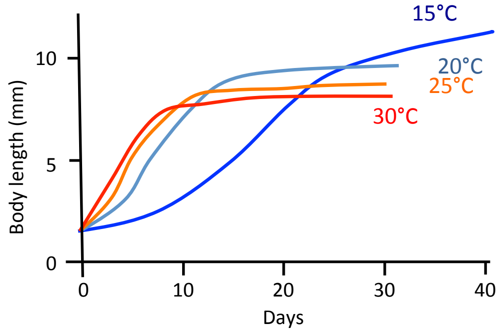
1. Bergmann's rule:

Species or populations increase in size towards colder areas (Bergmann clines)

*However, the opposite **converse Bergmann** is also observed mainly in insects*

Phenotypic variation, includes genotypic differences and plasticity

2. Temperature-size rule (TSR): ectotherms grow larger at lower developmental temperatures.

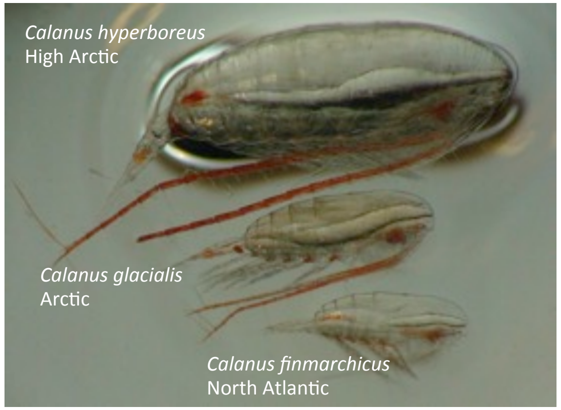


Growth of midge larvae (from one populations; sibs) raised at different temperatures

Phenotypic plasticity Experimental studies

Bergmann clines appears more common in aquatic (notably marine) than terrestrial systems.

Marine copepods



Many calanoid copepods show ***interspecific*** Bergmann clines.

- What about ***intraspecific*** Bergmann clines?
- How does these responses relate to ***genome size***?

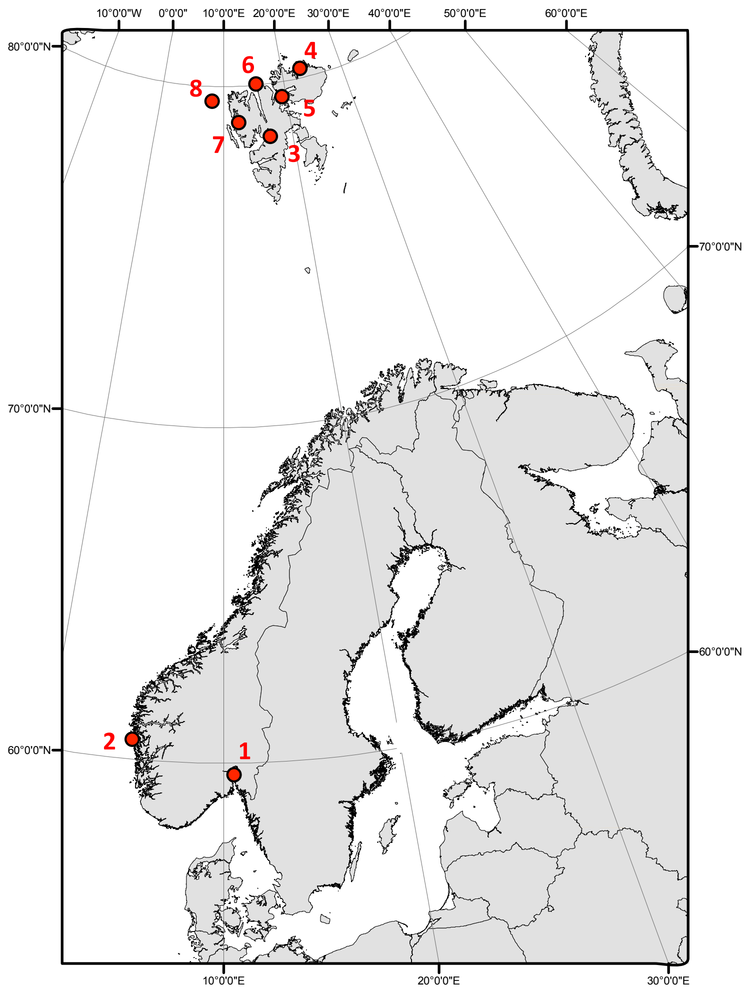
Terrestrial springtails

Springtails have more flexible or free running life cycle than insects.

Implications for body size variation along climate gradients?

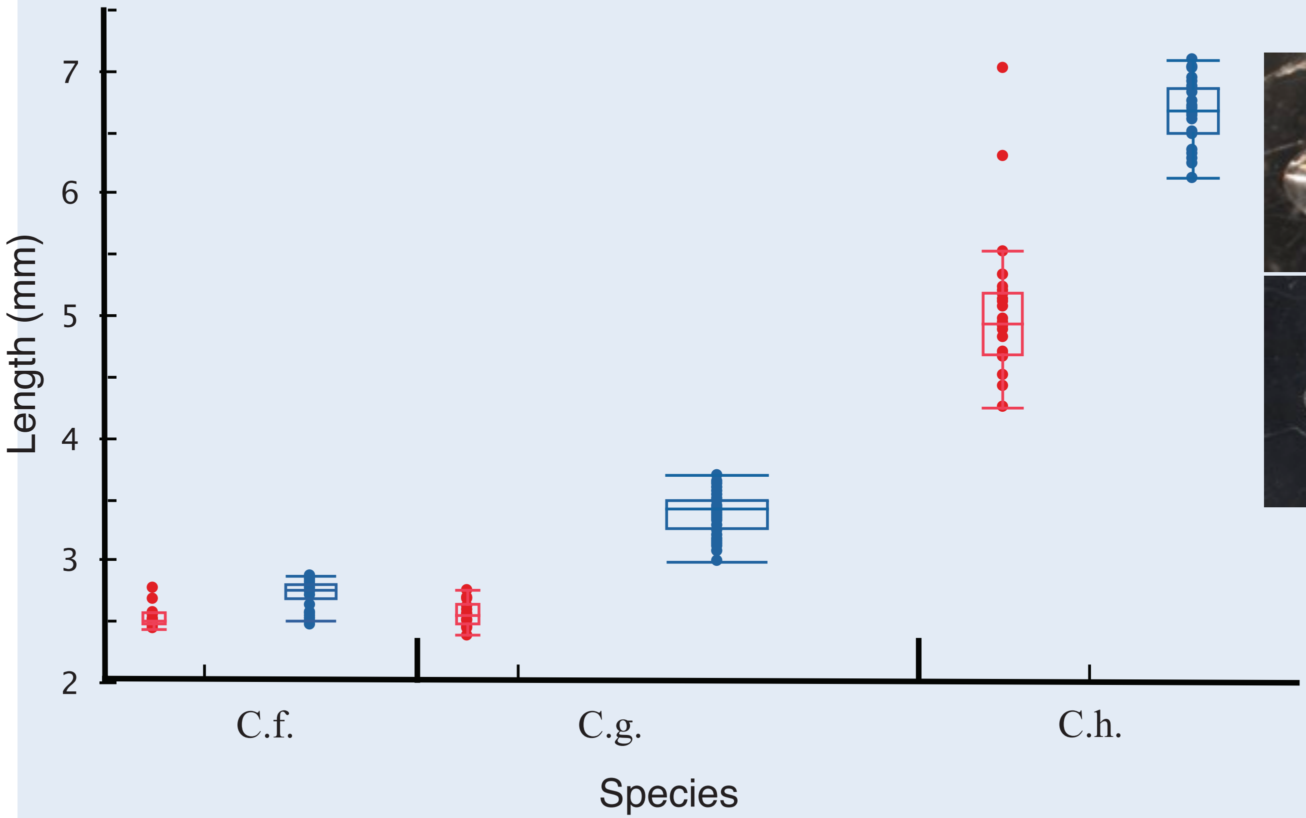
Calanoid copepods; sampling sites

Calanus finmarchicus,
C. glacialis &
C. hyperboreus
and
Paraeuchaeta norvegica



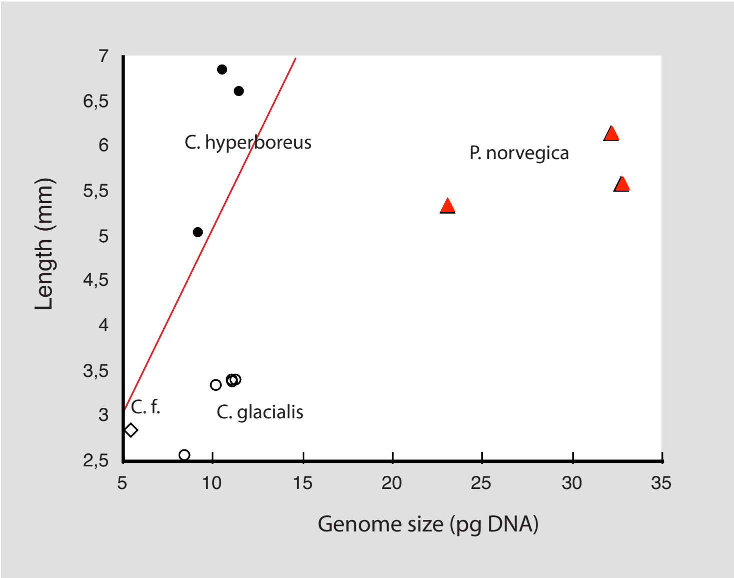
(Leinaas et al. 2016)

Adult body size of three *Calanus* species from temperate and cold waters



Body length of *Calanus finmarchicus*, *C. glacialis* & *C. hyperboreus*, from temperate (red) and arctic (blue) waters

Genome size of calanoid copepods



Genome size – body length relationship in populations of four calanoid species from temperate and arctic waters.

Calanoid copepods

Both ***Inter - and intraspecific*** Bergmann clines

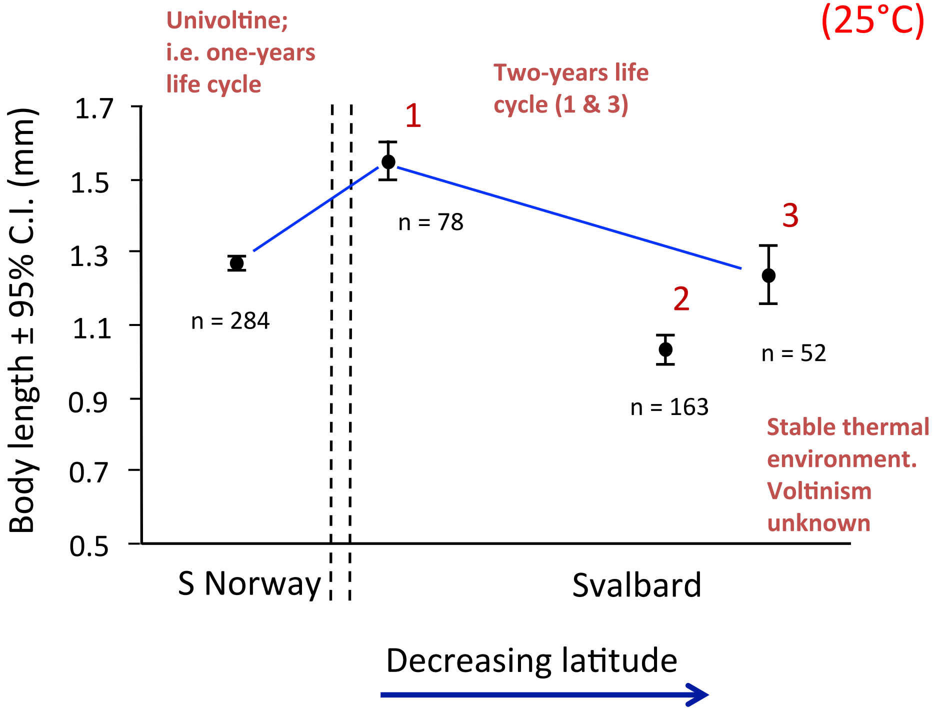
No clear ***interspecific*** *body size - genome size relationship,*
but distinct ***intraspecific*** correlations between body- and genome-size within each of the four species

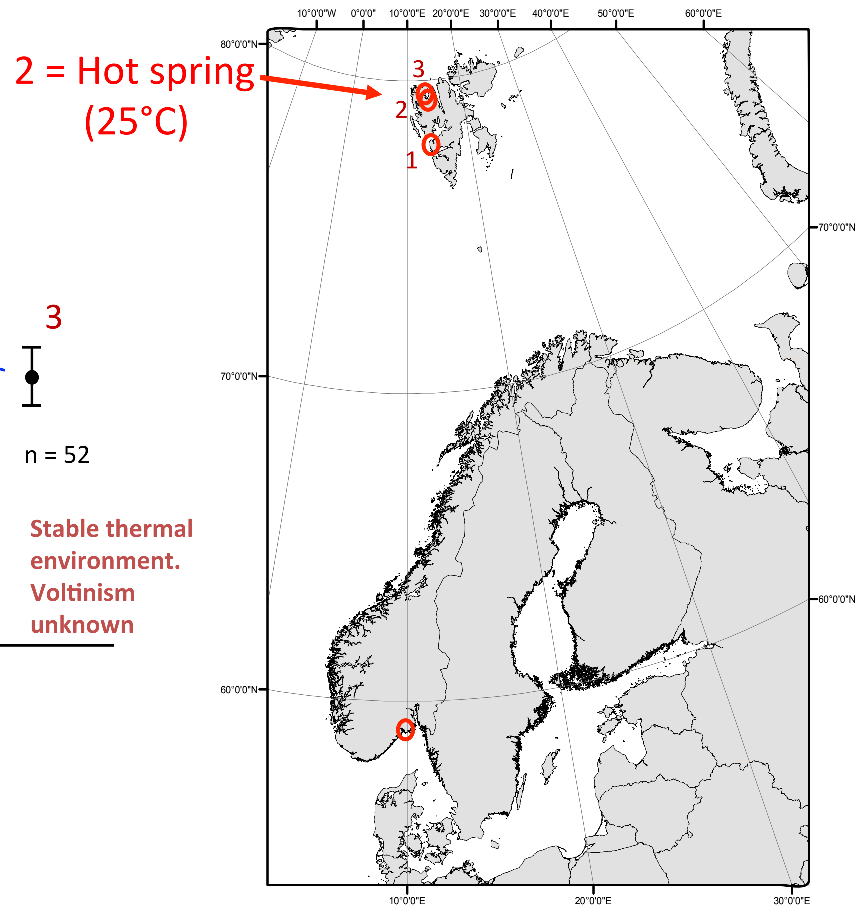
Strongly suggests a micro evolutionary basis of the intraspecific Bergmann clines (and not just phenotypic plasticity) (causation unclear)

However: Disentangling phenotypic plasticity and evolutionary changes requires ***common garden experiments***

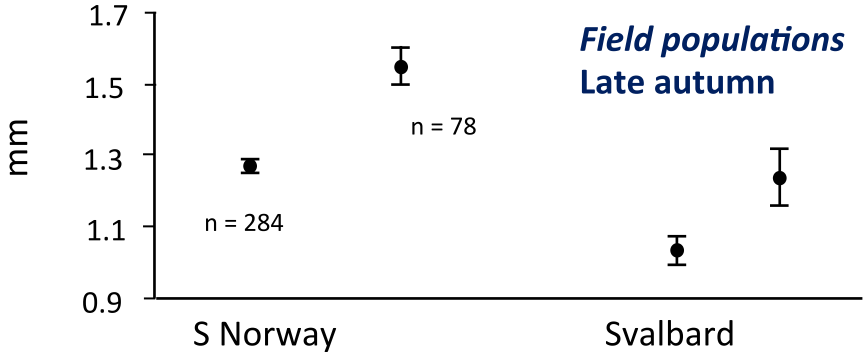
Springtails

Hypogastrura viatica: body length (± 95% c.i.) in field populations at the end of their growth season

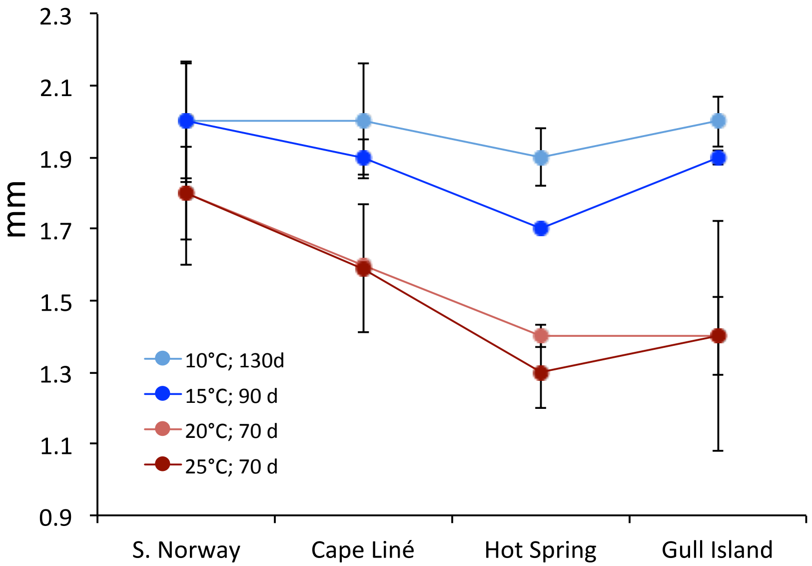




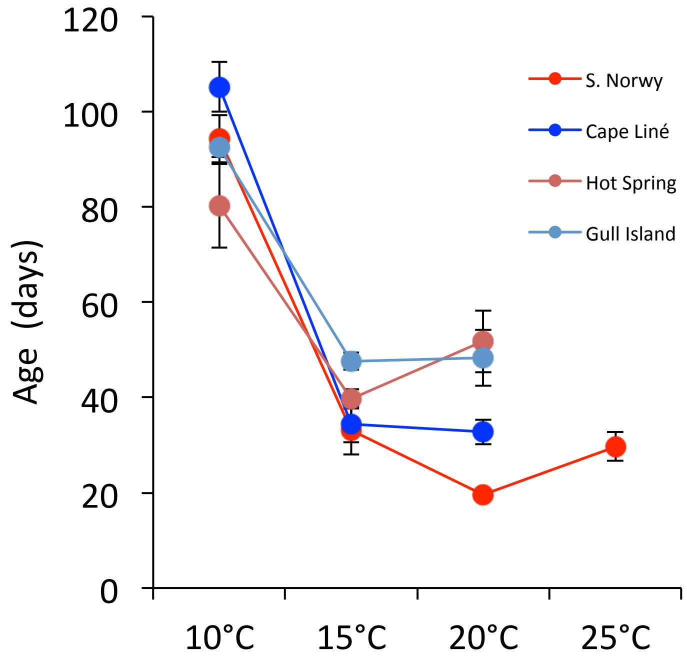
Hypogastrura viatica: population variation in body size among field collected animals, and in common garden experiments



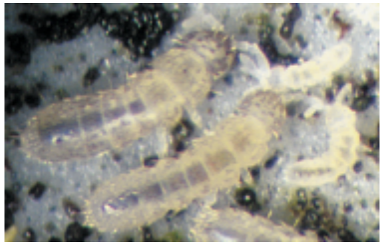
Body length at temperature specific ages

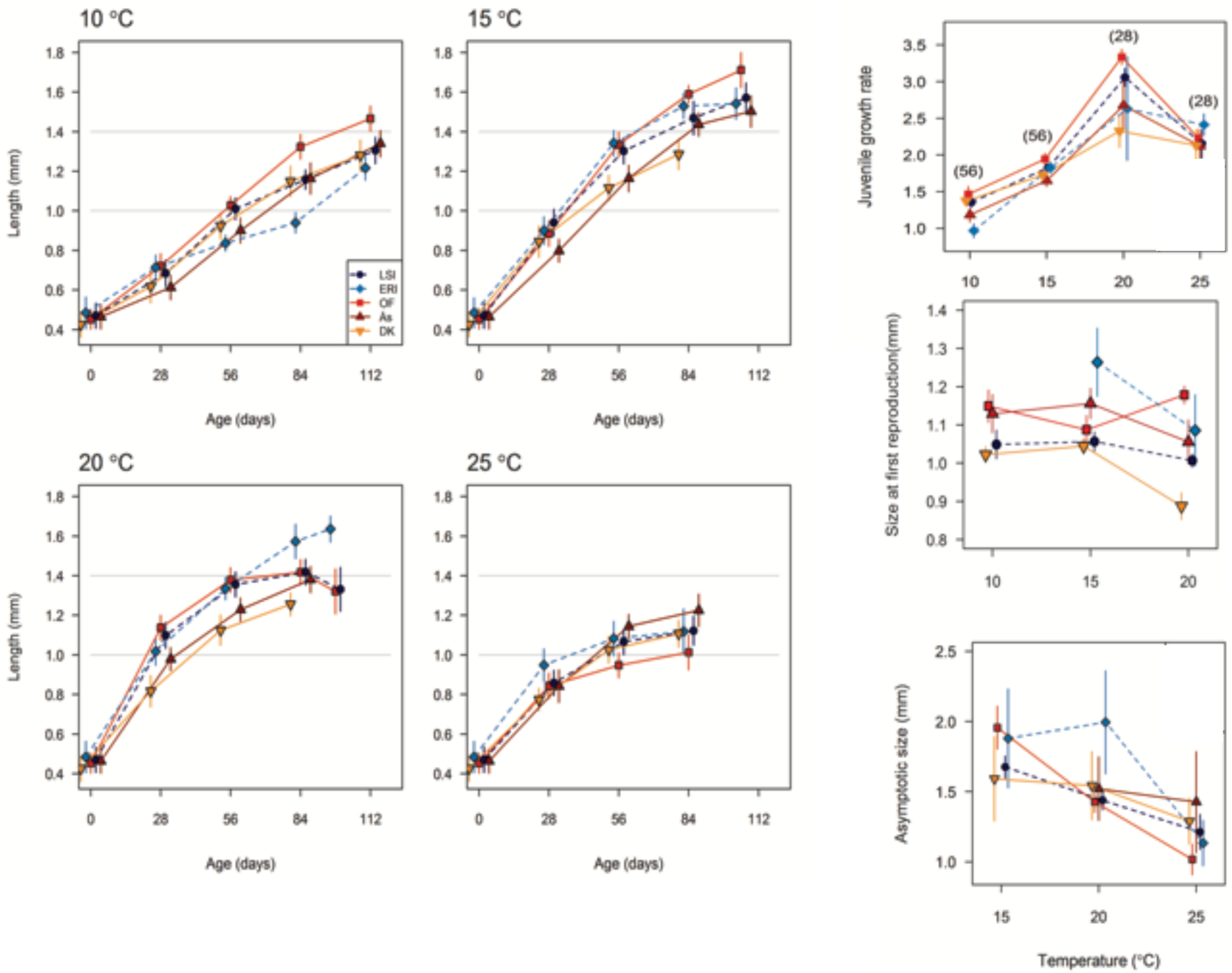


age at first reproduction



Folsomia quadrioculata: population specific variation in body size and reaction norms





High Arctic Svalbard
High Arctic Canada
Oslo conif. forest
Oslo open field
Denmark decid. forest

Little effect of latitude or macro climate

Comparison of temperature dependent performance in a temperate forest and a high arctic population of *Folsomia quadrioculata*

Performance

	Linkage to juvenile processes			*Linkage to adult processes*		
Temp. (°C)	**Juv. growth rate**	**Juv. dev. rate**	**Size at first reproduction**	**Asymptotic size***	**Reproduction (120 d)**	**Survival**
10	OF = LSI	OF = LSI	OF	OF	OF	OF = LSI
15	OF = LSI	LSI	OF	OF	OF = LSI	OF = LSI
20	OF	LSI	OF	OF = LSI	LSI	OF (= LSI)
25	OF = LSI	-	-	LSI	-	LSI

General tendency across traits that the **temperate forest population (OF)**, is performing best at low and the **arctic population (LSI)** best at high temperatures

Temperature - size relations in ectotherms appears much more complex among terrestrial than marine taxa

Marine:
Little temperature variation.
Direct effect of (mean) temperature, possibly with some indirect effect of $[O_2]$.
Commonly showing Bergmann clines and following TSR

Terrestrial:
Summer heat sum and time limitation, as well as temperature fluctuation and stochasticity may be stronger drivers on adaptations than the ambient mean temperature.
Depending on other adaptive responses on time limitation, such as increased thermal efficiency or change in voltinism, this may counteract or strengthen the tendency to increase in size at low temperature. Dispersal ability of species may affect importance of local adaptation vs. macroclimate in latitudinal patterns.

Growth experiments often show **consistency with TSR**, without necessarily leading to Bergmann cline in the field.

These differences may suggest that community structure and trophic interactions in marine and terrestrial food webs may respond differently on climate change