Trait-Heritability: A Neglected Aspect of Adaptation Studies in Zooplankton

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Key Points

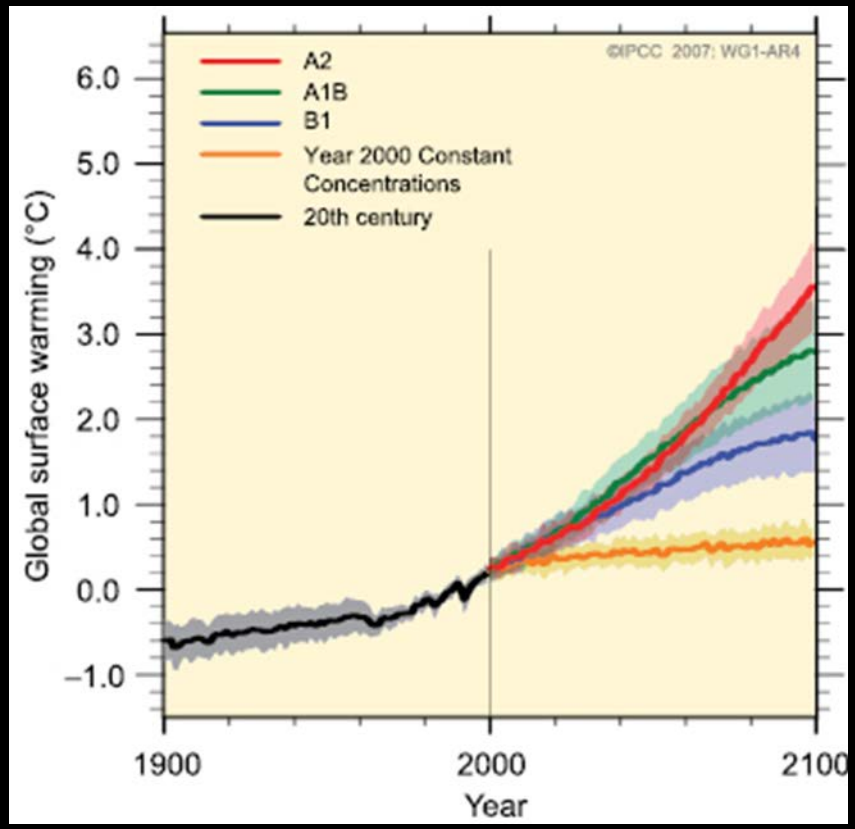
Adaptation:

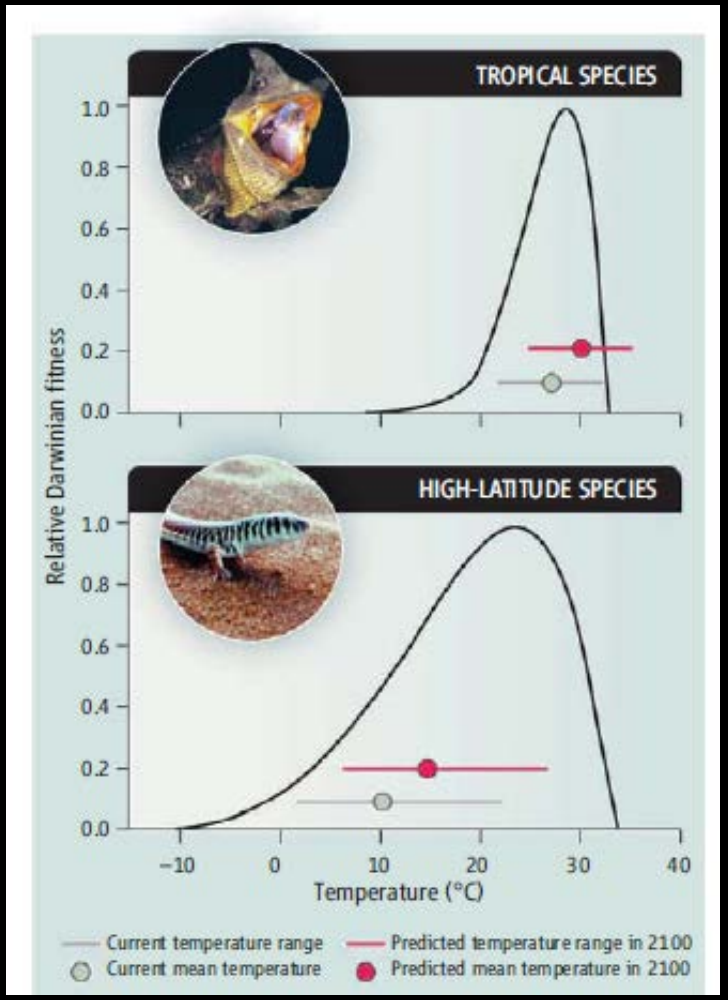
- Phenotypic plasticity (intragenerational)
- Evolutionary change (intergenerational)

Coping with change:

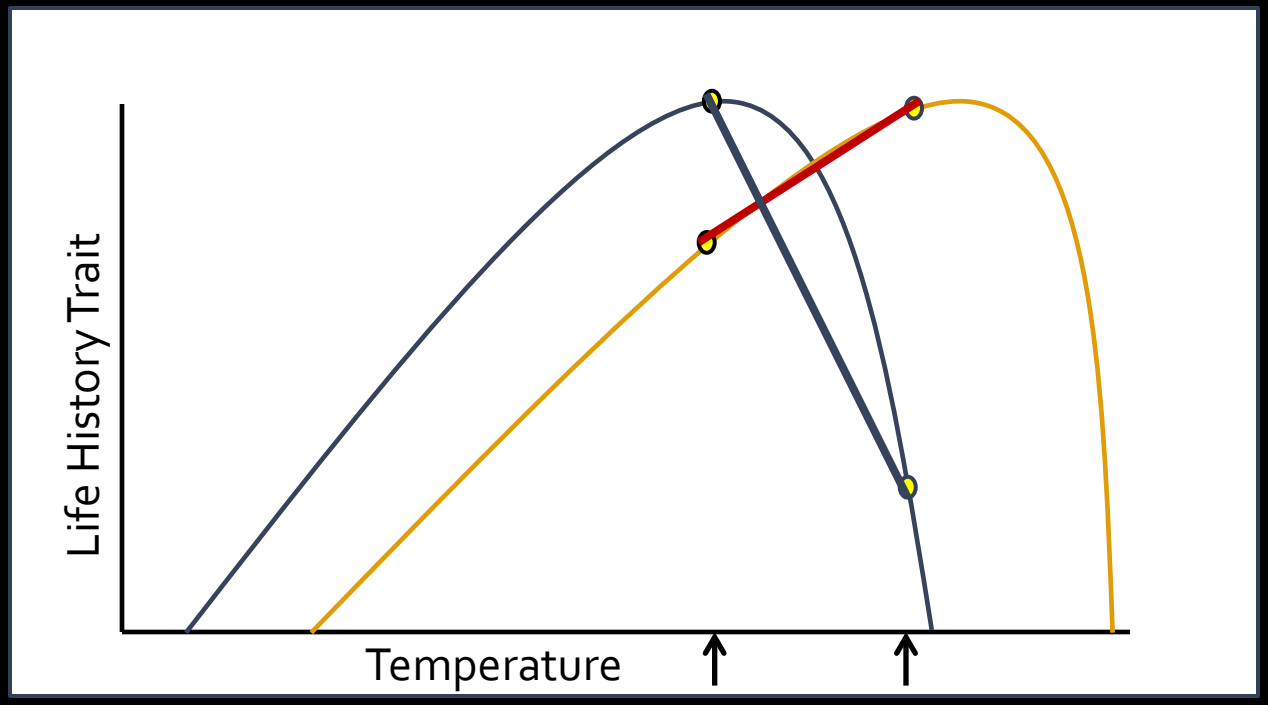
- Rate of change versus rate of adaptation
- Latter requires knowledge of heritability
- Heritability of life-history traits in zooplankton poorly explored
- Heritability may help identify winners and losers in changing environments

Can Species *W* Adapt to *XYZ* Change?

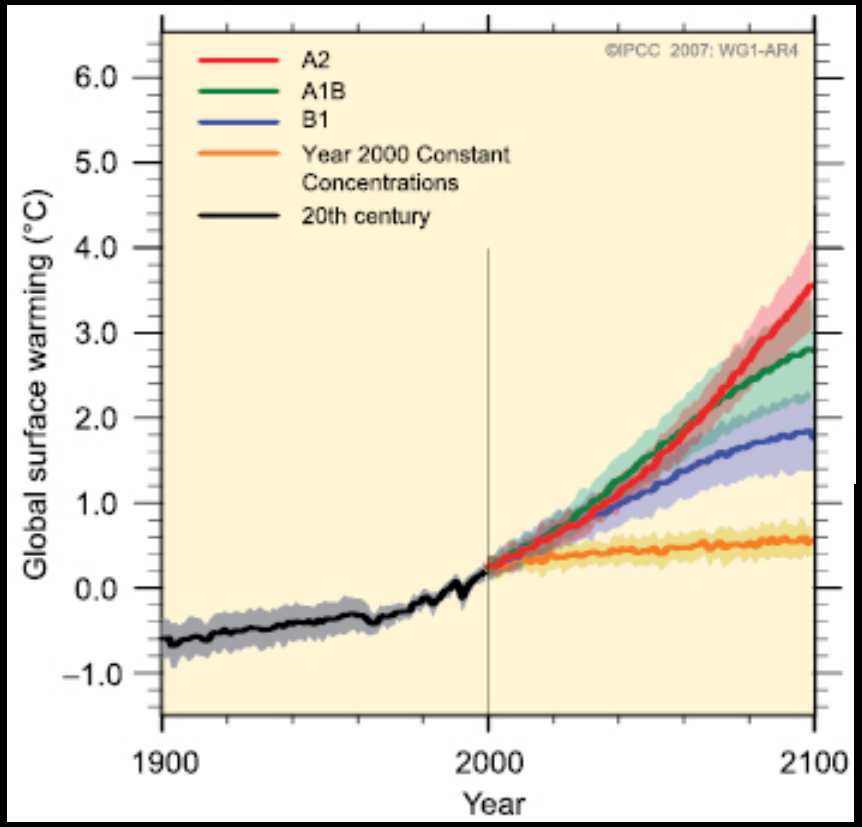




Evolution of Performance



$V_p = V_G + V_E + V_{GxE}$; G is heritable



$$n_c = \sqrt{\frac{2r_{max}\gamma}{T}} \frac{h^2\sigma^2}{|B-b|}$$

$$r = h^2 S$$

r_{max} = growth rate

h^2 = heritability

T = generation time

γ =stabilizing selection

σ^2 = genetic variance

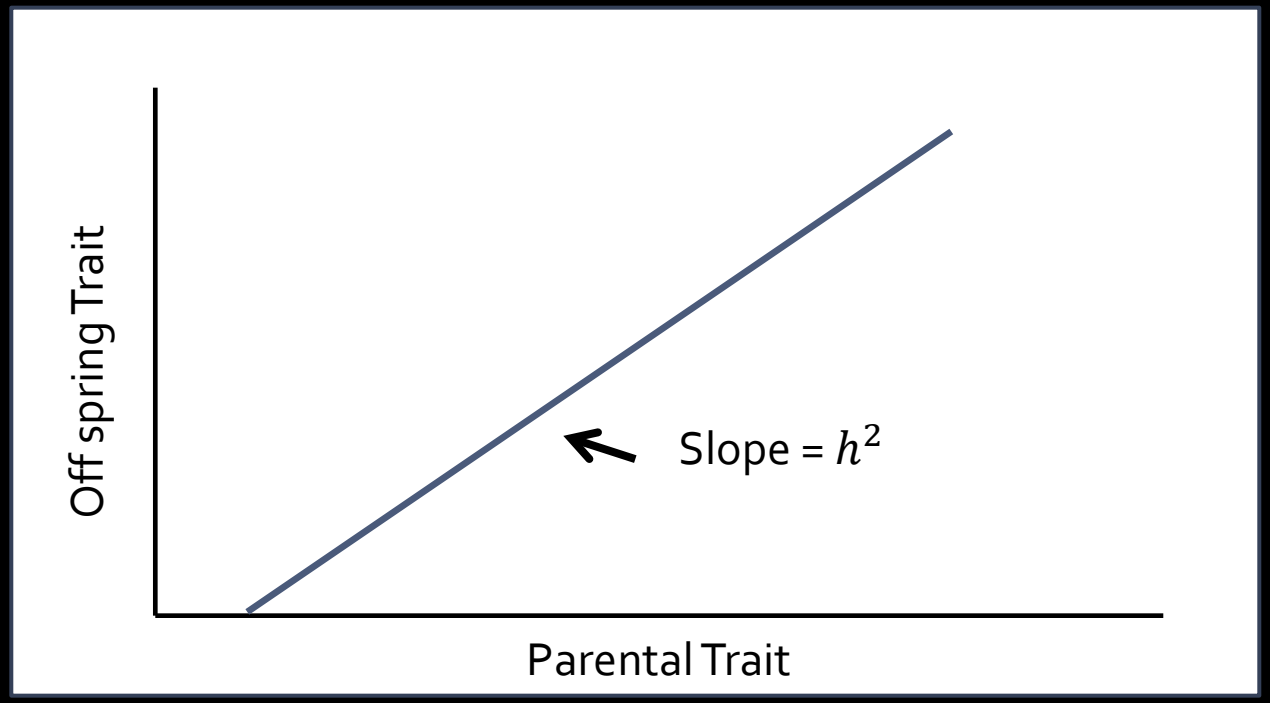
S = selection gradient

B= environmental sensitivity of selection

b = phenotypic plasticity

Heritability

$$h^2 = \frac{\textit{Additive Genetic Variation}}{\textit{Total Phenotypic Variation}}$$



Zooplankton-Heritability Survey

Heritability poorly explored in zooplankton ☹

Prior work excluding Daphnia:

- 18 studies total, 10 species
  - 4 Marine studies, 4 species
    - 6 traits
    - 1 life-history trait: pre-adult mortality

Case study: *Evolutionary a*daption to warming in *Acartia*

Cosmopolitan Coastal Copepods

Central Trophic Position

Ectothermic

Hypothesis

Acartia spp. contain significant, heritable within- population genetic variation to increased temperature:

- Egg production
- Adult longevity

Conclusions

A. tonsa (warm water) contains heritable within-population genetic variation for life history traits to increased temperature.

A. hudsonica (cold water) has insignificant within-population variation in the same traits. Hence, limited potential to adapt to warming!

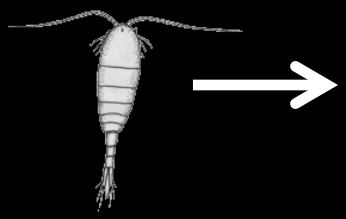
Experimental Design

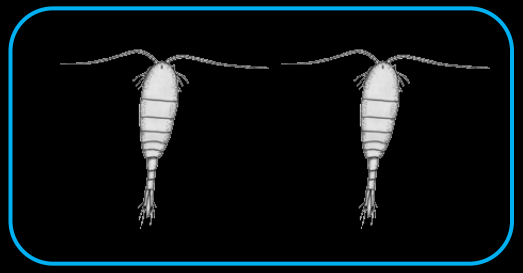
Split-Family Design

Families

F3 generation
(remove maternal effects)

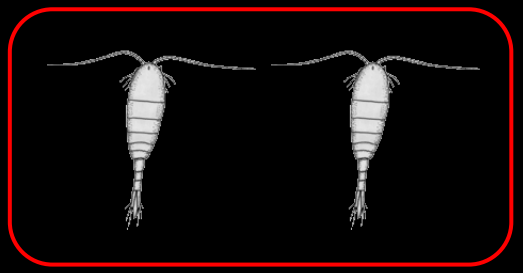
Mothers





+2°C

Nested ANOVA:
Temperature(Family)



+4°C

~15 Families
6-8 individuals per Temp(Fam)
~200 individuals

$$h^2 = \frac{Additive\ Genetic\ Variation}{Total\ Phenotypic\ Variation}$$

$$\hat{h}^2 = \frac{2V_{AF}}{V_{AF}+V_{AT}+V_{WT}}$$ (ANOVA)

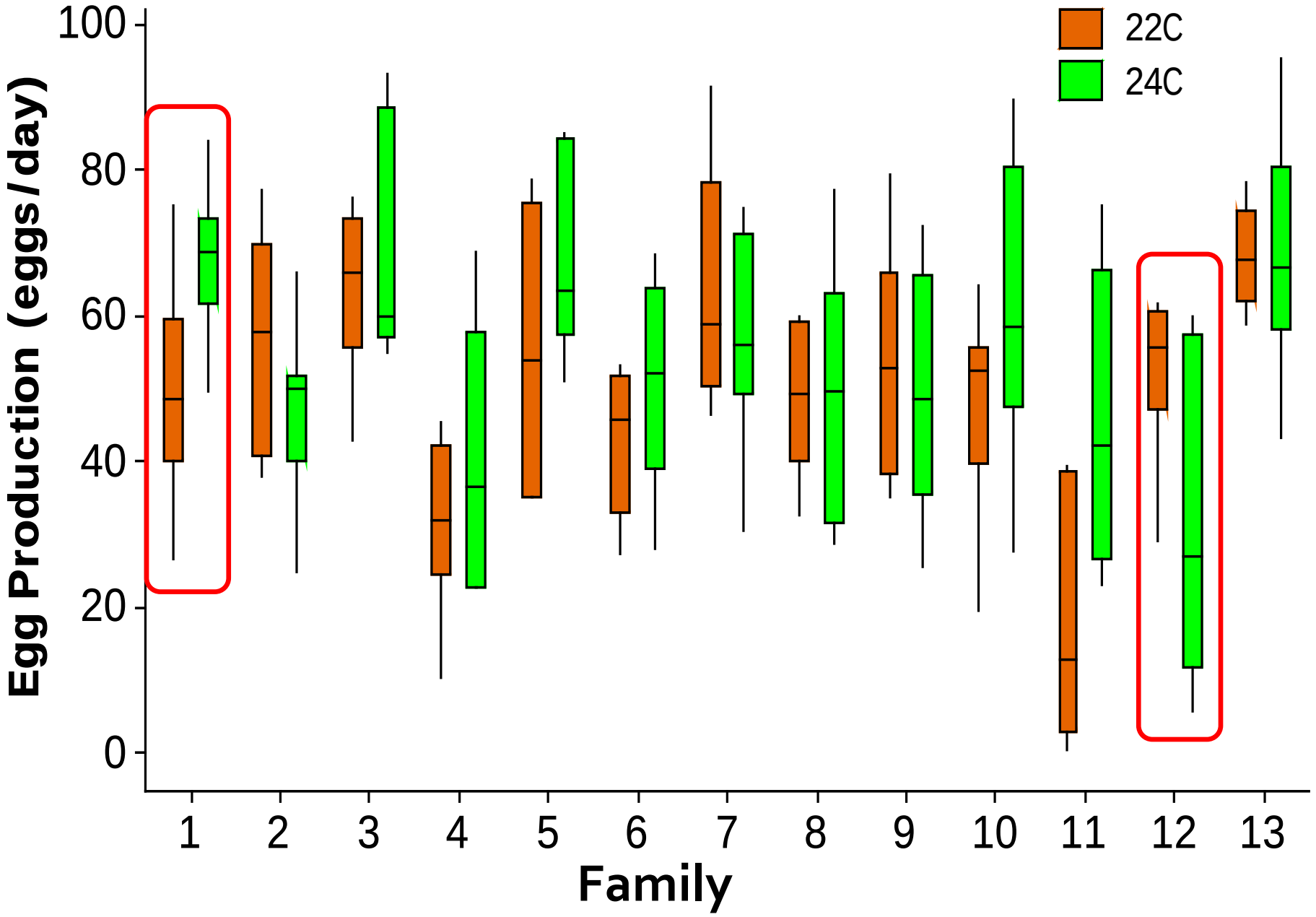
Among families

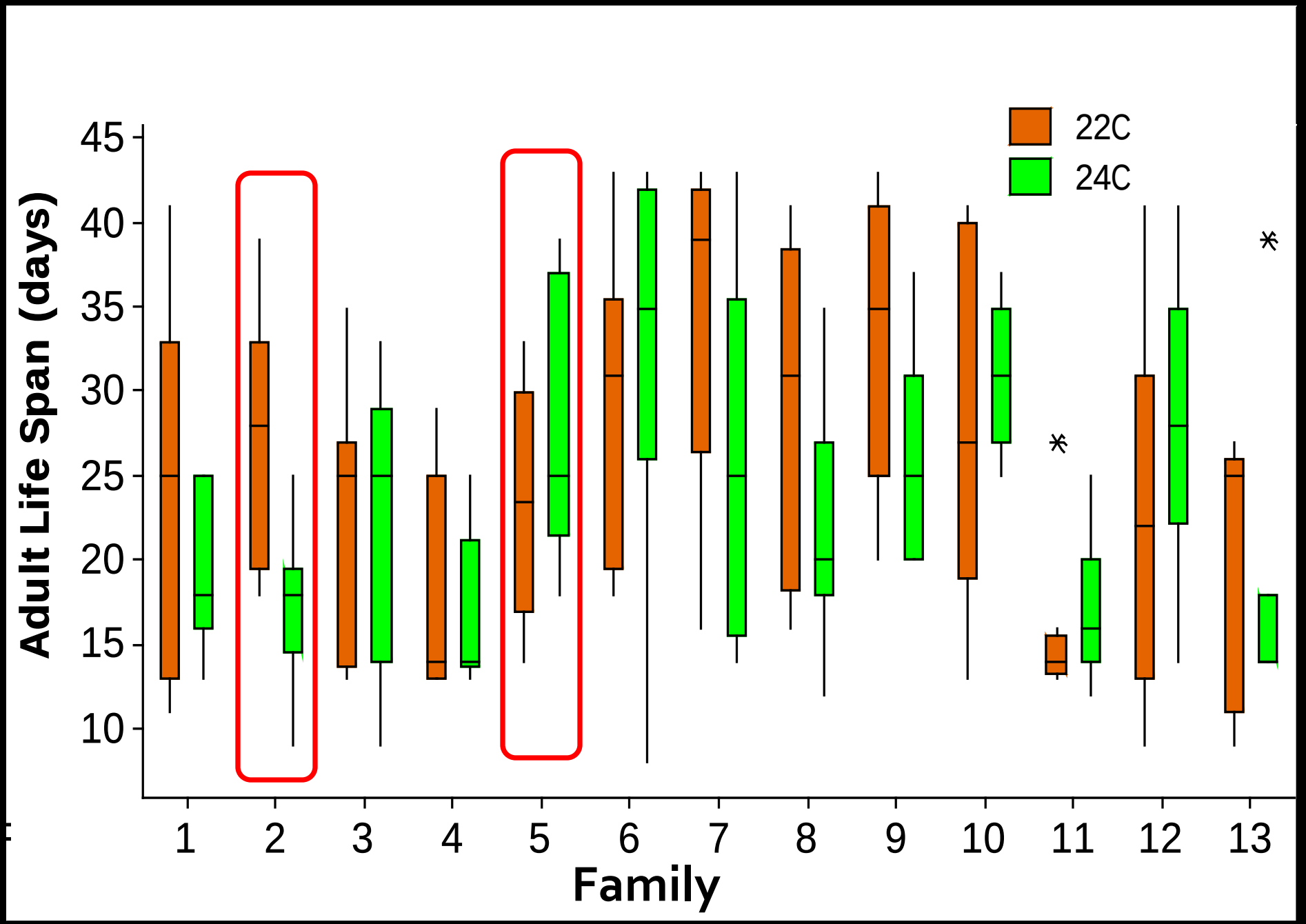
Among progeny between temperatures

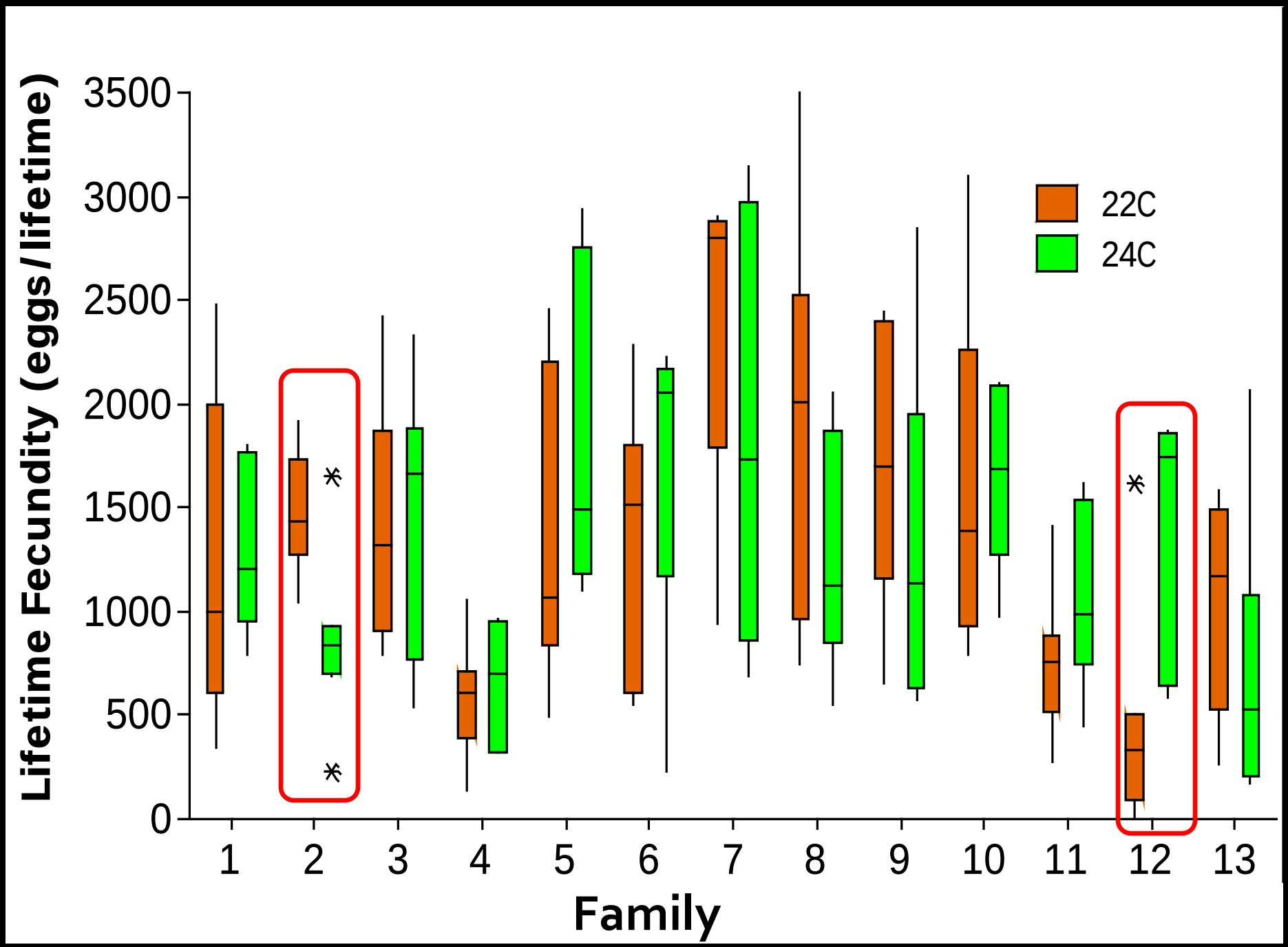
Among progeny within temperatures (error)

Evolutionary Quantitative Genetics (Roff 1997)

Split-Family Results
Acartia tonsa


22C
24C
Egg Production (eggs/day)
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Family


22C
24C
Adult Life Span (days)
45
40
35
30
25
20
15
10
1
2
3
4
5
6
7
8
9
10
11
12
13
Family

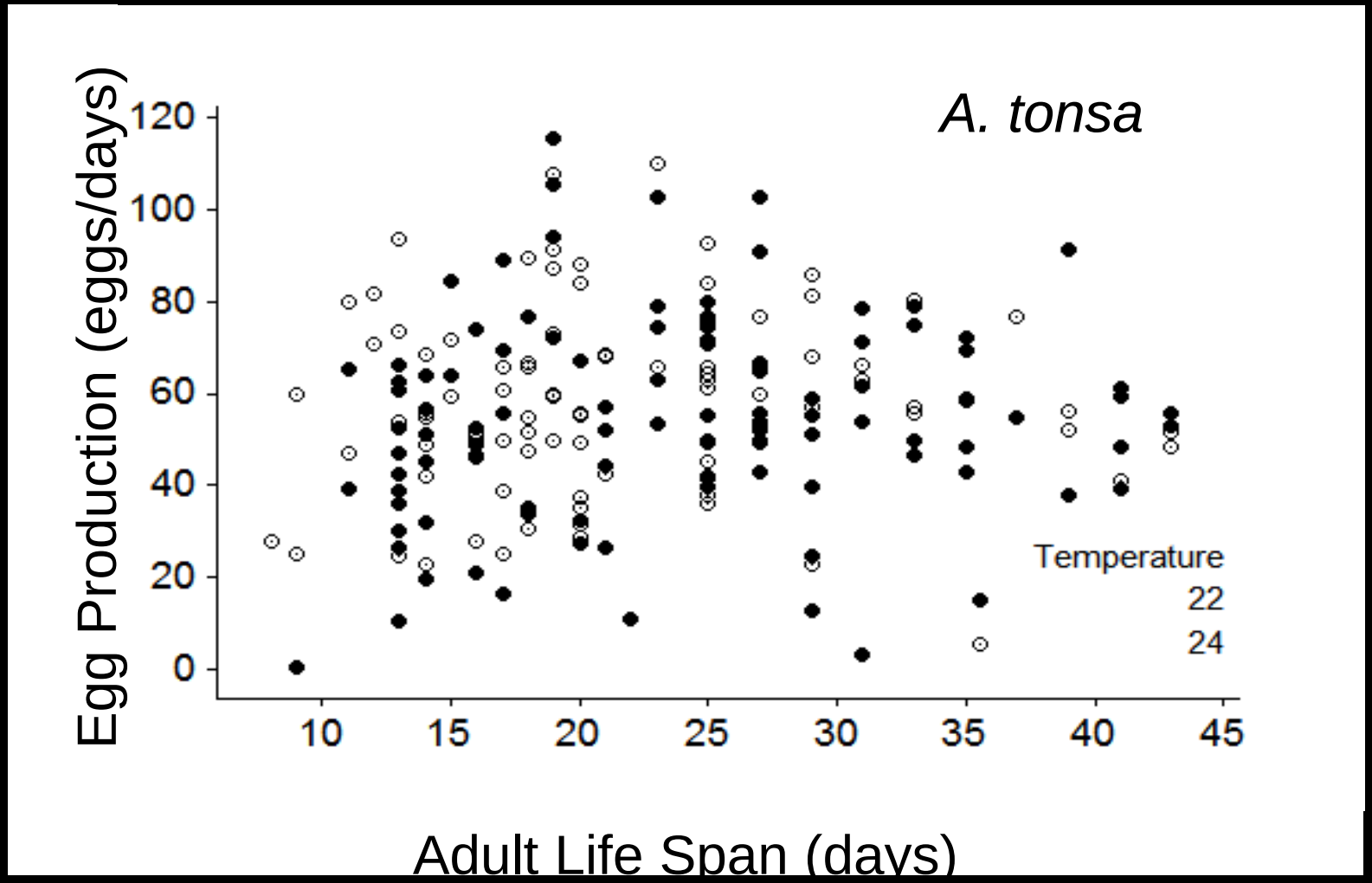

Lifetime Fecundity (eggs/lifetime)
3500
3000
2500
2000
1500
1000
500
0
22C
24C
1
2
3
4
5
6
7
8
9
10
11
12
13
Family

Summary

A. tonsa		
Trait	h^2	P-Value
EPR	0.69±.18	0.020
ALS	0.39±.15	0.030
LF	0.26±.19	0.027

A. hudsonica		
Trait	h^2	P-Value
EPR	-	0.347
ALS	-	0.325
LF	-	0.826

Trade-off?


A. tonsa
Egg Production (eggs/days)
120
100
80
60
40
20
0
10
15
20
25
30
35
40
45
Temperature
22
24
Adult Life Span (days)

Fast Evolutionary Rate of Traits (*Acartia tonsa*)

Trait	Temperature (°C)	Trait Mean±SE	Selection Differential	Response±SE (trait units)	Response±SE (haldanes)
Egg Production	22	53.82±2.04	7.19	4.96±1.30	0.23±0.06
(eggs/day)	24	57.91±1.90	6.26	4.32±1.13	0.22±0.05
Adult Life Span	22	23.65±0.89	3.71	1.45±0.55	0.17±0.06
(days)	24	21.52±0.79	3.14	1.22±0.48	0.16±0.07
Lifetime Fecundity	22	1302.91±74.13	413.31	107.46±78.53	0.15±0.11
(eggs/lifetime)	24	1285.25±62.09	290.41	75.51±55.17	0.13±0.09

Future Work

- Heritability of life-history vs morphological traits
- Heritability of traits vs heritability of fitness
- Heritability in generalists and specialists
- Habitat-dependent heritability
- Species living at the edge:
  - Low genetic variance & low heritability?

$$n_c = \sqrt{\frac{2r_{max}\gamma}{T}} \frac{h^2\sigma^2}{|B-b|}$$

$$r = h^2 S$$