Evolution of a Latitudinal Body Size Pattern in a Marine Isopod

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Body Size

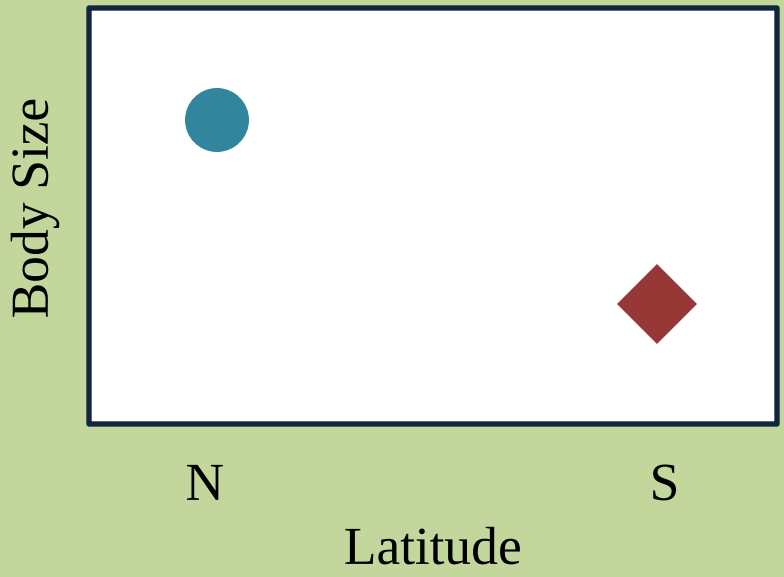
- Body size is widely studied phenotype
- Within living organisms, body mass spans 21 orders of magnitude
- “The most important attribute of an animal, both physiologically and ecologically is its size.“ –George Bartholomew

Intraspecific Variability

- Larger body size = greater fitness (generally)
  - Females have higher fecundity
  - Longer-lived
  - Greater mating success
  - Higher metabolic rates

Bergmann's Rule

Endotherms from cooler latitudes larger than warmer latitude congeners (or conspecifics)



Generality?

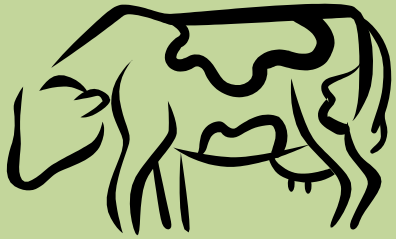
Follow:

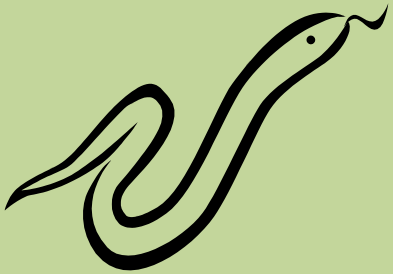
Birds Mammals

Arthropods Fish

Salamanders Frogs

Turtles Lizards Snakes





Reverse:

Birds Mammals

Arthropods Fish

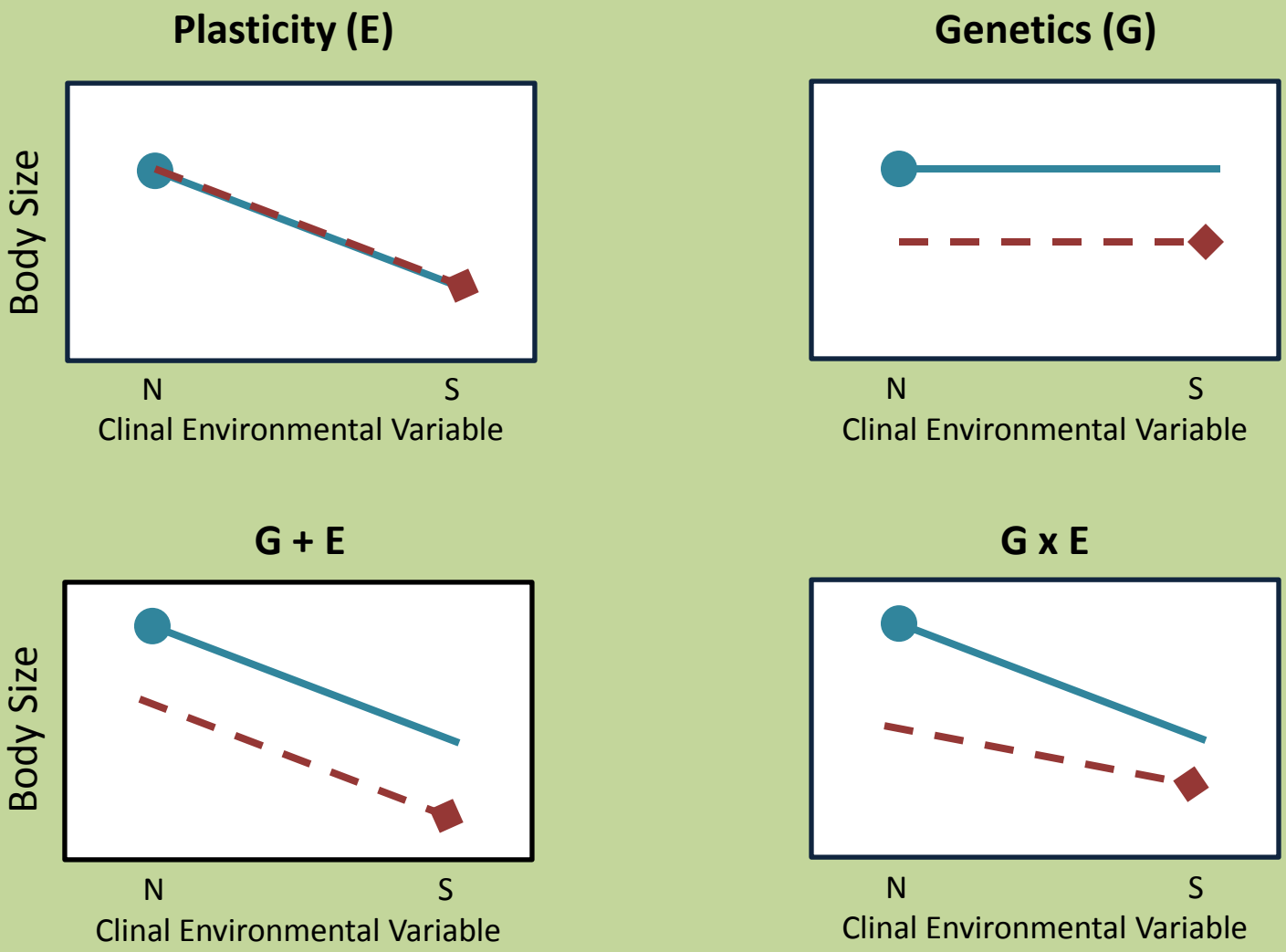
Salamanders Turtles

Lizards Snakes

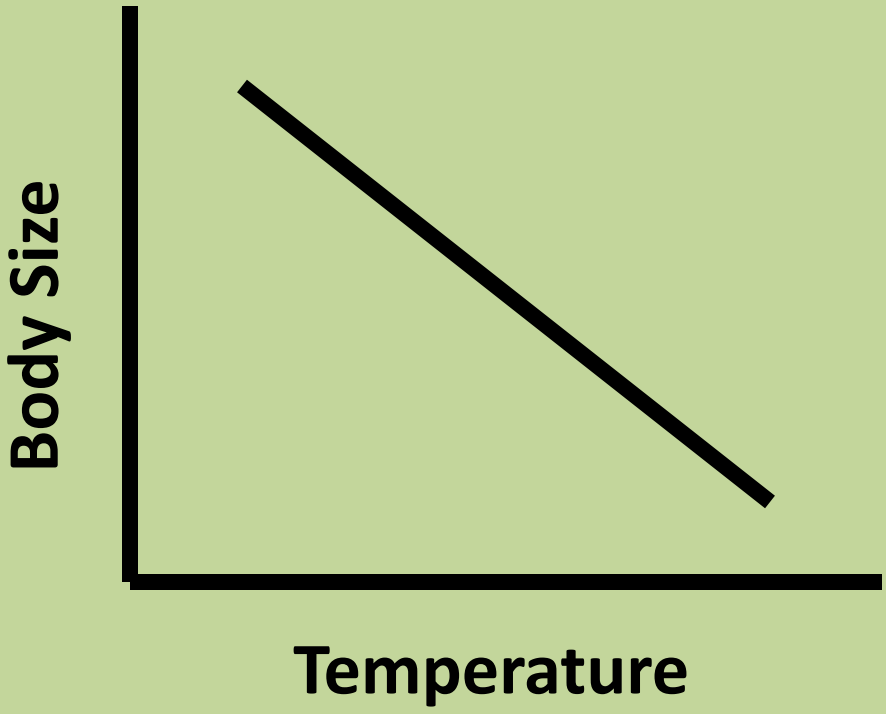
What's Missing?

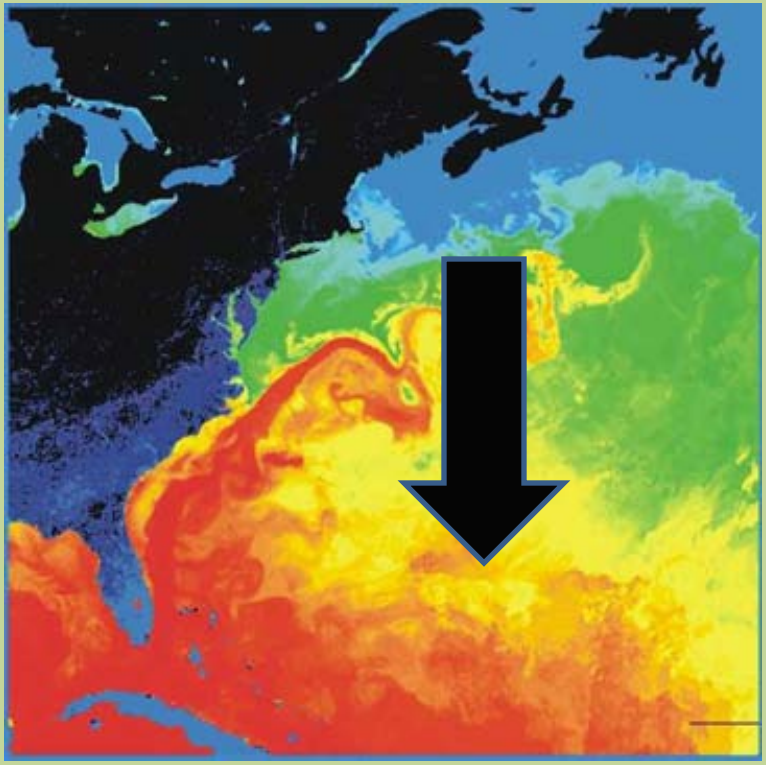
- Arguments over the generality/definition have detracted from:
  1. What role does plasticity and/or genetics play in maintaining this pattern?
  2. What co-grading environmental factors are responsible for this pattern?

Genetics vs. Plasticity

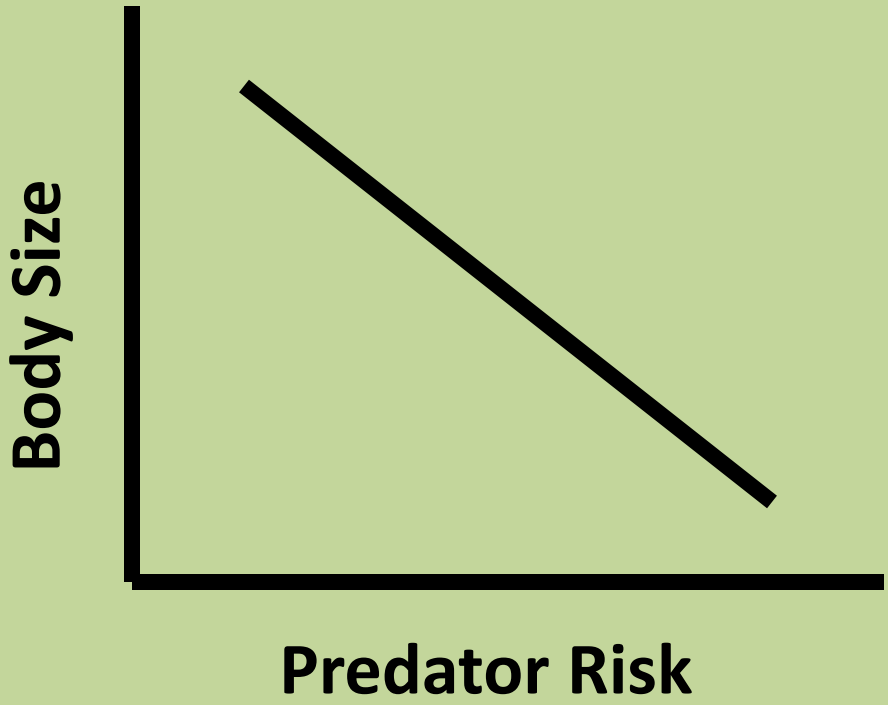


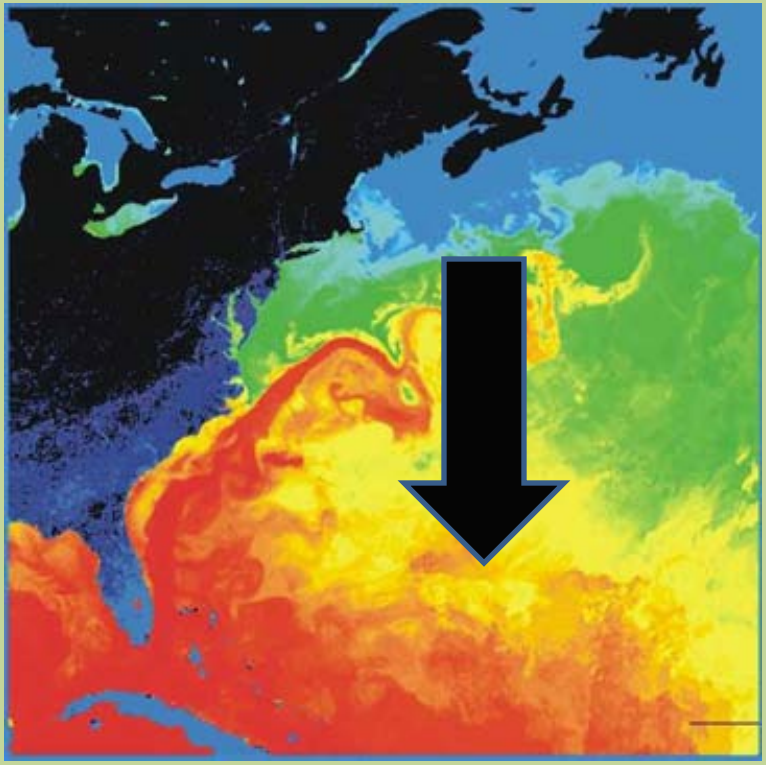
Temperature and Bergmann's Rule





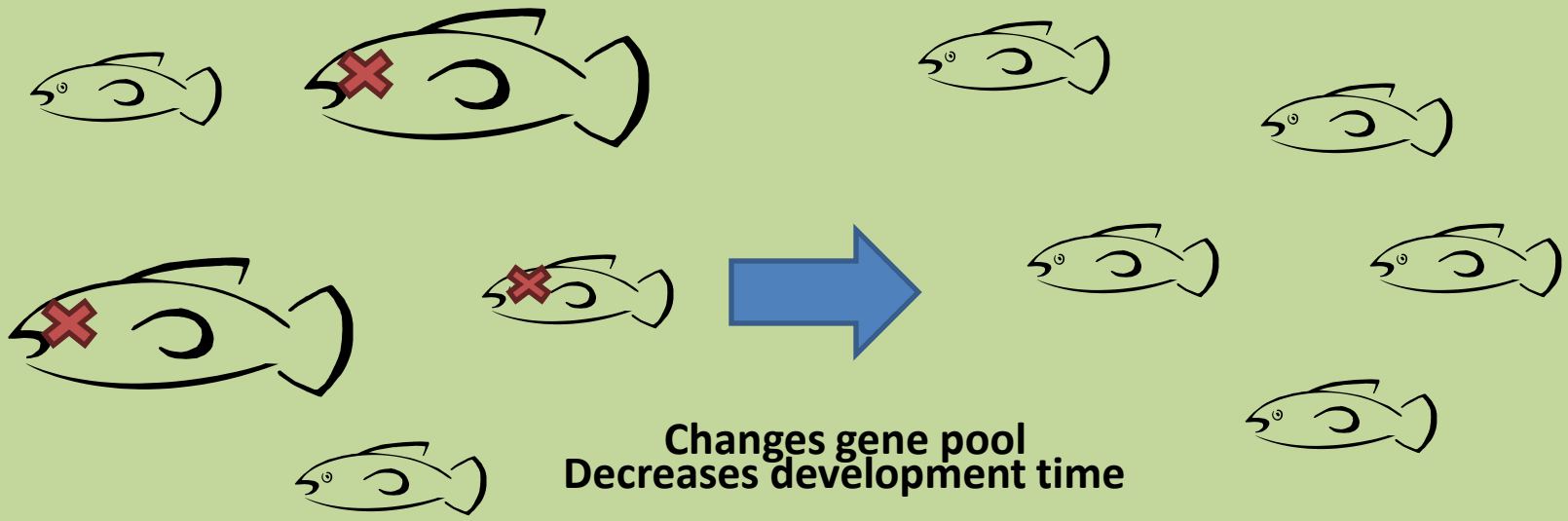
Bergmann's Rule Driving Forces





Predation

- Increased predation pressure can lead to reduced body sizes
  - Size-selective and non-selective predation can cause change

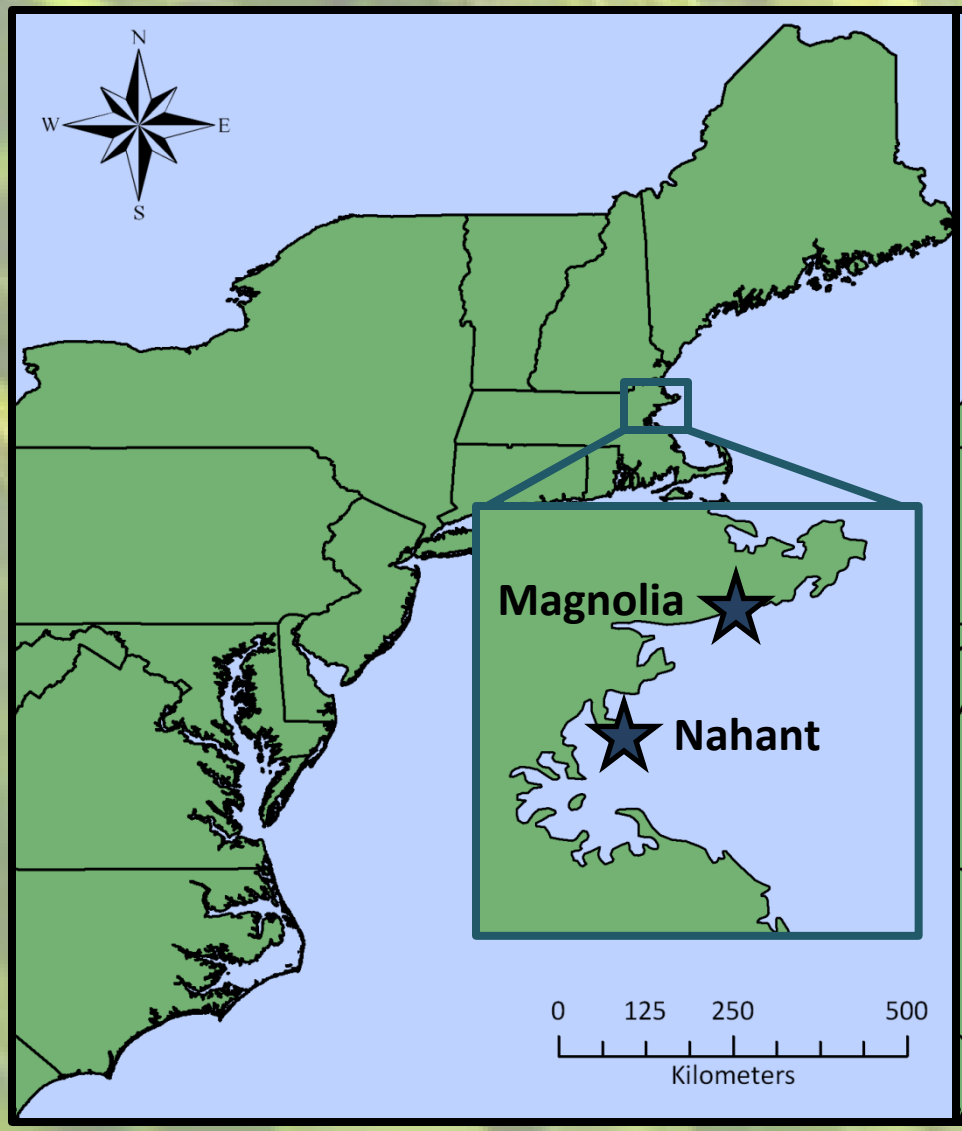


The Beast: *Idotea balthica*

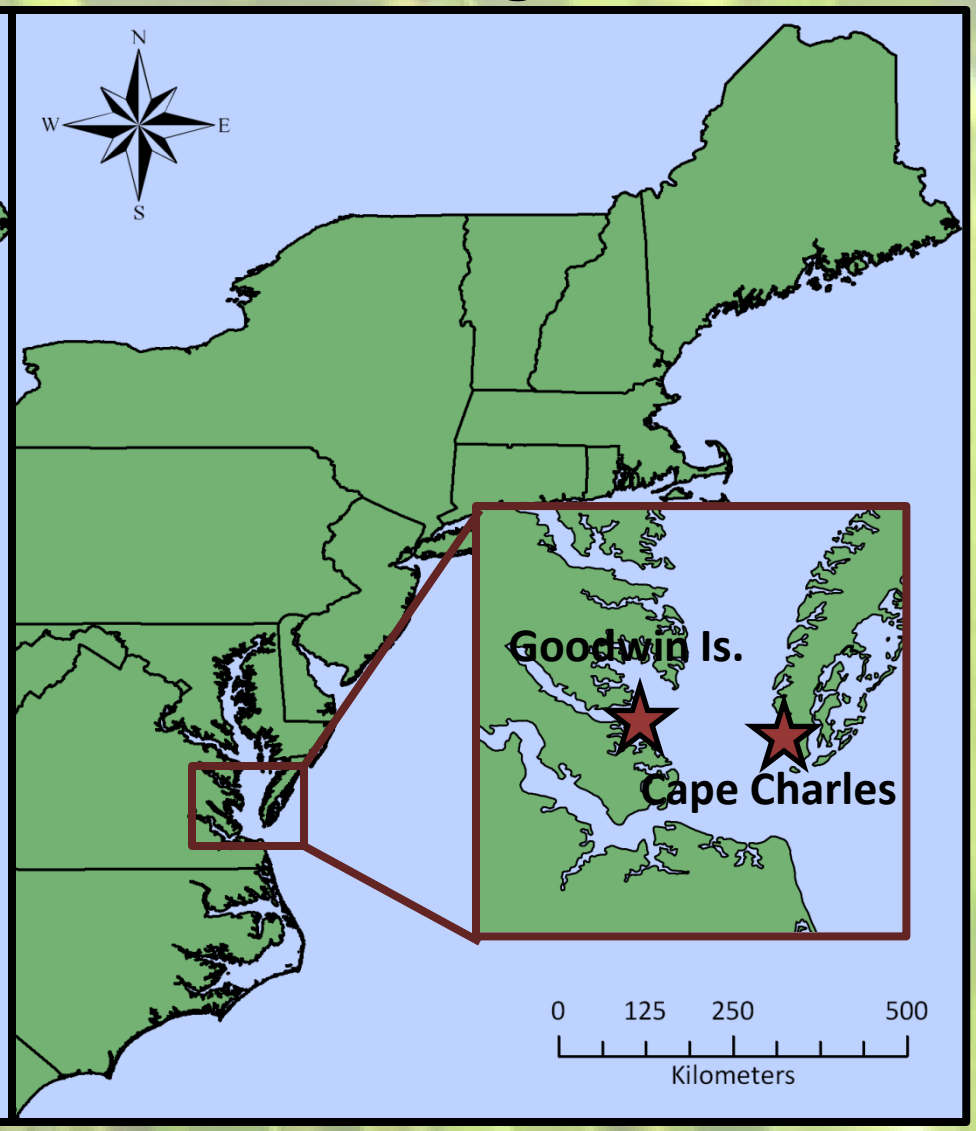
- Marine, herbivorous isopod
- Wide-ranging along Atlantic coasts; range from Virginia to Maine in U.S.
- Sexually dimorphic

Sites

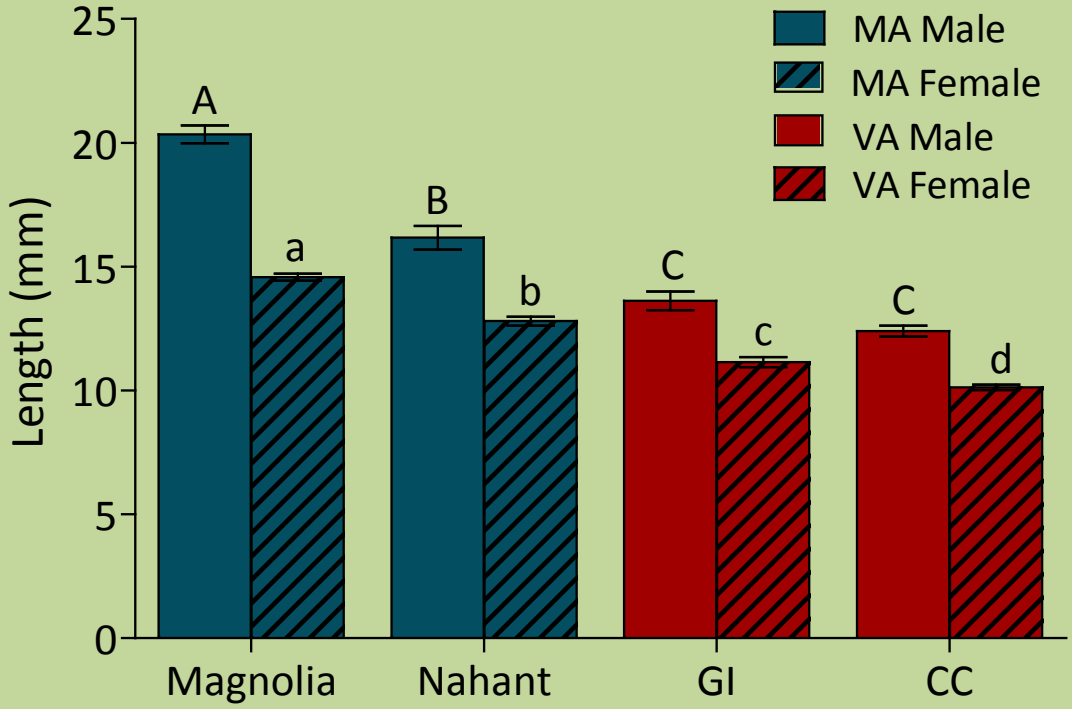
Massachusetts



Virginia



Field Collections



Source	P-Value
Population	<0.0001 *
Sex	<0.0001 *
S*P	<0.0001 *

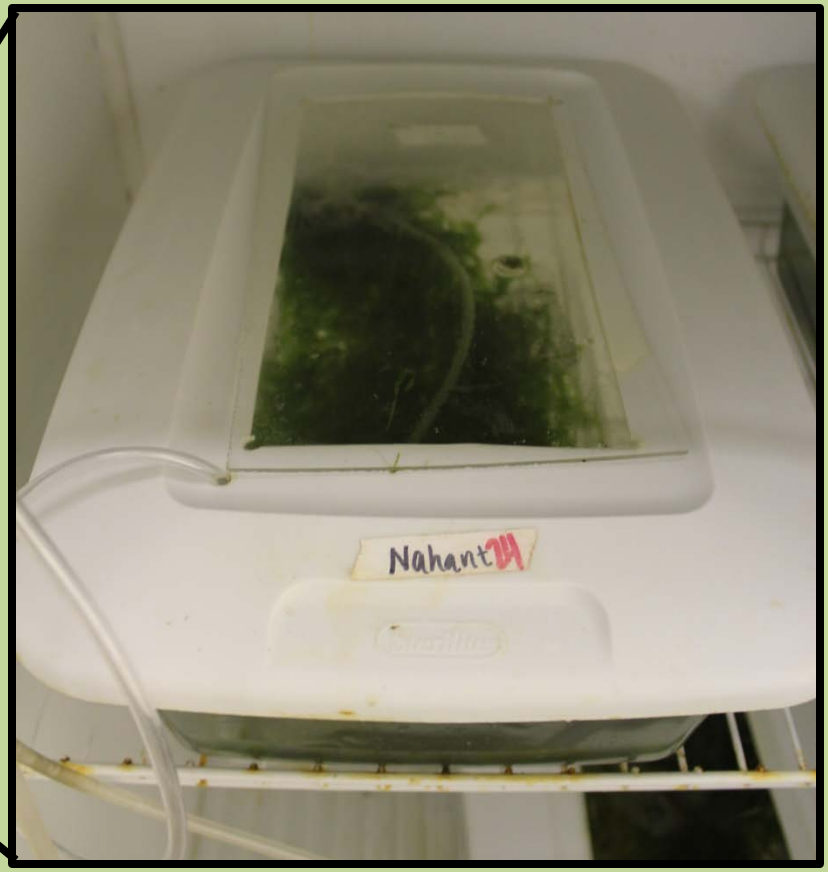
Questions

Given that we see this pattern:

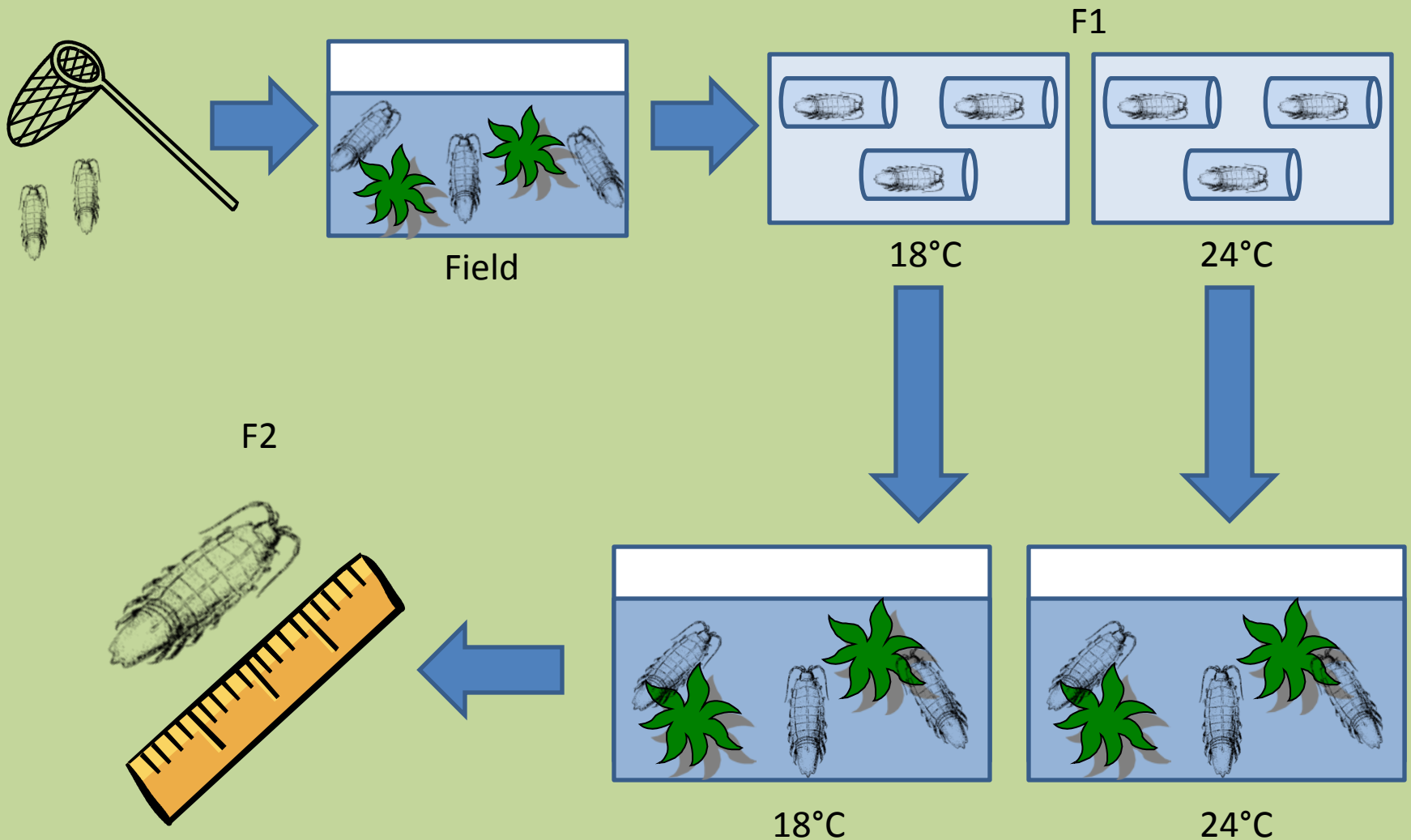
1. What role does genetics and/or plasticity play as the underlying mechanism?
2. What role does temperature play in sculpting this pattern?
3. What role does predation play in sculpting this pattern?

Genetics vs. Plasticity

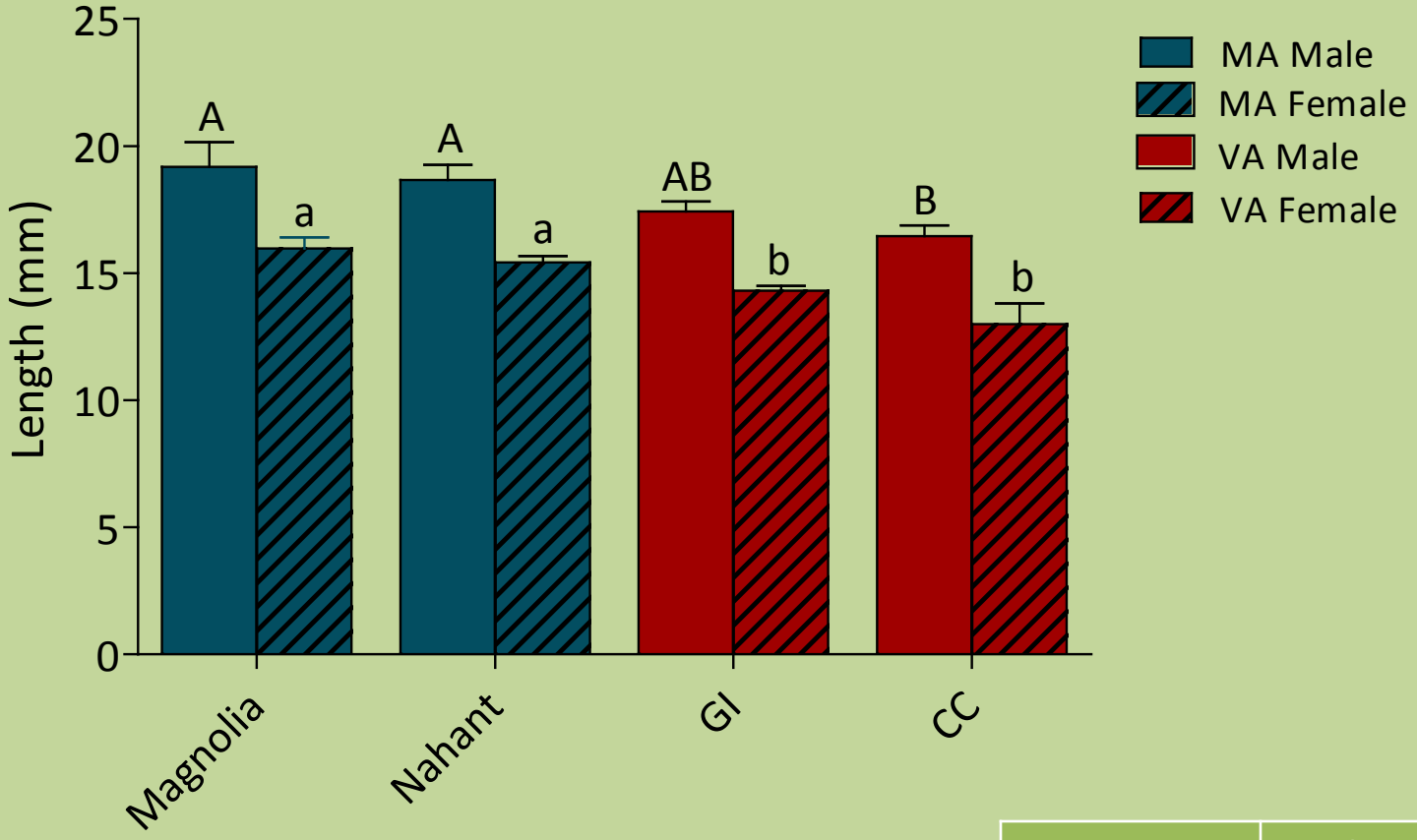
Methods



Methods



Culture Sizes

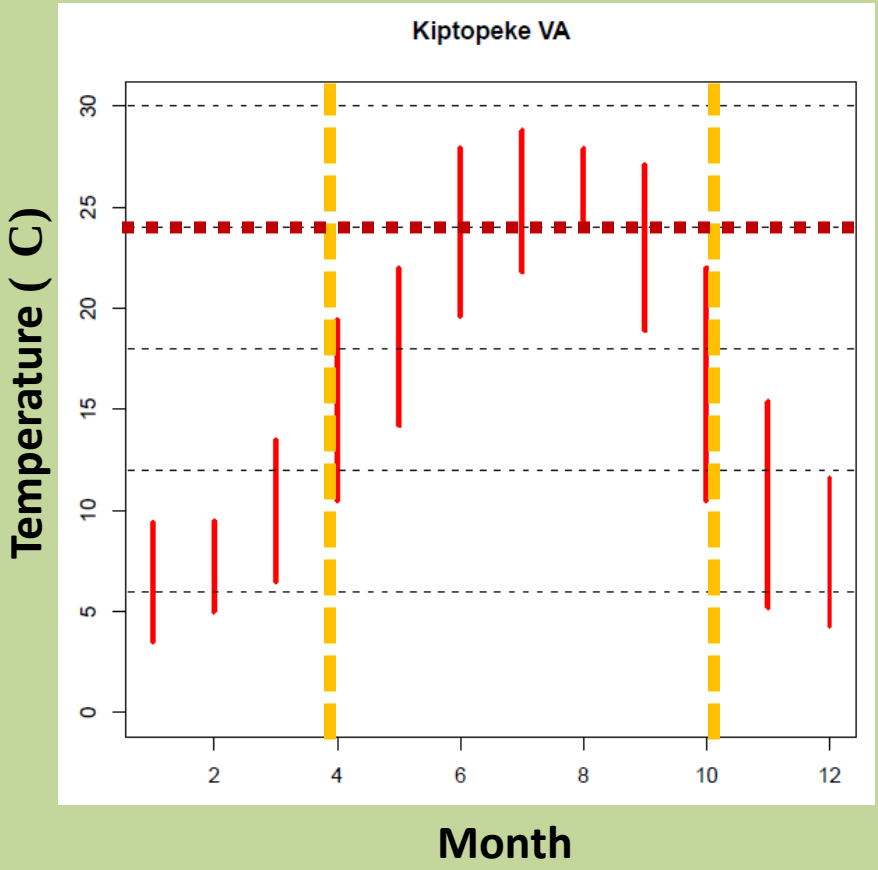


Source	P-Value
Population	0.0011 *
Sex	<0.0001 *
S*P	0.9919

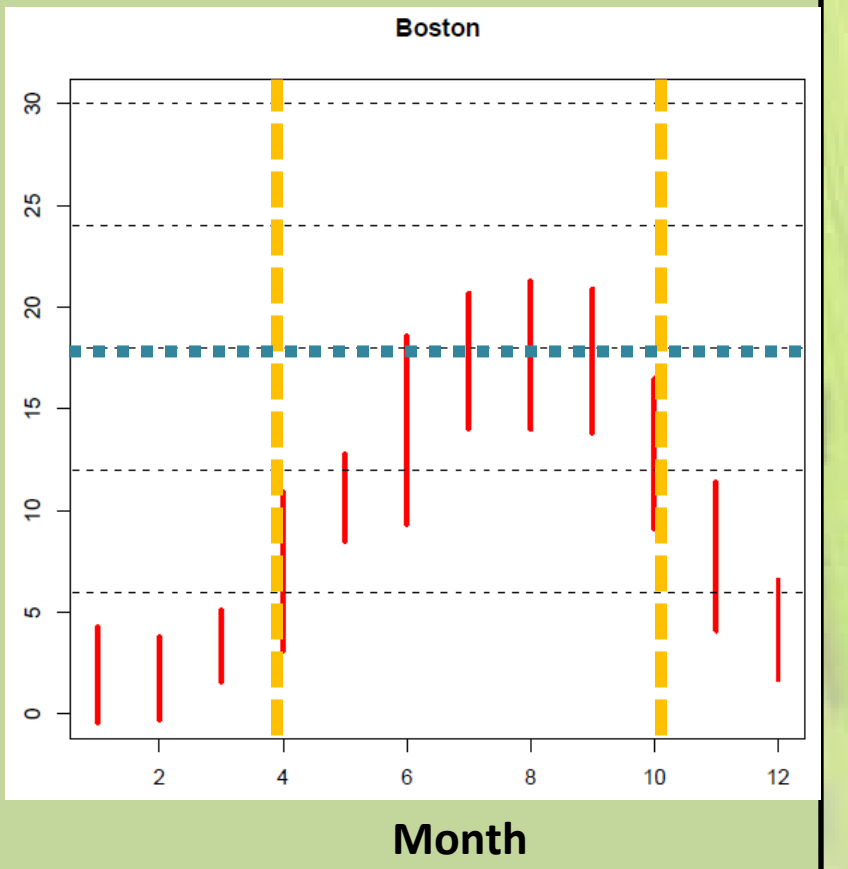
What role does temperature play?

Seawater Temperature

South
Cape Charles, VA



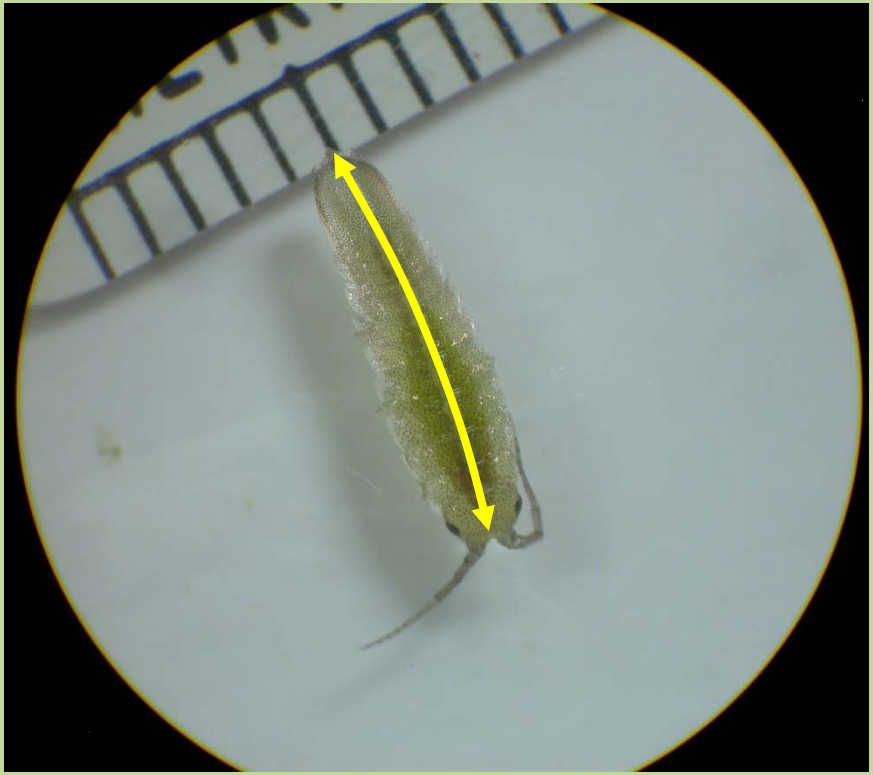
North
Boston, MA



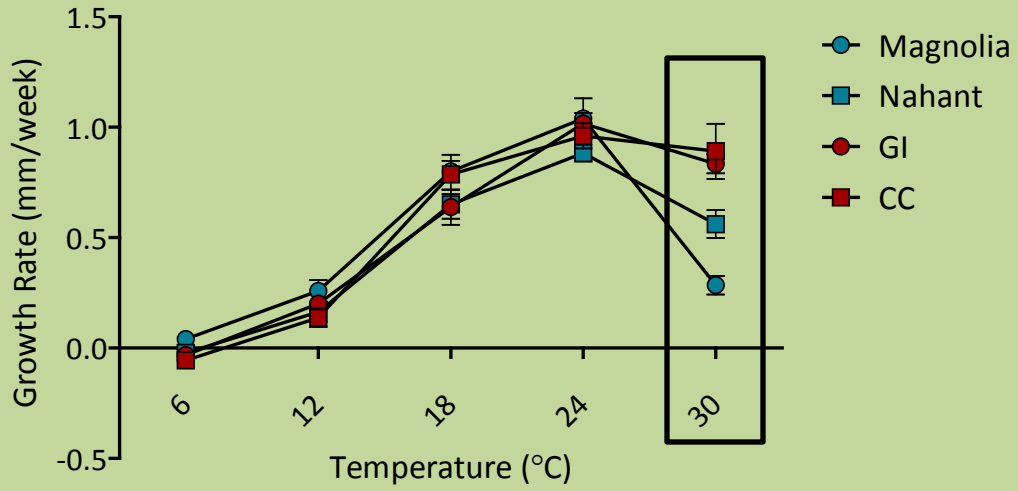
Experimental Methods

Measurements

- Experimentation ceased at maturity (18 and 24 C) or 15 weeks (6 and 12 C)
- Photographed at regular intervals throughout this time
- Measurements made on photographs using ImageJ software

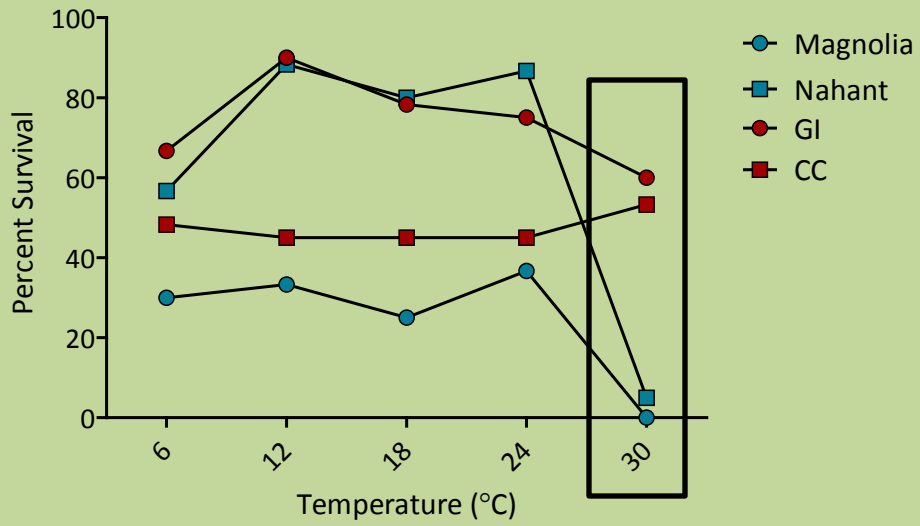


Growth

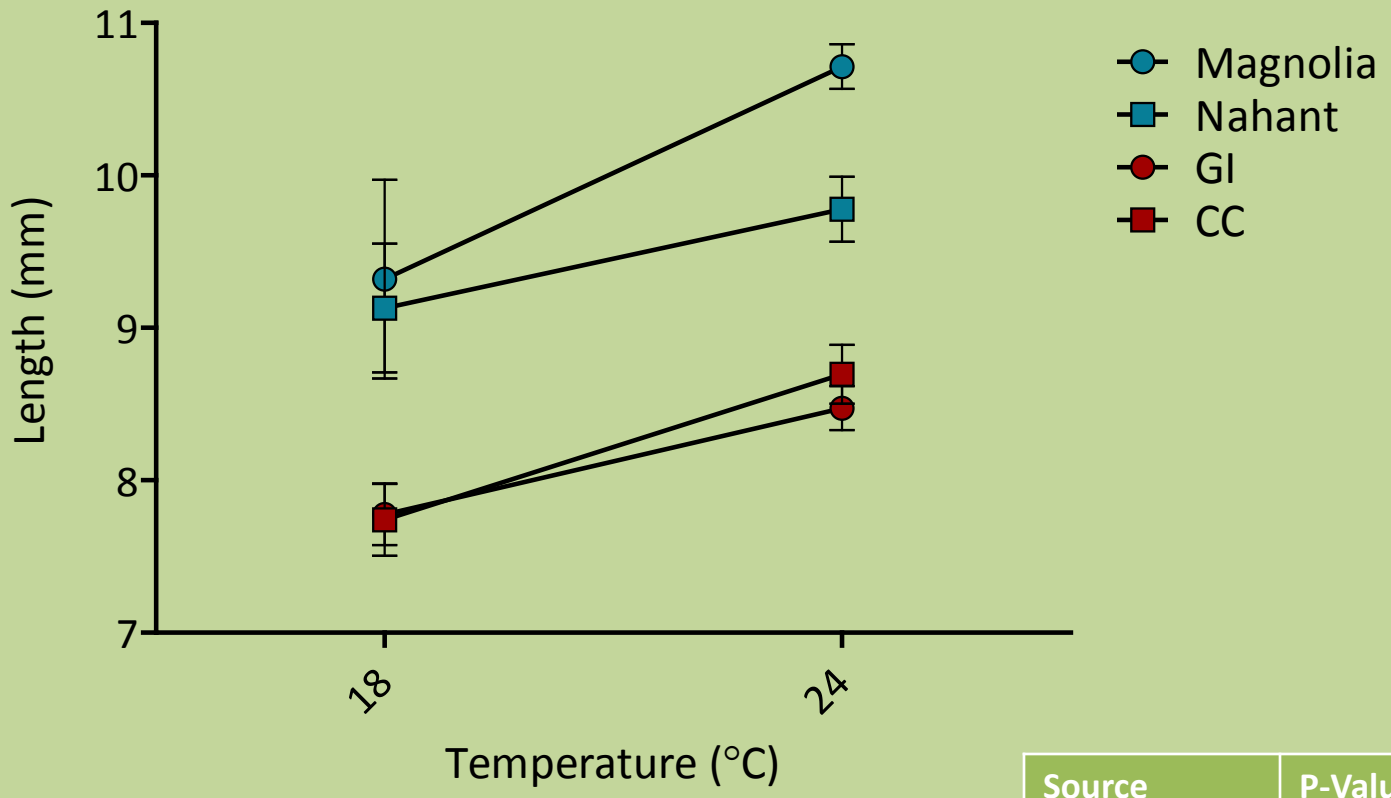


Source	P-Value
Log-Rank	<0.0001 *
Wilcoxon	<0.0001 *

Source	P-Value
Population	0.0511
Temperature	<0.0001 *
P*T	<0.0001 *



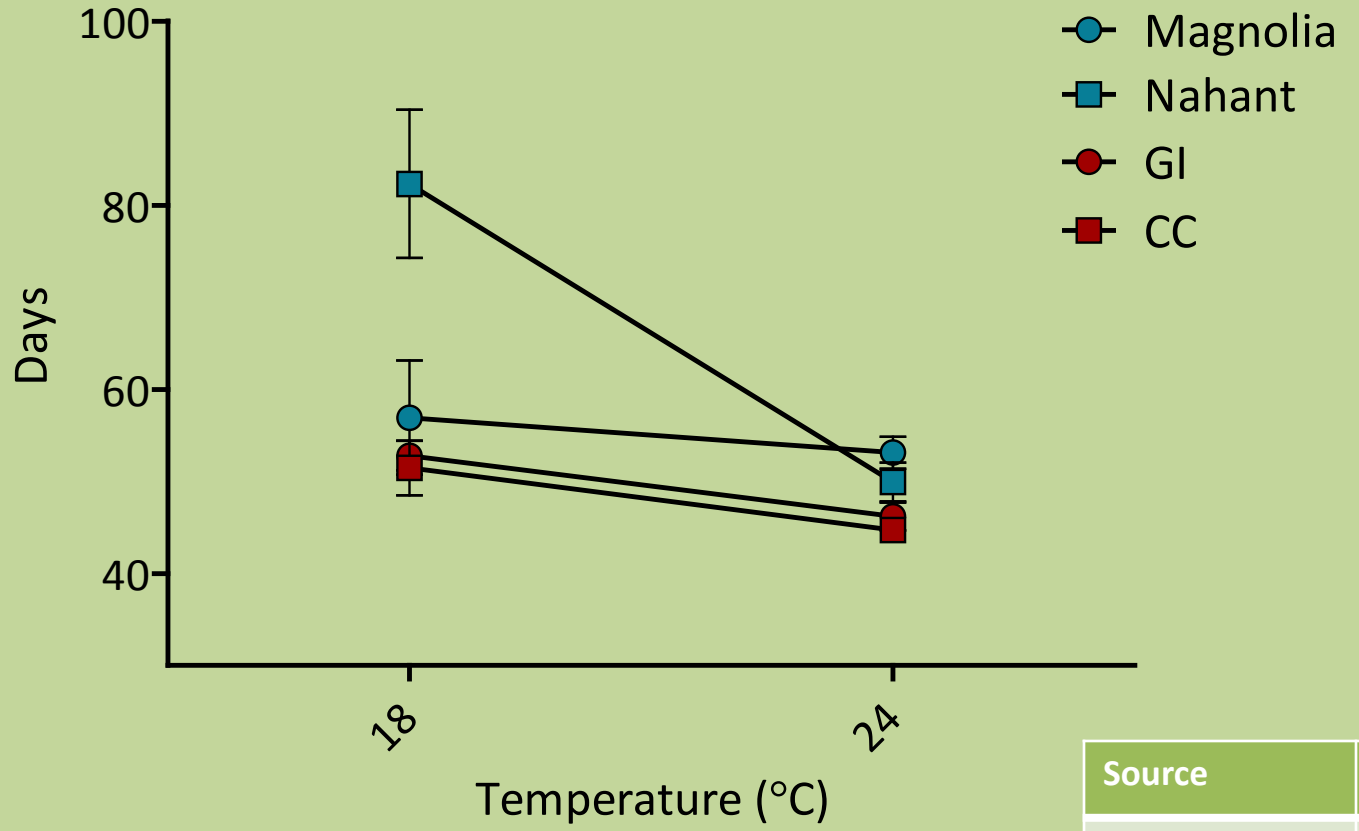
Size at Maturity



Source	P-Value
Population	<0.0001 *
Temperature	<0.0001 *
P*T	0.4165

Temperature not likely driving force!

Time to Maturity



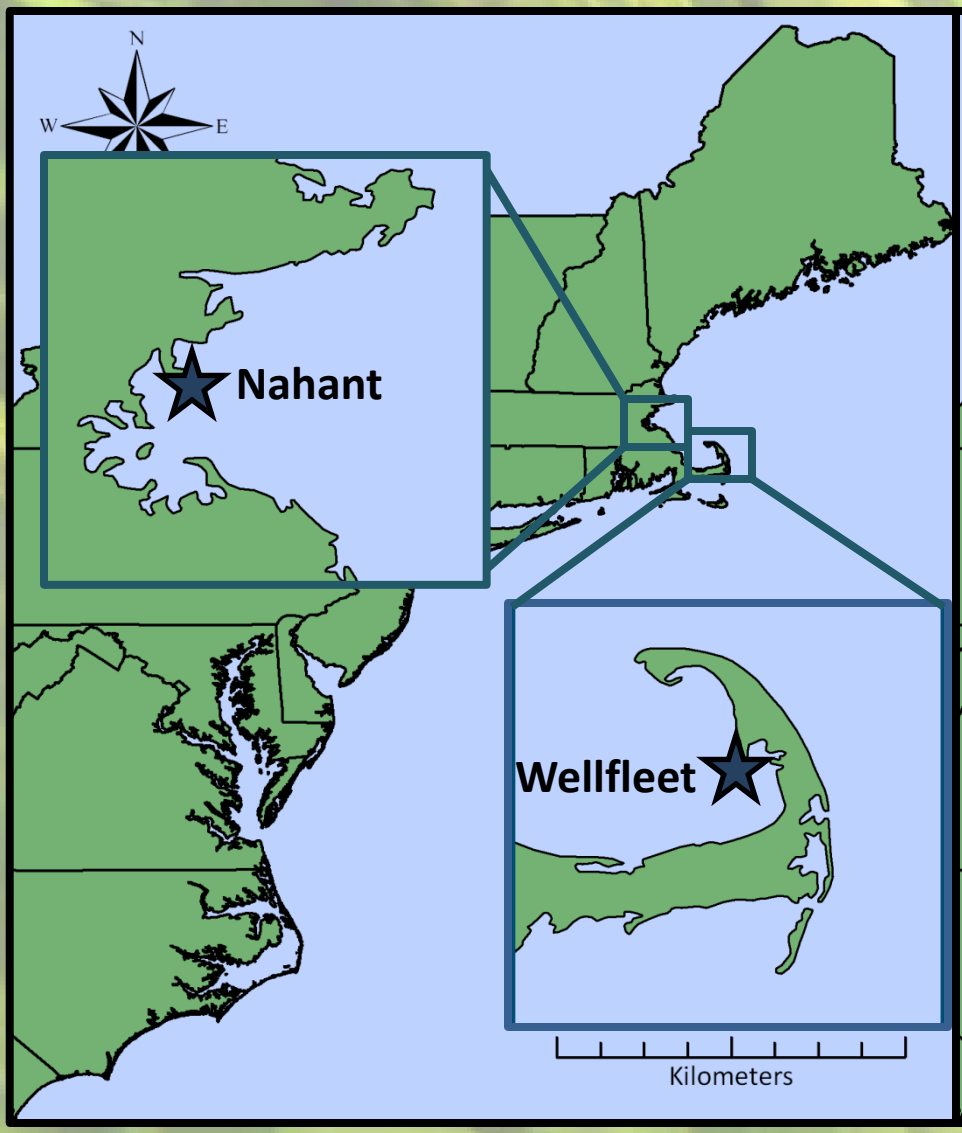
Source	P-Value
Population	<0.0001 *
Temperature	<0.0001 *
P*T	<0.0001 *

Activity

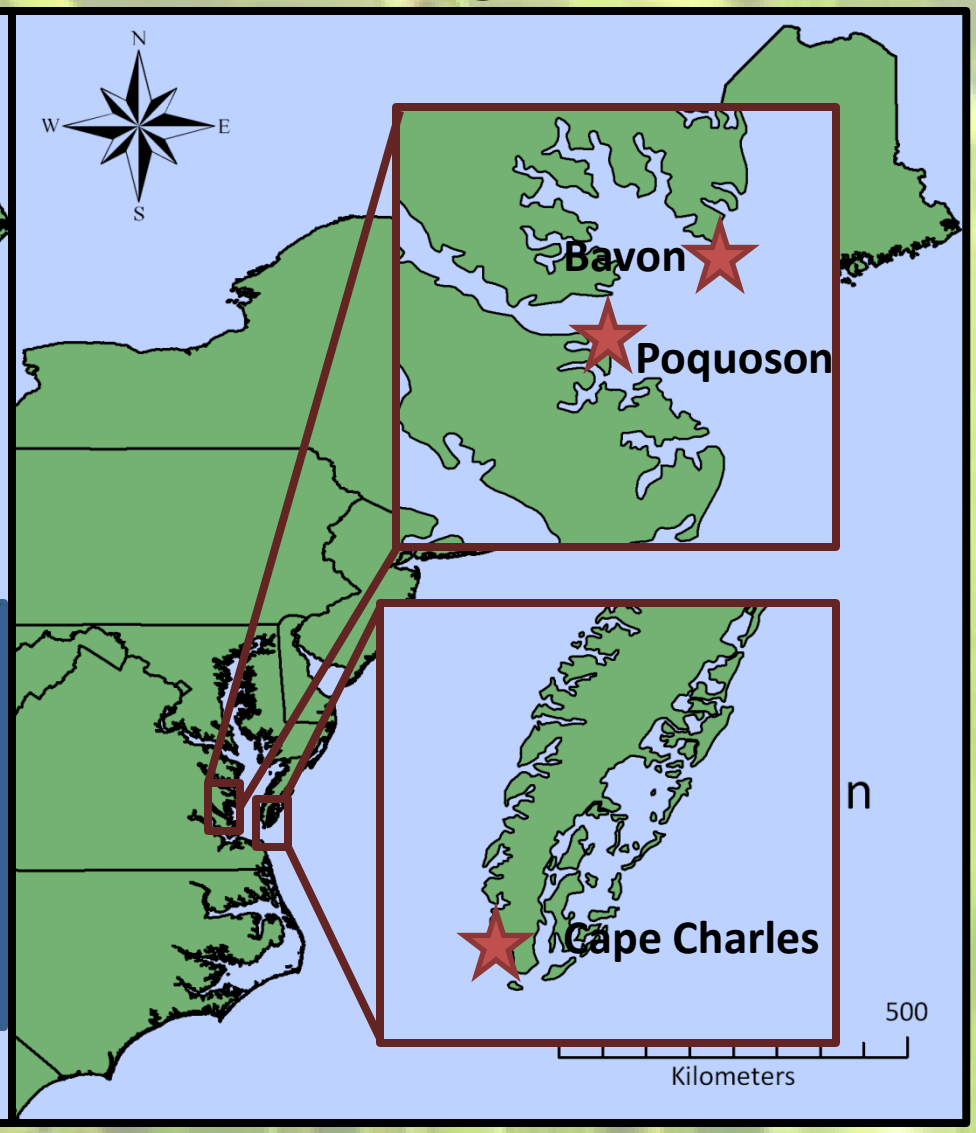
What role does predation play?

Sites

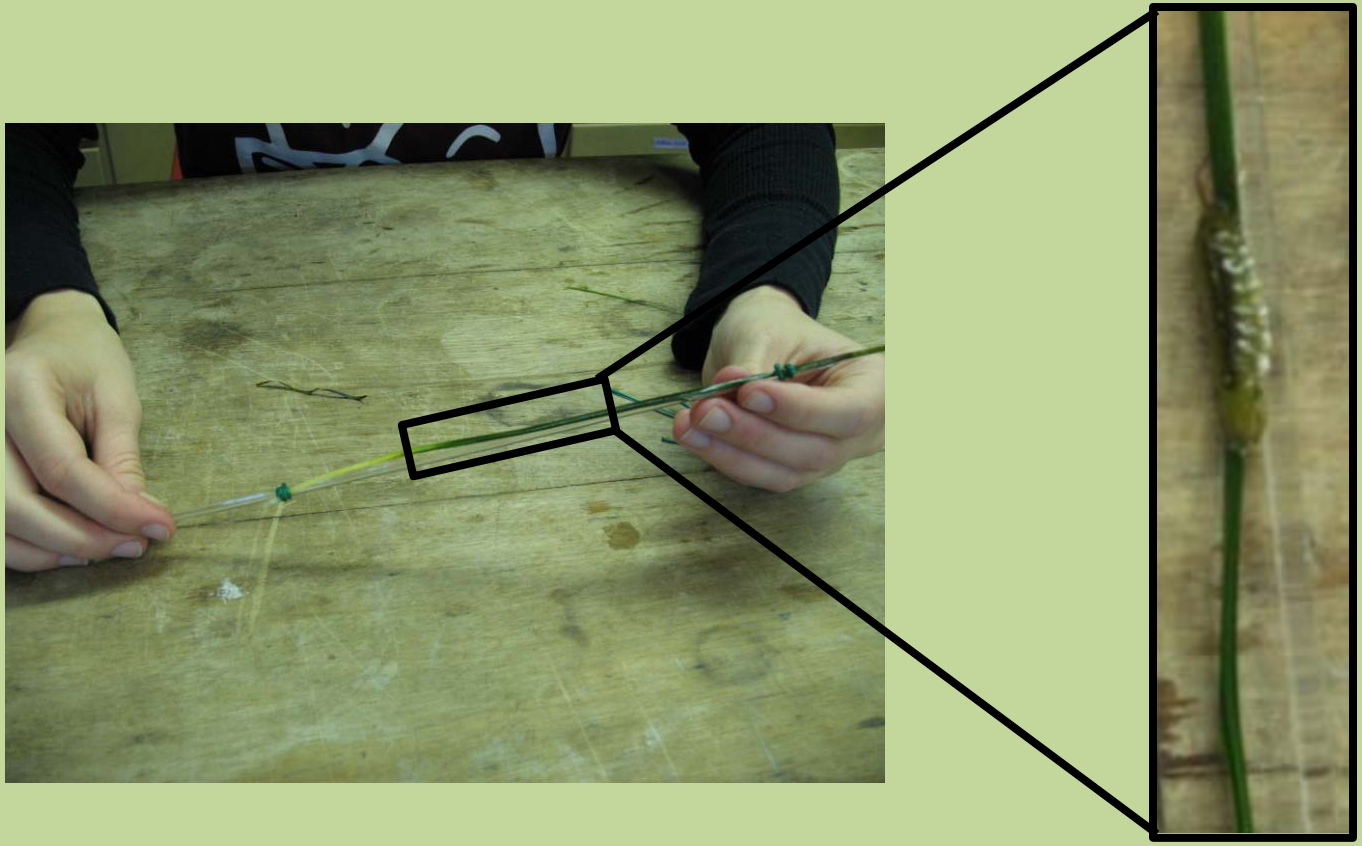
Massachusetts



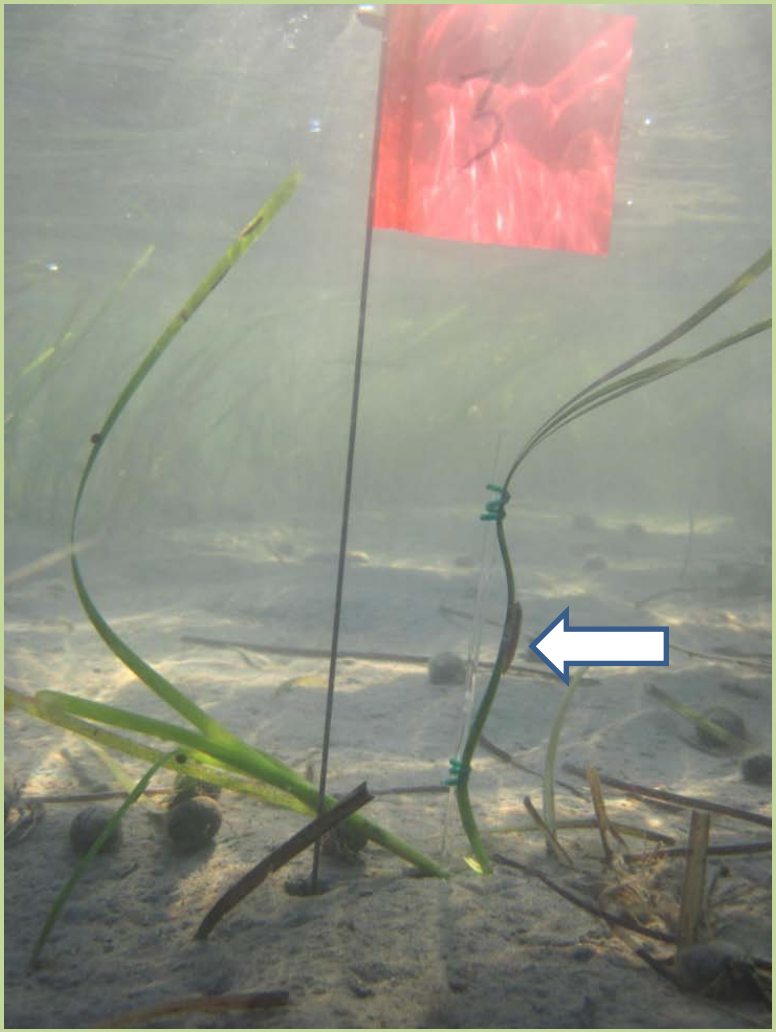
Virginia



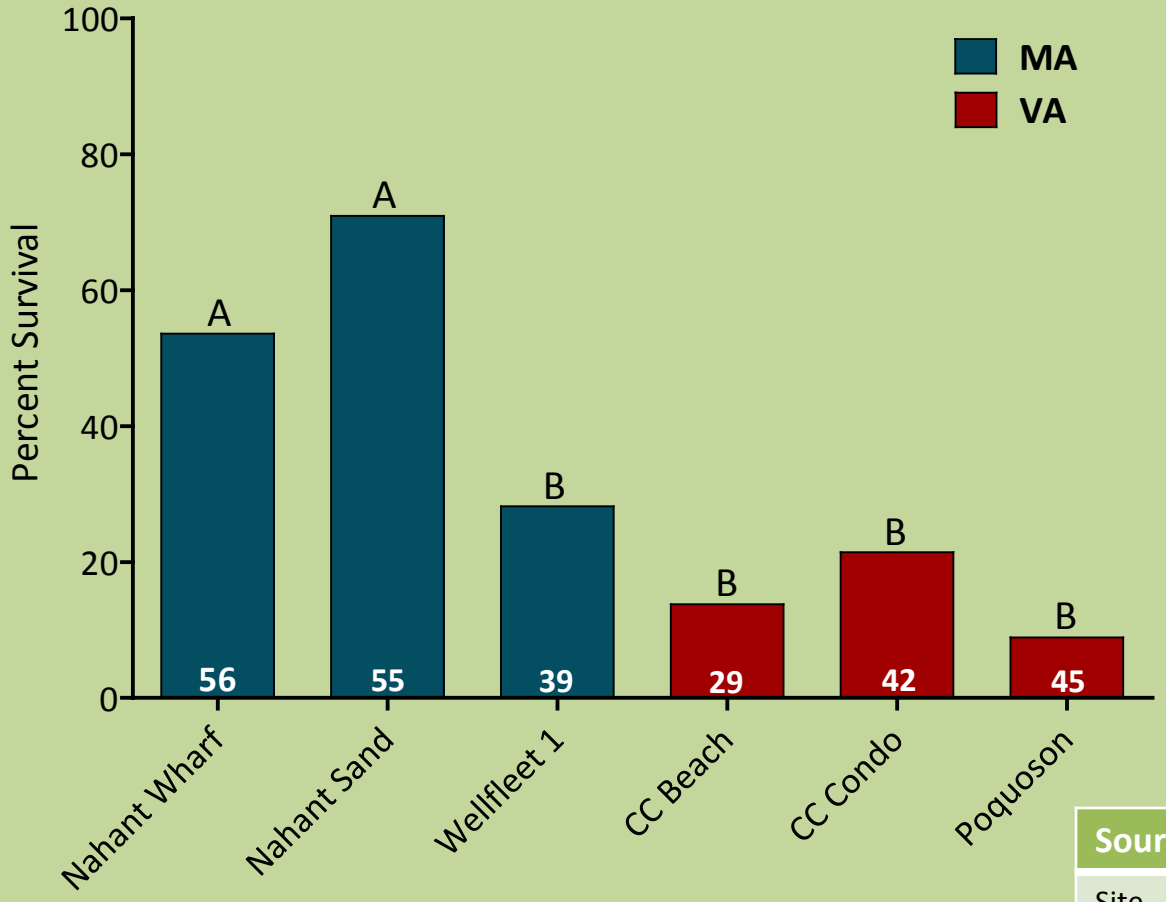
Methods



Methods

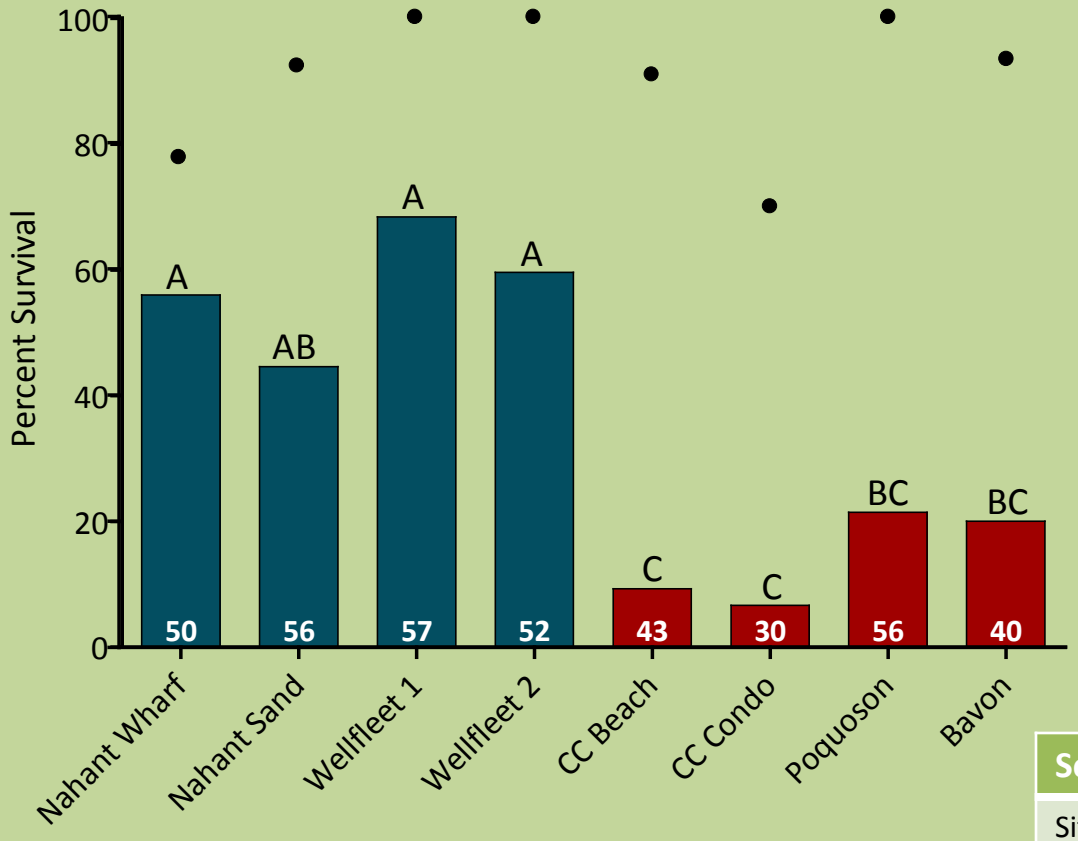


June Predation



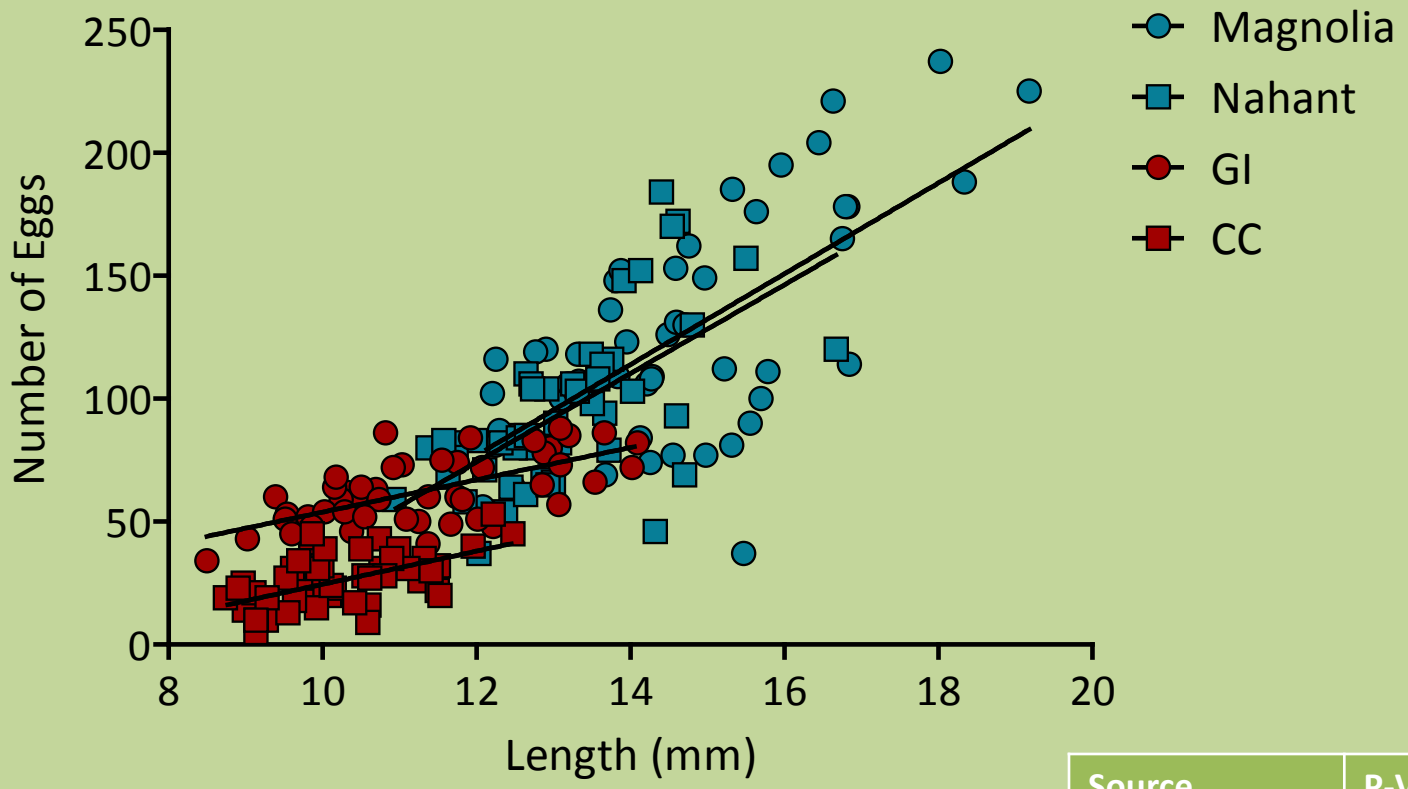
Source	P-Value
Site	<0.0001*
Length	0.7646
S*L	0.0575

August Predation



Source	P-Value
Site	<0.0001*
Length	0.1036
S*L	0.0794

Egg Data



Source	P-Value
Population	<0.0001 *
Length	<0.0001 *
P*L	0.0624

Trade-Offs?

- Reduced reproductive output in VA populations, but:
  - Reduced development time → Reduced generation time → More reproductive events/year

Conclusions

- *I. balthica* follows Bergmann's rule
- Massachusetts isopods have lower thermal tolerance to higher temperatures than Virginia
- *I. balthica* reverses TSR
- Genetic difference in body size underlies pattern (plasticity also seems to play a part)
- Predation is likely important in evolution of body size pattern

Acknowledgements

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Thank you!

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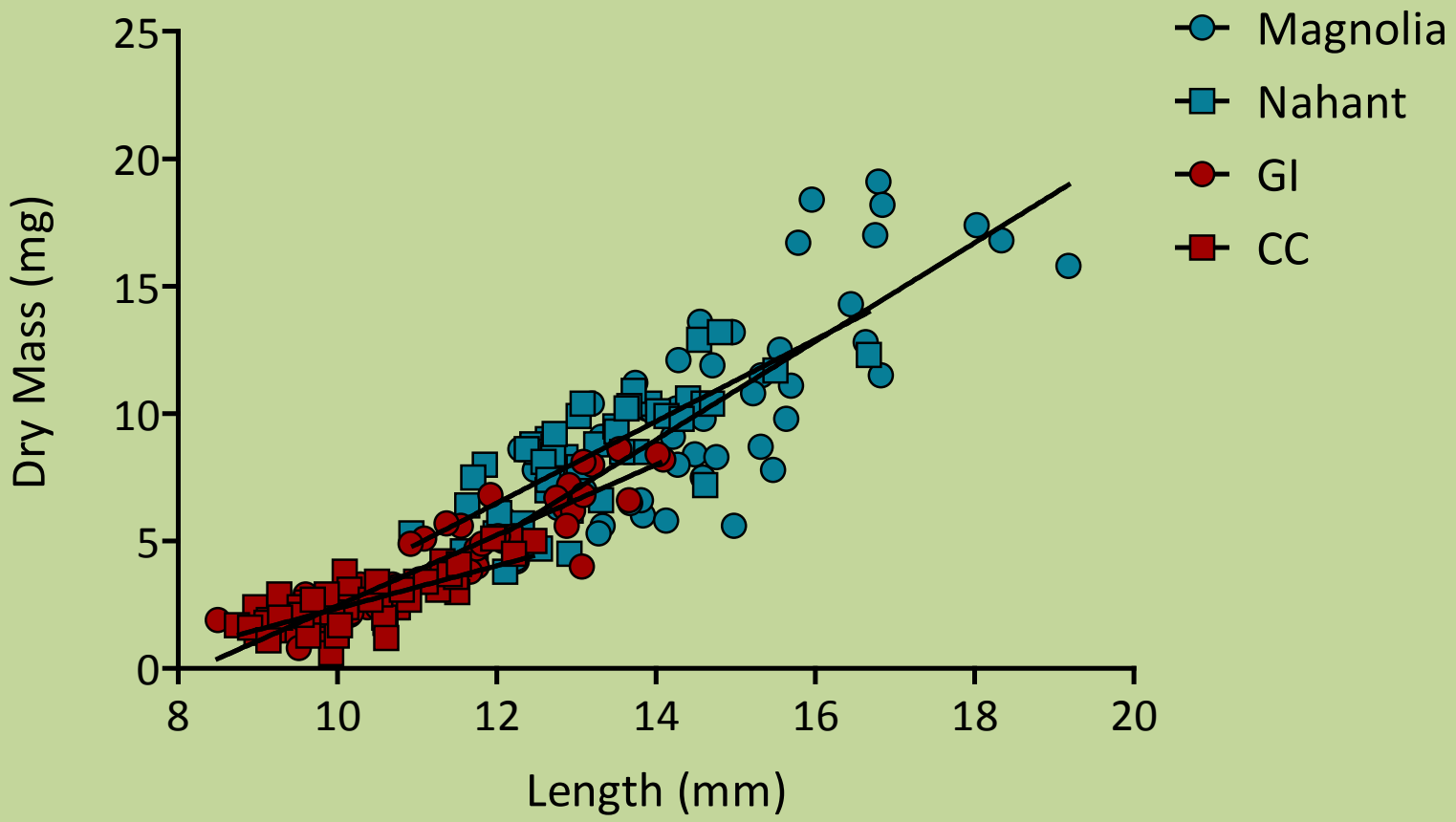
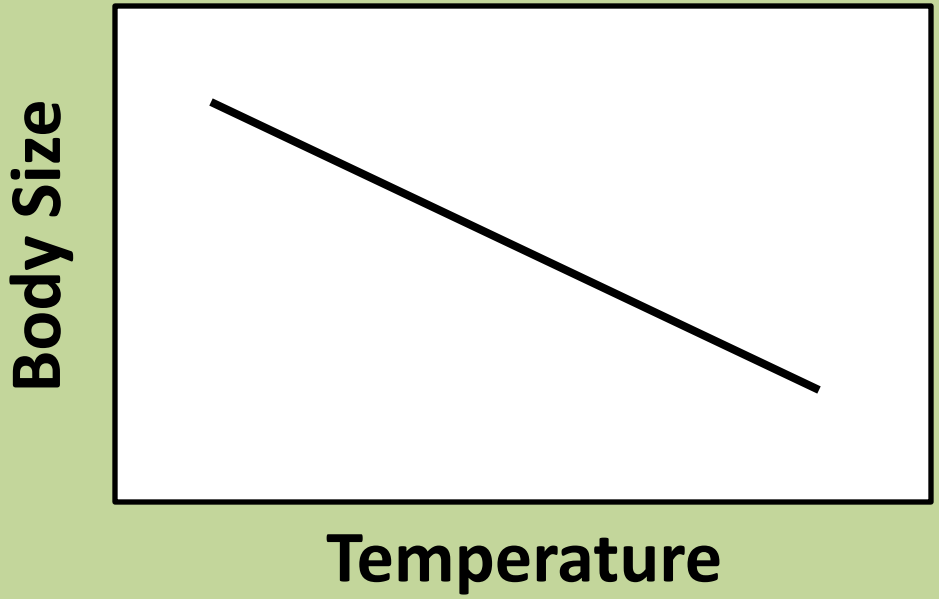
Dry Mass


Dry Mass (mg)
25
20
15
10
5
0
8
10
12
14
16
18
20
Length (mm)
Magnolia
Nahant
GI
CC

Temperature-Size Rule

- In ectotherms, increased rearing temperature results in reduced size-at-stage (e.g. size at maturity)
- Observed in 80% of ectotherms examined

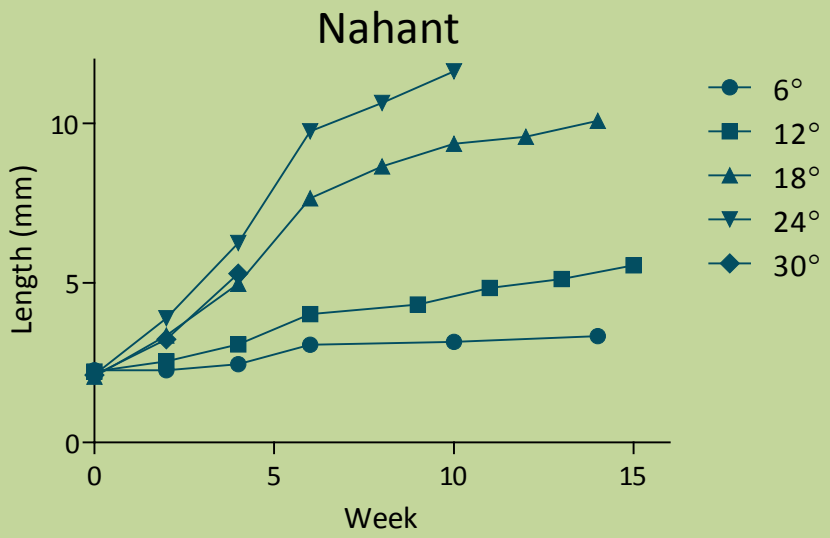


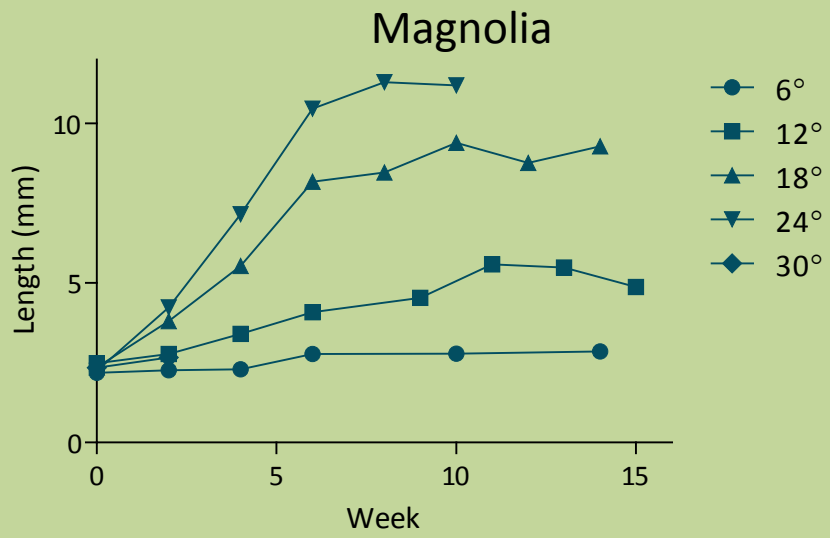
Temperature-Size Rule

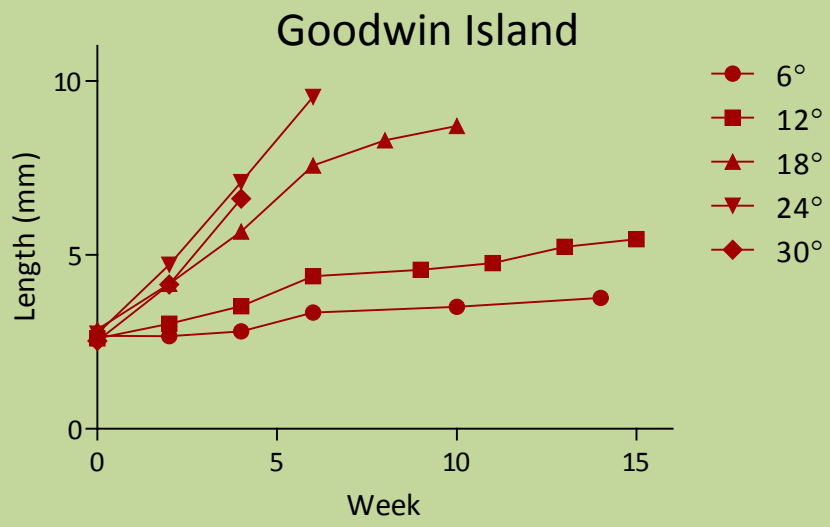
- Increased temperatures increases:
  - Metabolism
  - Growth rates
  - Development rates
- Therefore, we would expect body size to increase with temperature

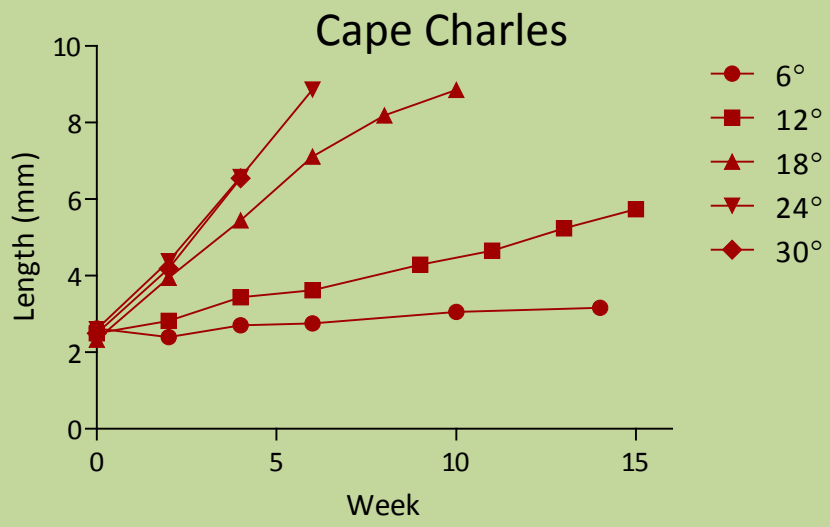
→ Thermal responses of growth and development rates decoupled

Growth Curves

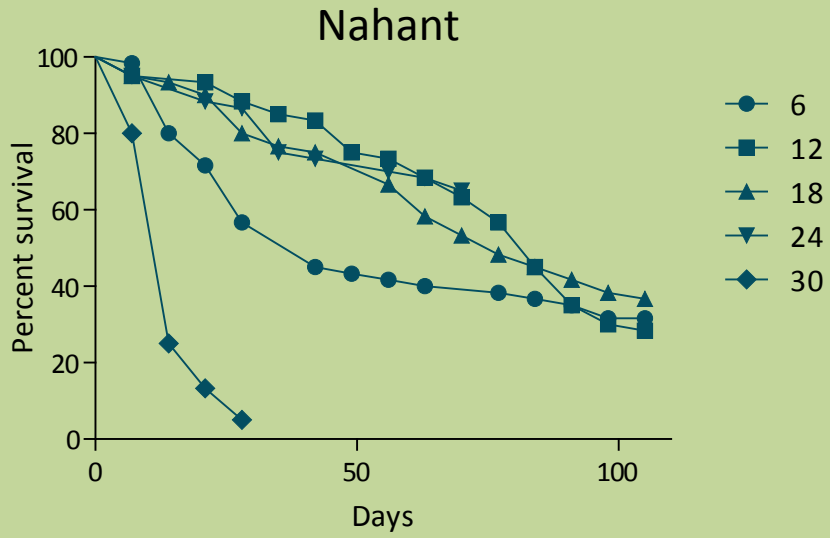


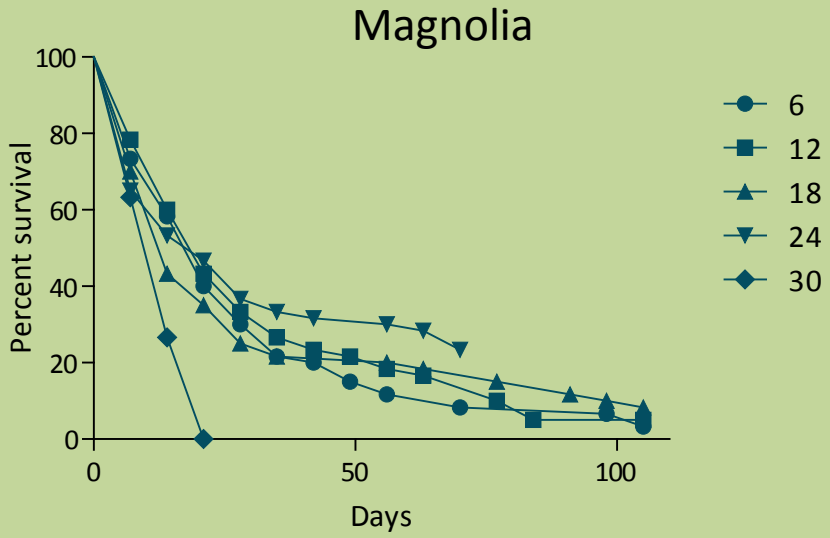


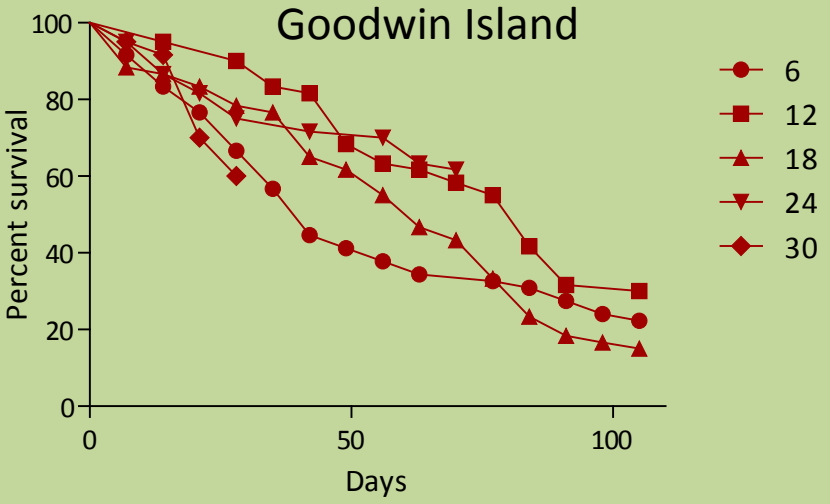


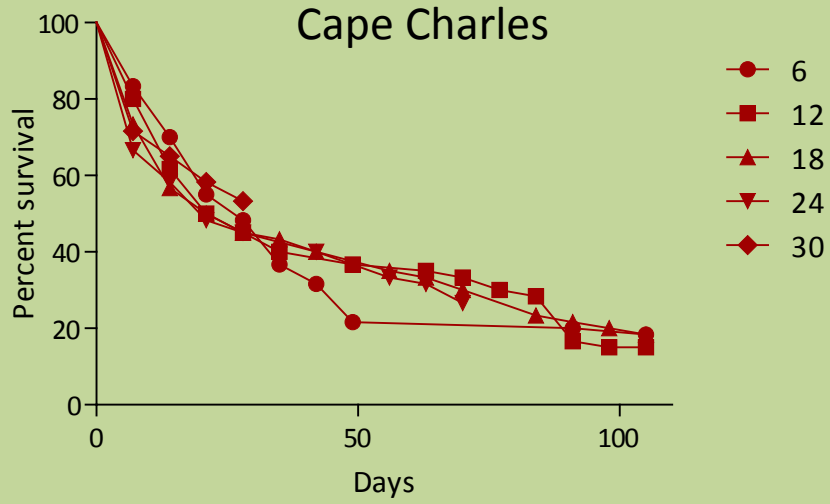


Survival Curves

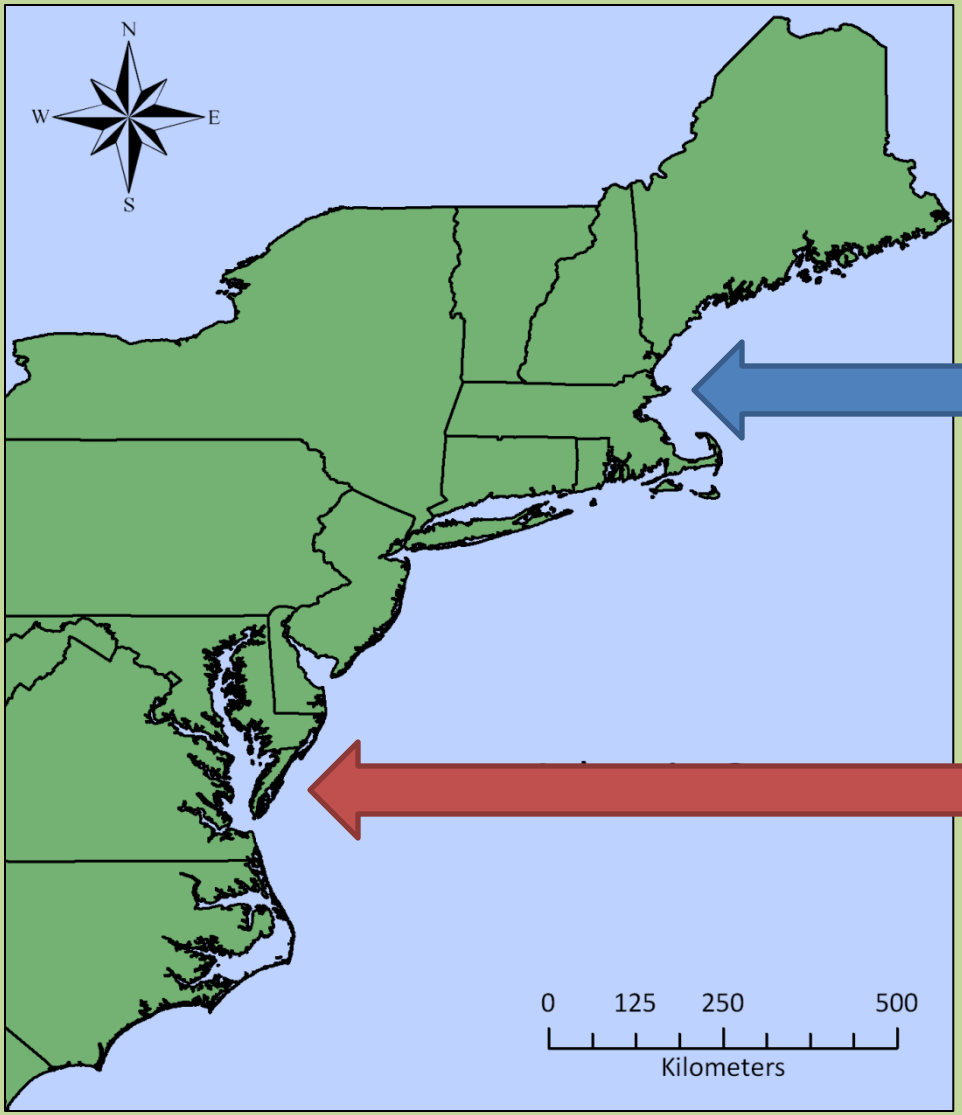


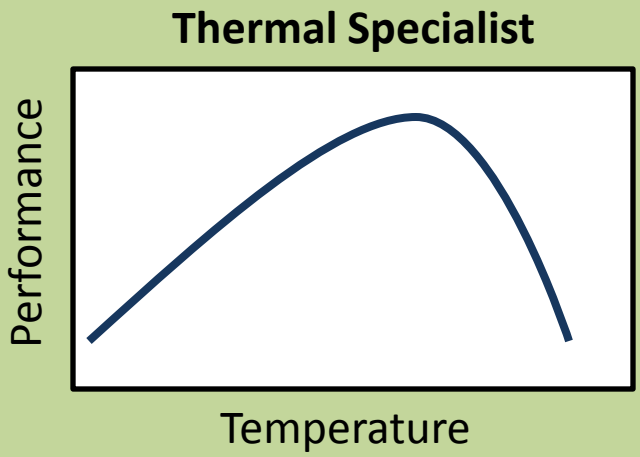


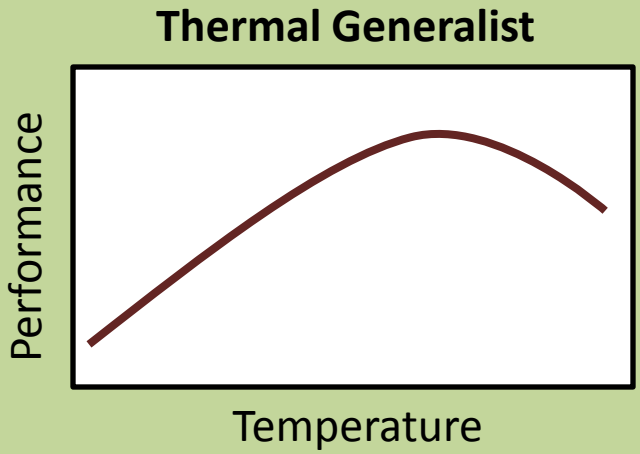




Thermal Response Curves







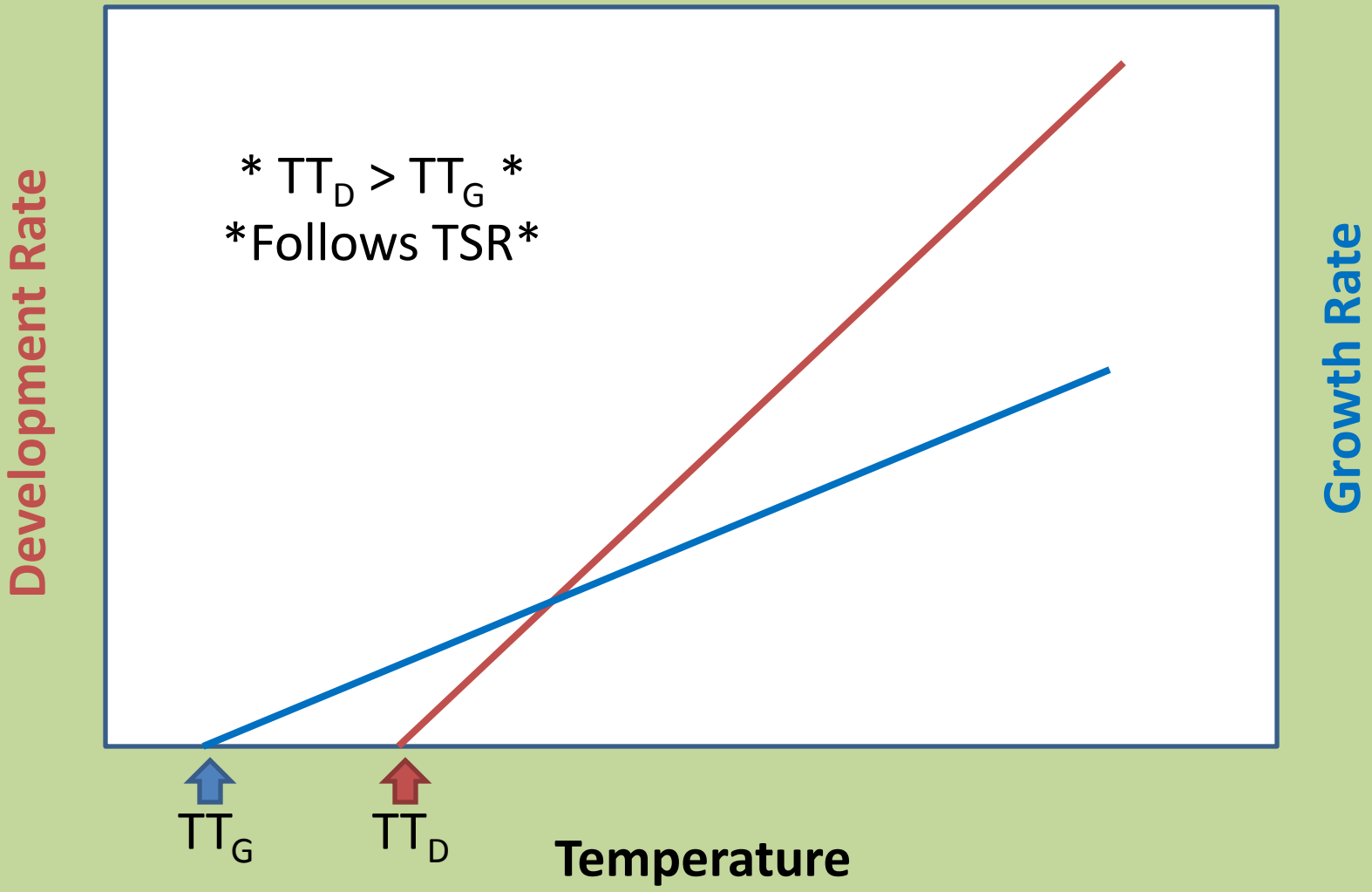
Thermal Threshold Model

$$m_A = m_0 + \frac{S_G}{S_D}\left(\frac{T - TT_G}{T - TT_D}\right)$$

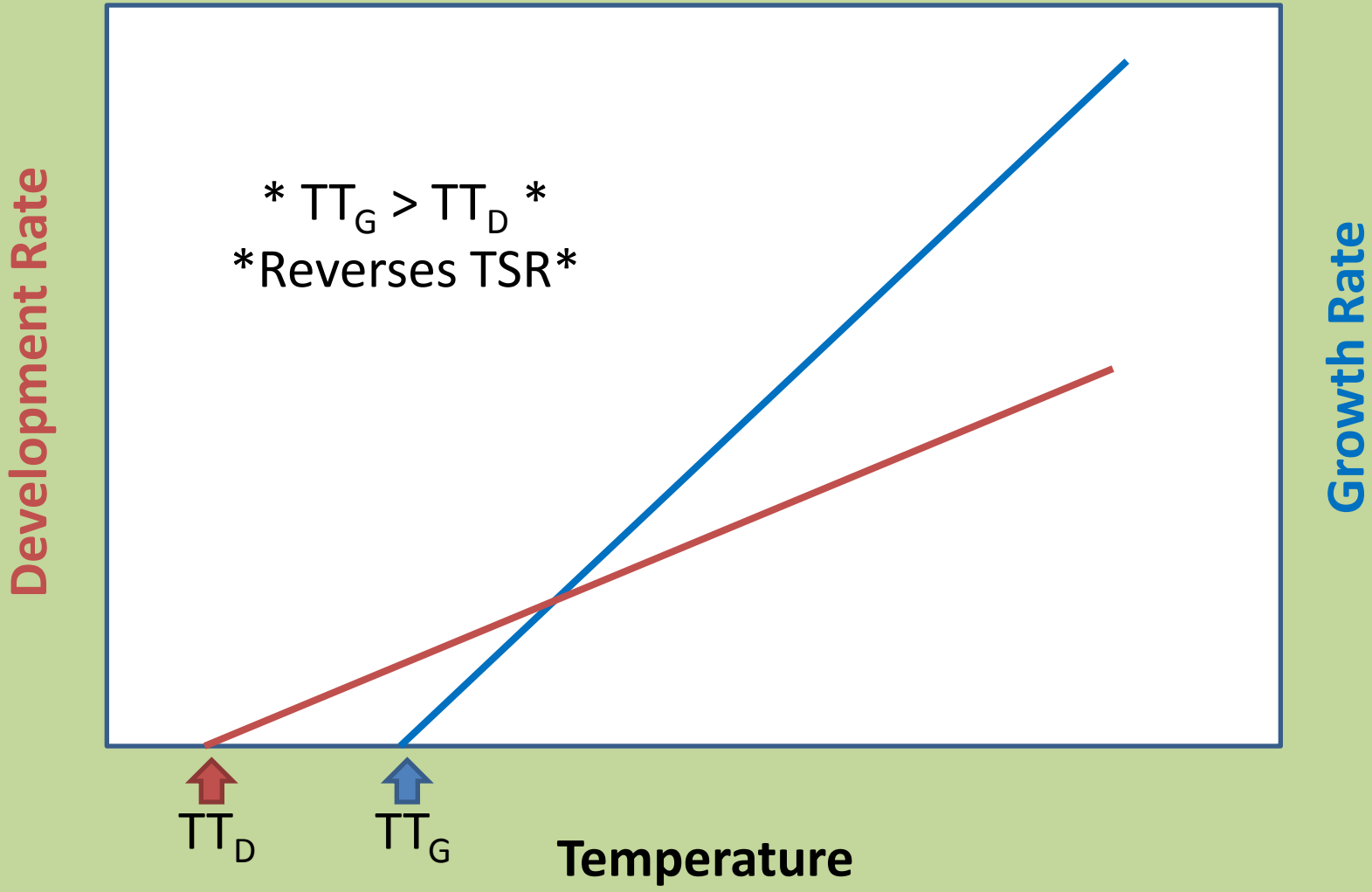
m_A = adult mass
m_0 = initial mass
S_G = slope of growth rate across temperature
S_D = slope of development rate across temperature
T = incubation temperature
TT_G = thermal threshold of growth
TT_D = thermal threshold of development

Walters and Hassall 2006

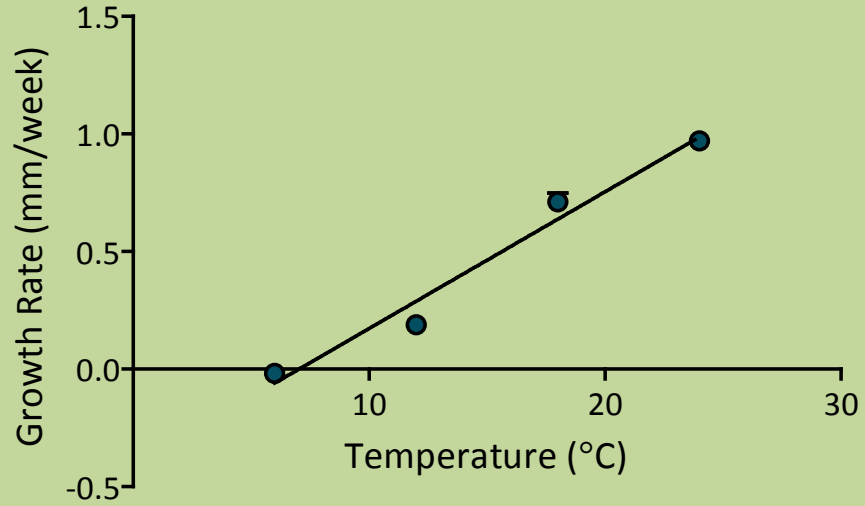
Thermal Threshold Model

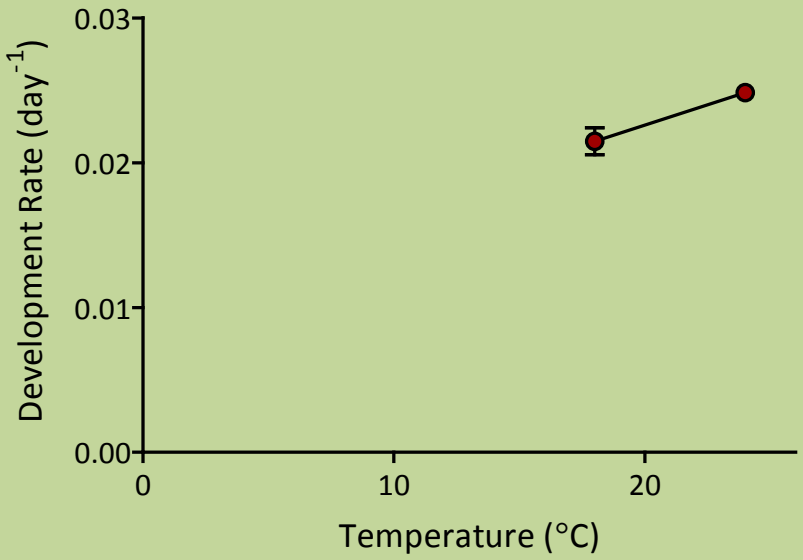
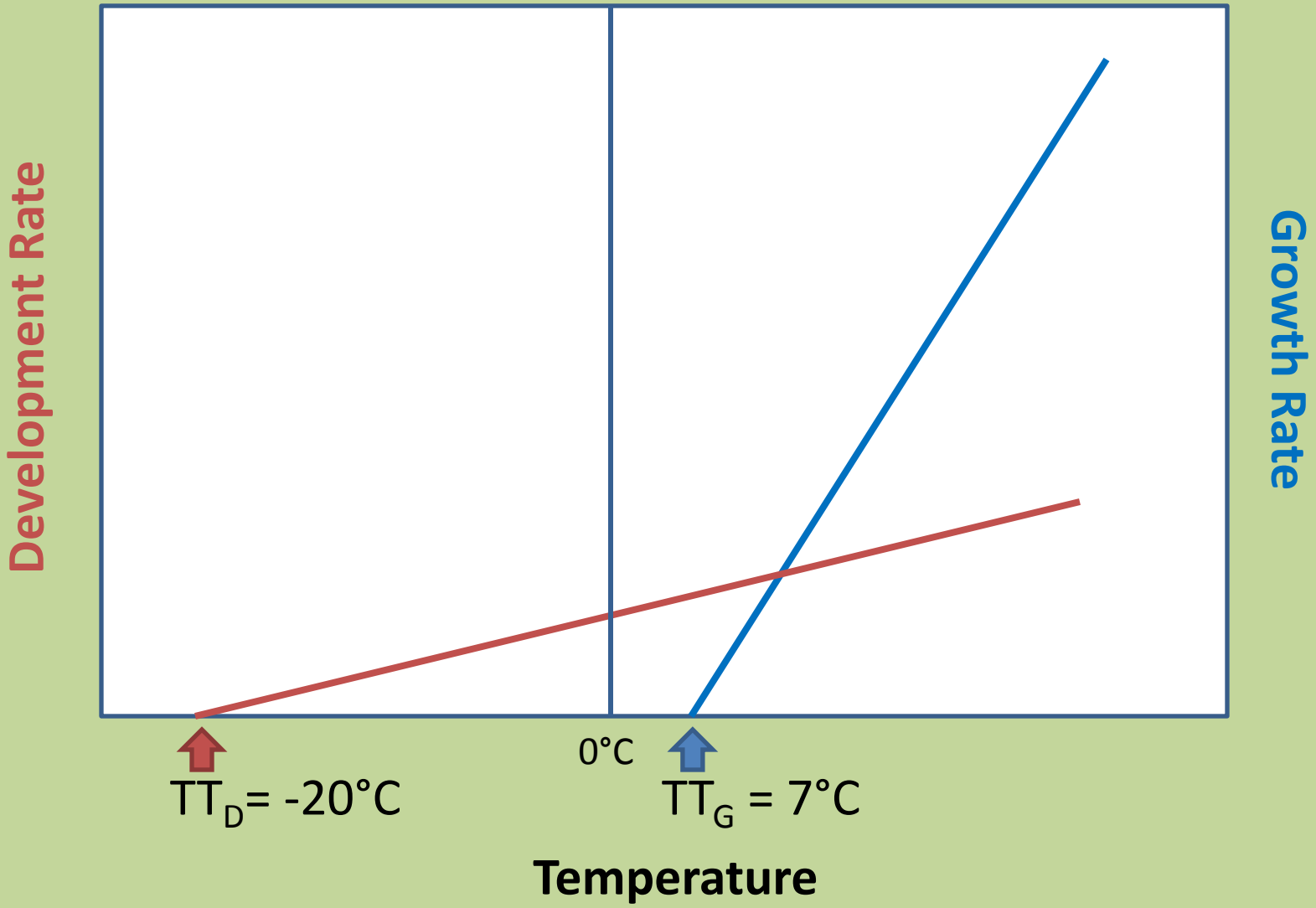


Thermal Threshold Model



Calculating Thermal Thresholds





My Results