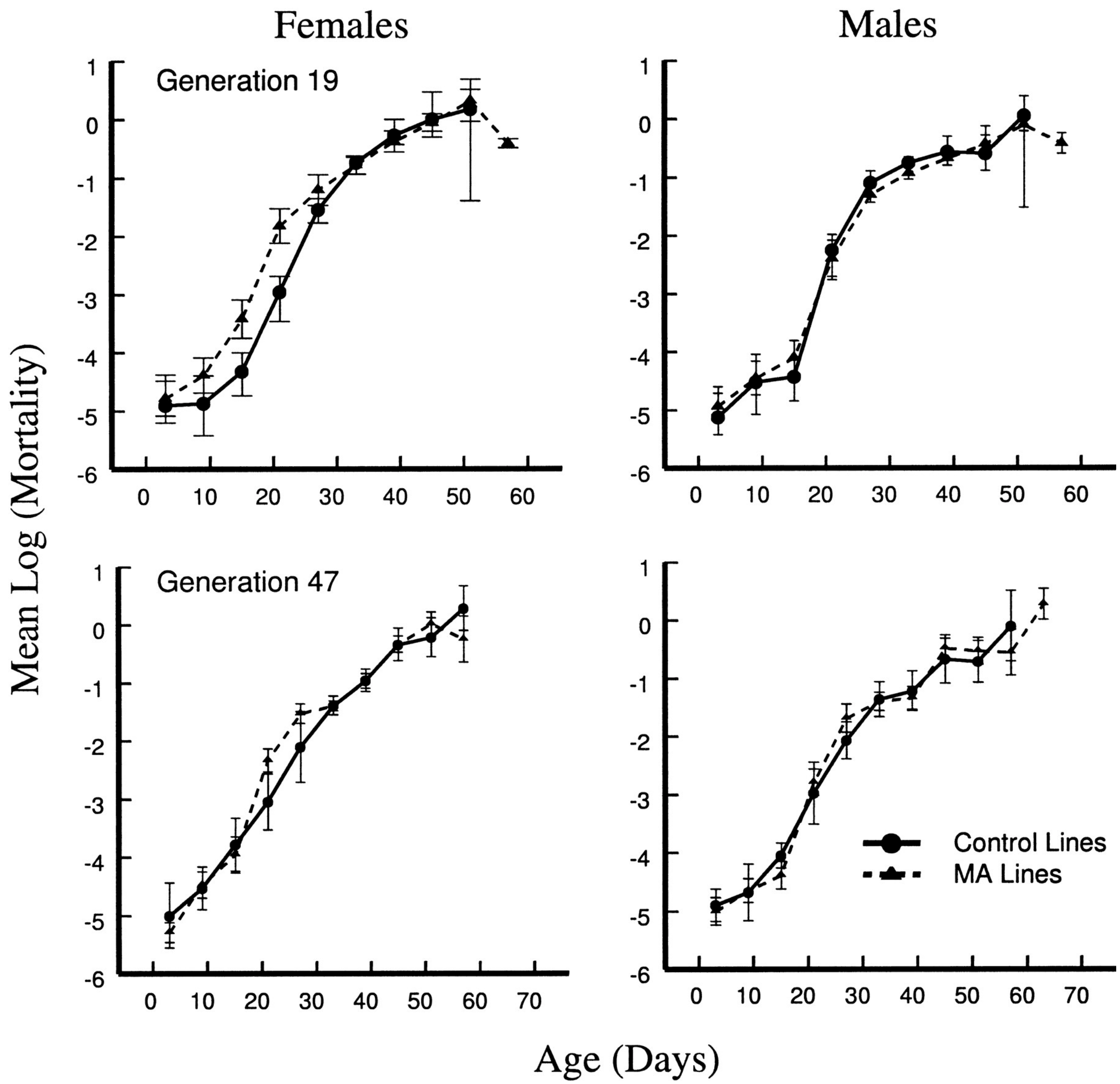
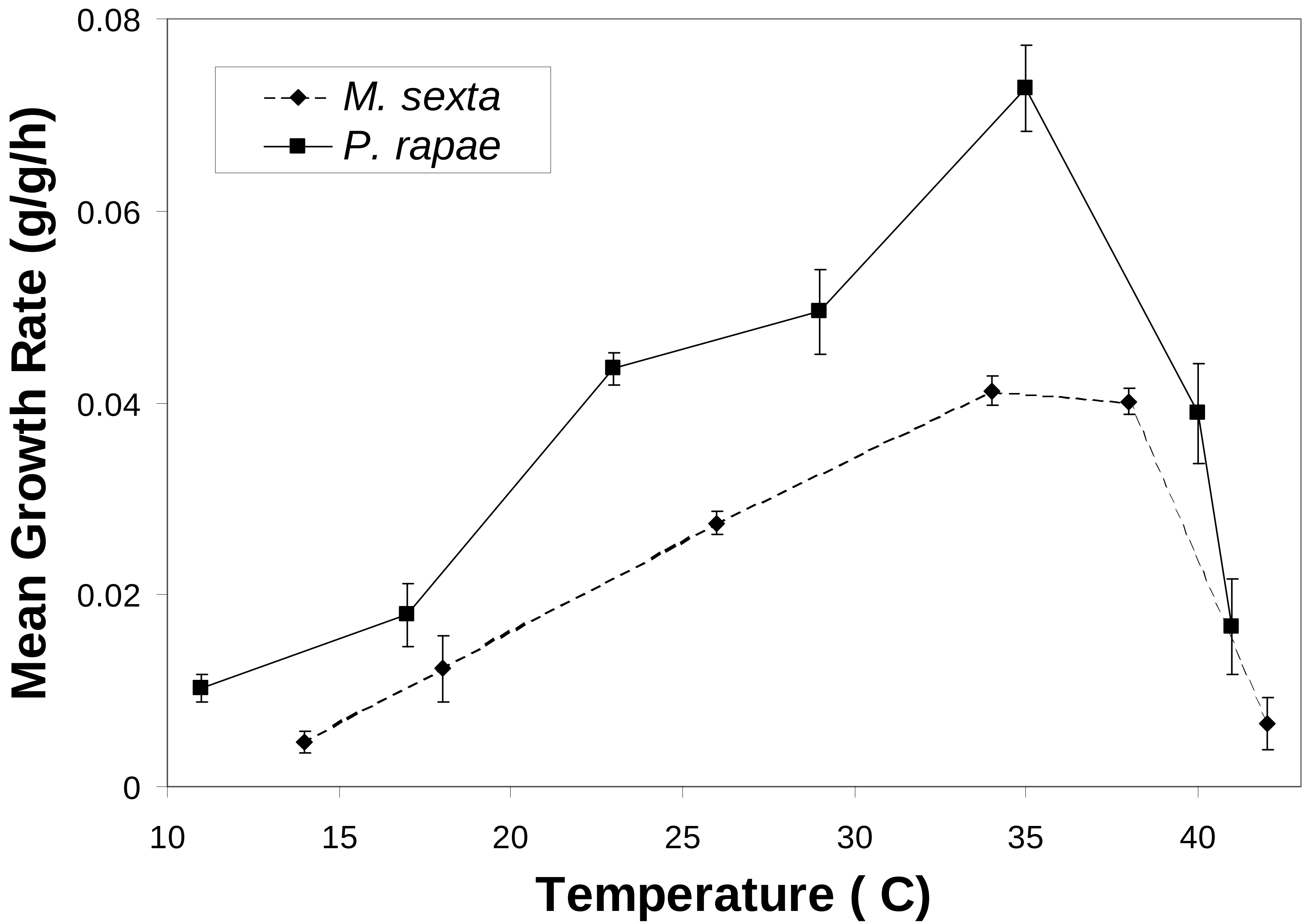
Evolution of functional traits
(Recap)

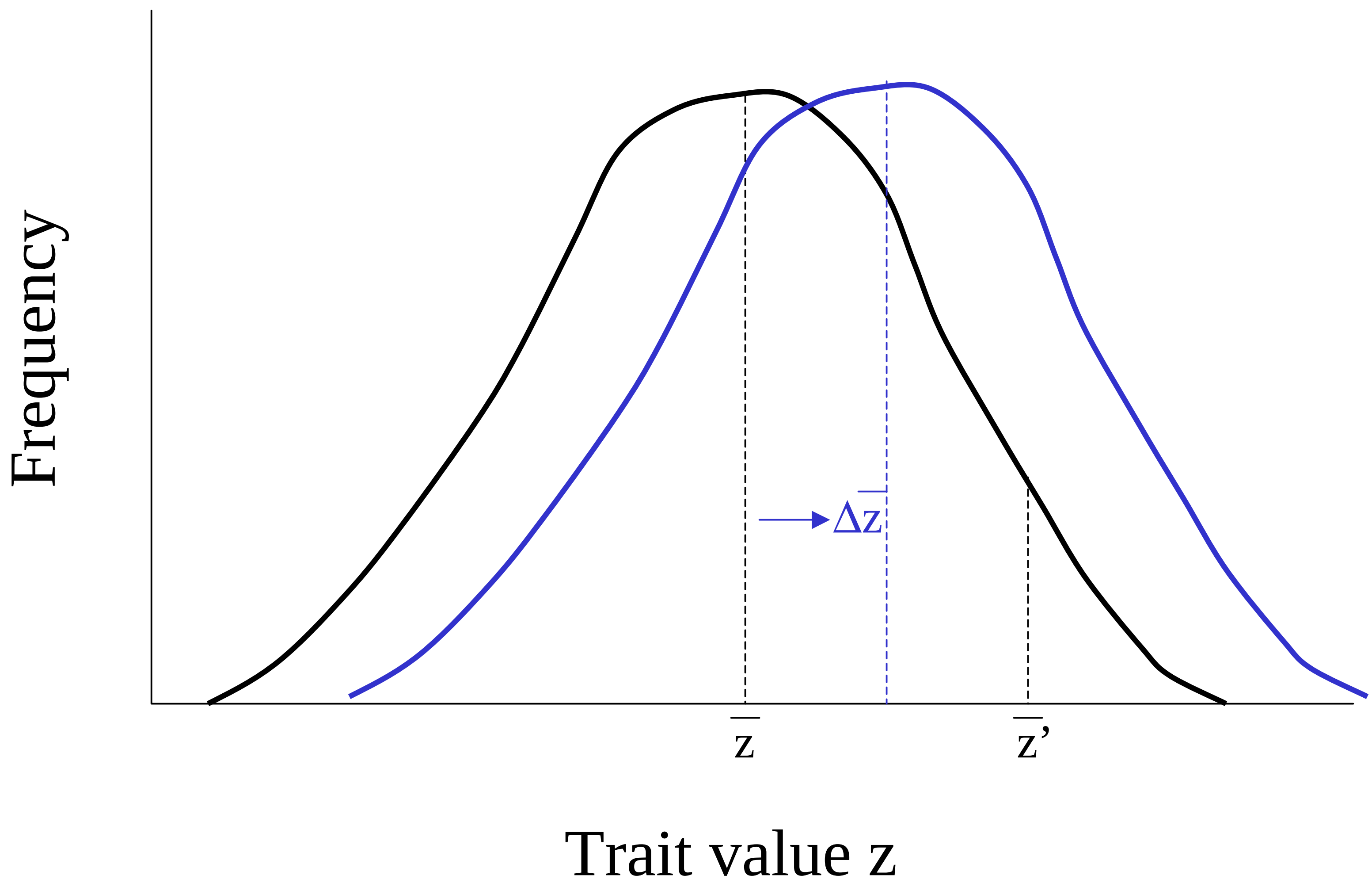
- Traits as functions: functional, function-valued, infinite-dimensional
- A primer in evolutionary models:
  - Variation, inheritance, selection, evolution
- Approaches to analysing functional traits:
  - understanding and estimating genetic variation

Age-specific mortality rates (*Drosophila*)
Pletcher et al, Genetics (1999)




M. sexta
P. rapae
Mean Growth Rate (g/g/h)
0.08
0.06
0.04
0.02
0
10
15
20
25
30
35
40
Temperature (C)

Evolution, in 3 easy steps (3)



Evolution of quantitative traits: some basics

- Individual organism:
  - Phenotype: observable trait with value *z*
  - Genotype: genetic ‘type’ (usually inferred)
- Population:
  - Phenotypic variance, P = G + E
  - Genetic variance, G
- Evolution = change in mean trait value per generation, $\Delta\bar{z}$

A simple evolutionary model

- Variation and inheritance
  - Variance: $P = G + E$
- Selection
  - Selection gradient: $\beta = P^{-1}(\bar{z}' - \bar{z})$
  - Also: $\beta = d[\ln(\bar{W})]/dz$, where $\bar{W}$ = mean population fitness
- Evolutionary response

  $\Delta\bar{z} = G\,\beta$

$$\Delta\bar{z} = G\,\beta$$

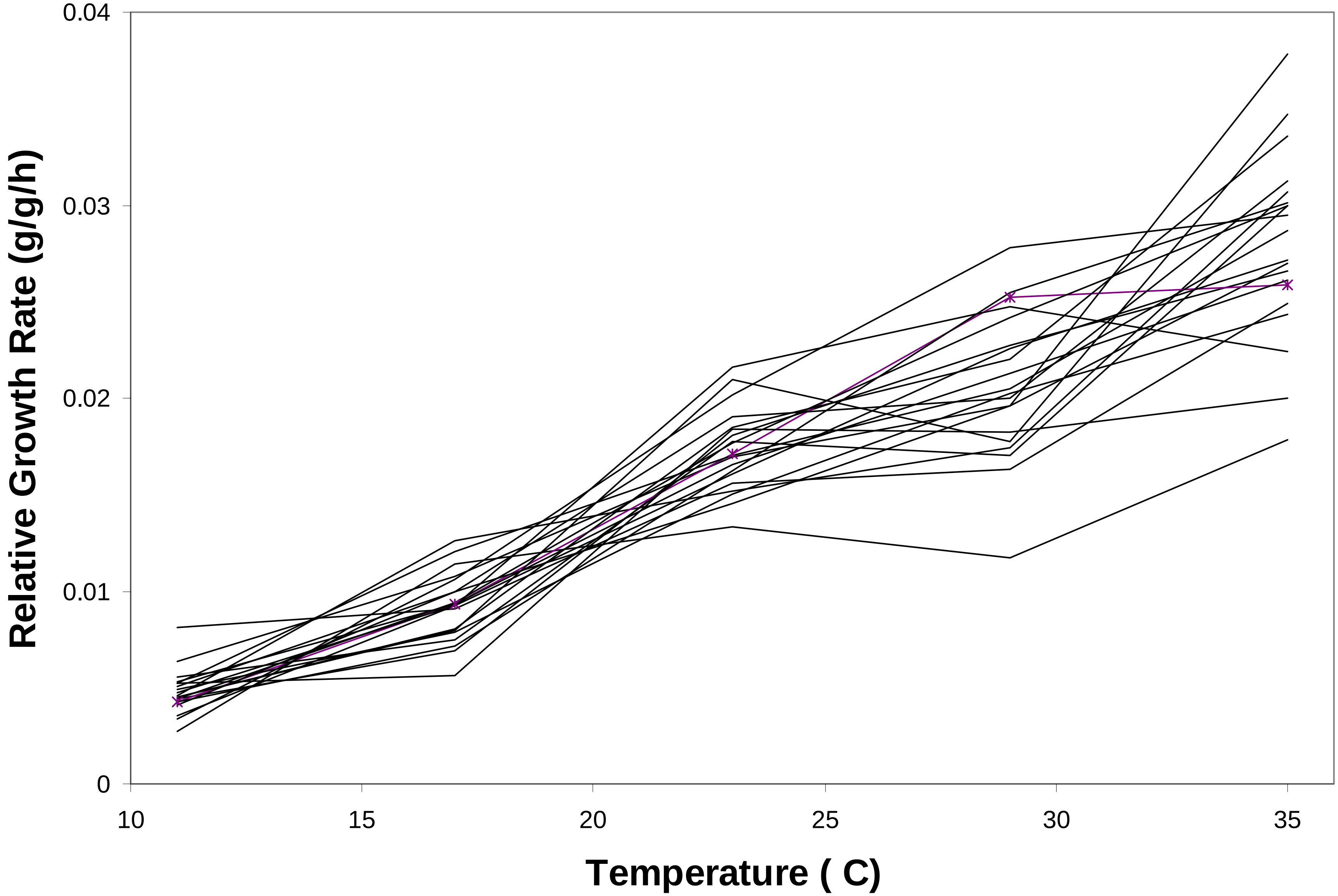
z may be:

- a scalar
- a vector
- a function

$$\Delta\bar{z}(t) = \int G(t,s)\,\beta(s)\,ds$$

Genetics recap: Temperature and caterpillar growth rate curves

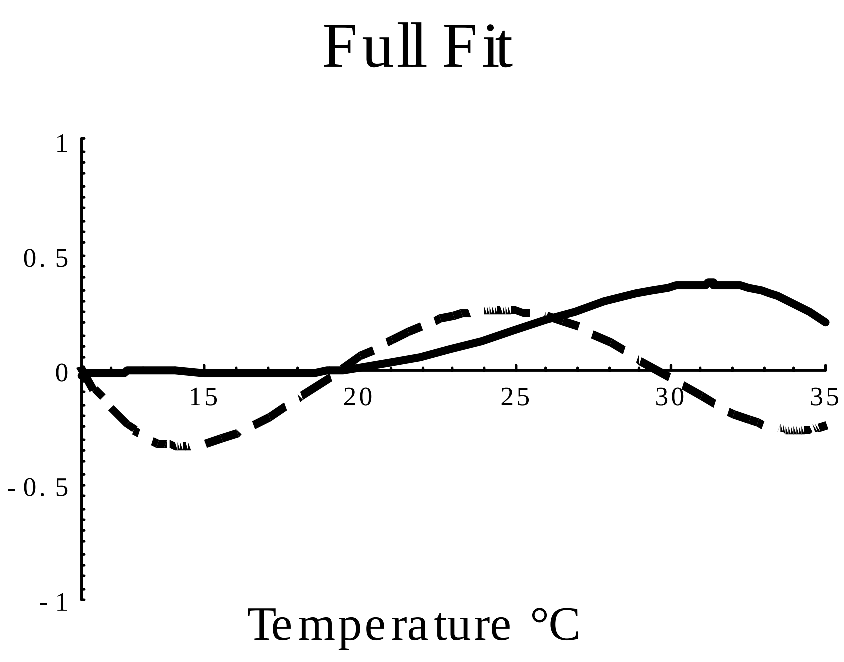
- Genetic variation in TPCs
- Eigenfunction analysis

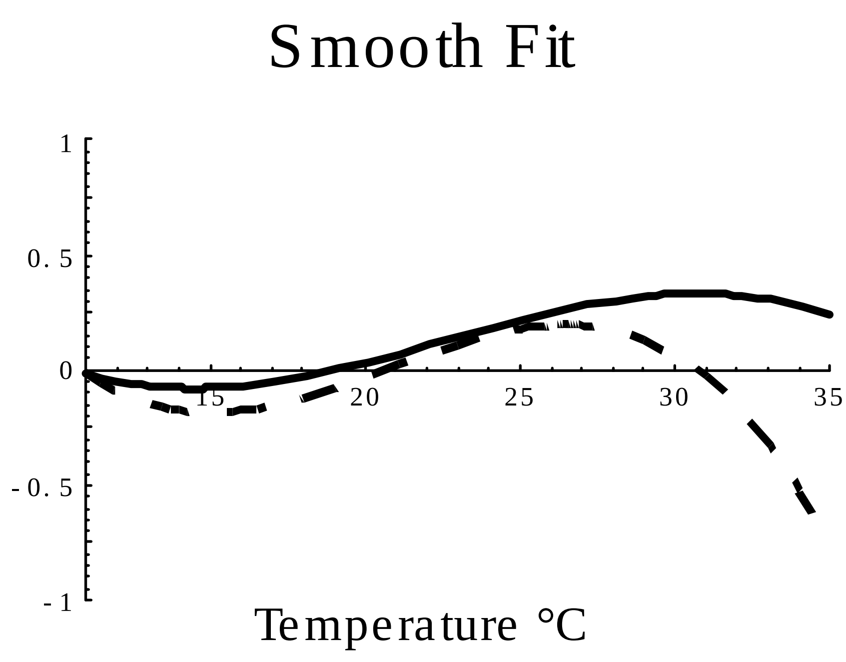


0.04
0.03
0.02
0.01
0
10
15
20
25
30
35
Relative Growth Rate (g/g/h)
Temperature (C)

Caterpillar growth rates

Leading and Second Eigenfunctions





Evolution of functional traits
(Take II)

- Why does genetic variation (G) matter?
  - Direct and indirect responses to selection
  - Constraints on directions of evolution
- Understanding selection
  - What is selection?
  - Selection on a functional trait: an example
  - Selection and environmental variation
- Predicting evolutionary trajectories

Why G matters

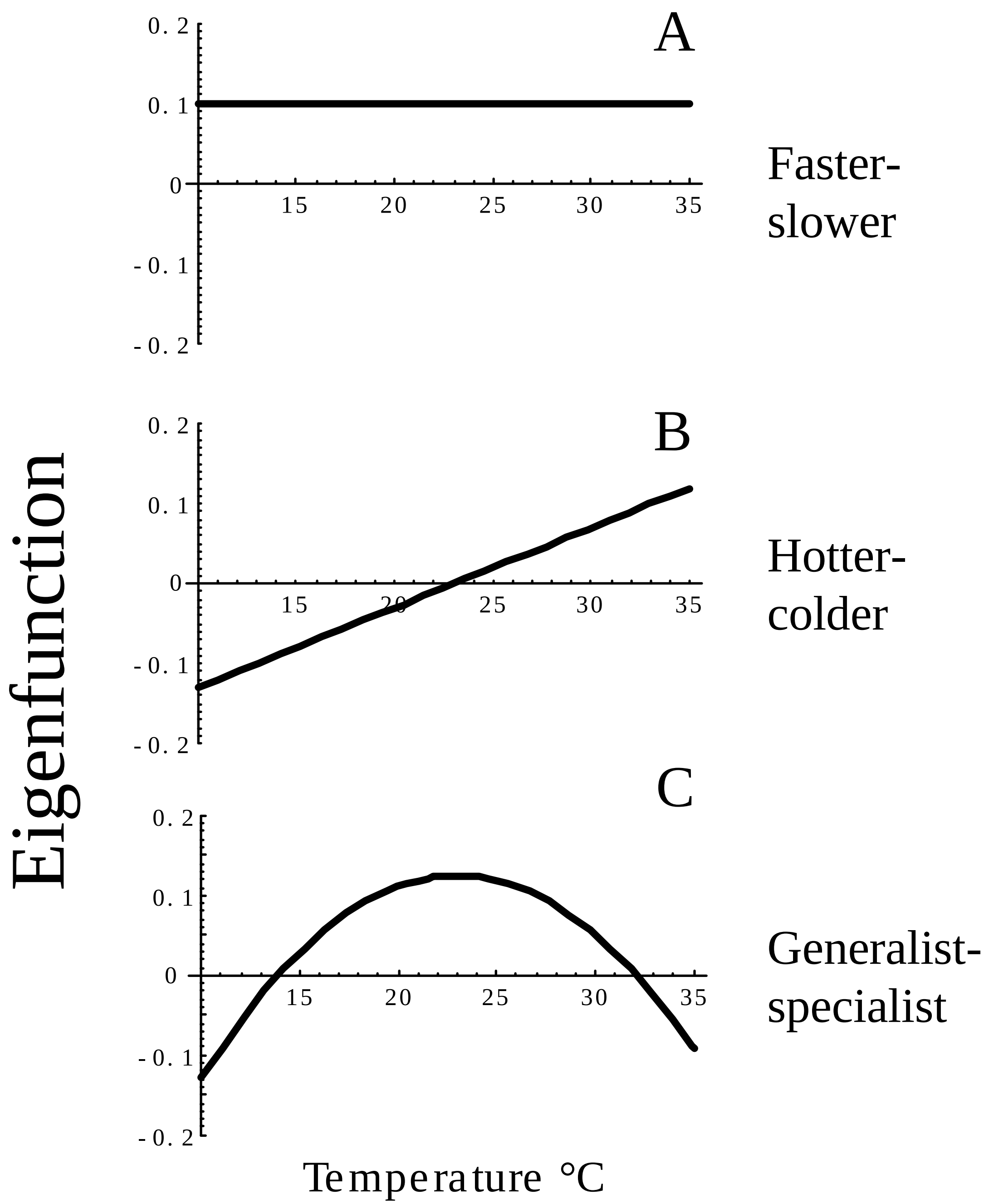
G and the response to selection

$$\Delta \bar{z}(t) = \int G(t,s)\beta(s)ds$$

Direct and indirect responses to selection

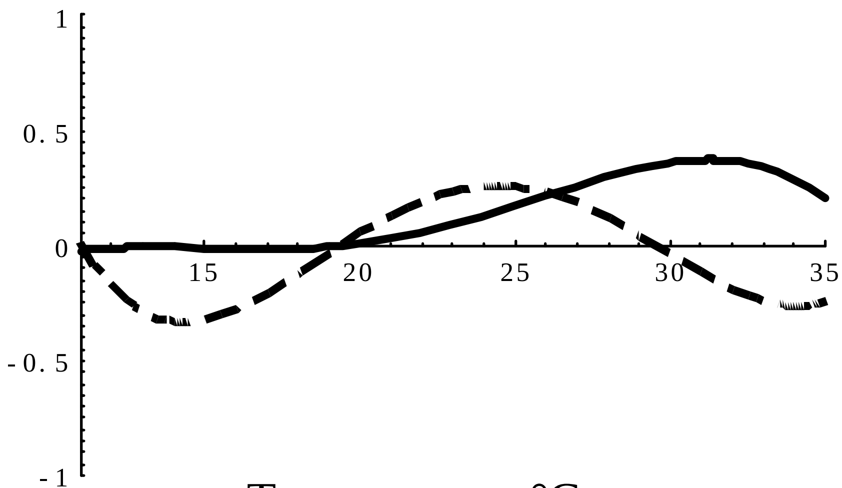
–

Constraints: when evolution won't go


Eigenfunction
A
Faster-
slower
B
Hotter-
colder
C
Generalist-
specialist
Temperature °C
0.2
0.1
0
-0.1
-0.2
15
20
25
30
35

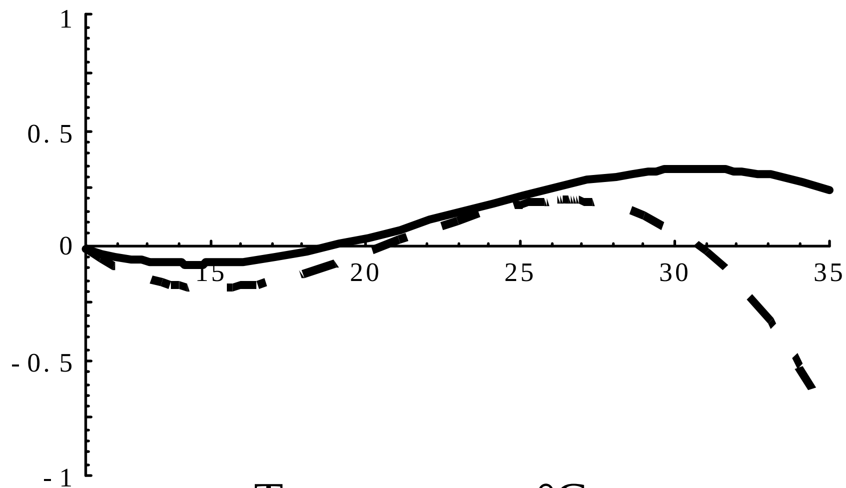
Leading and Second Eigenfunctions

Full Fit



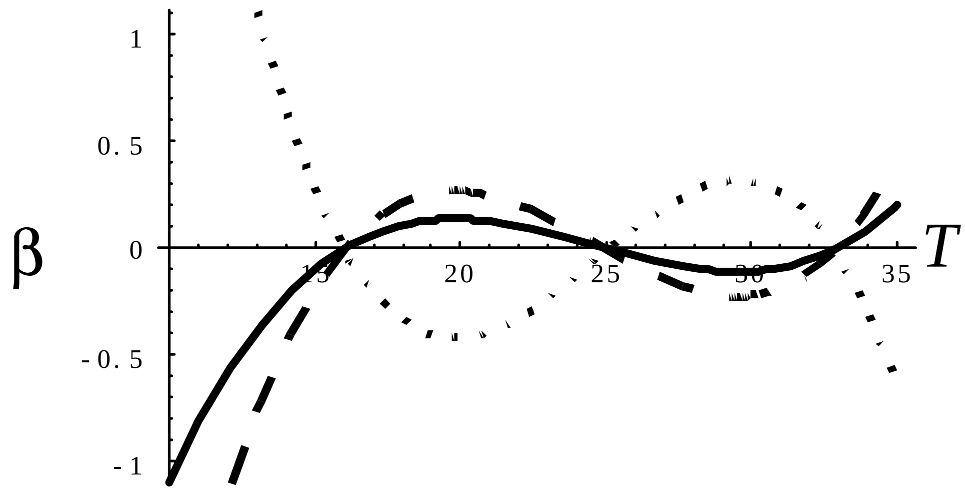
Temperature °C

Smooth Fit



Temperature °C

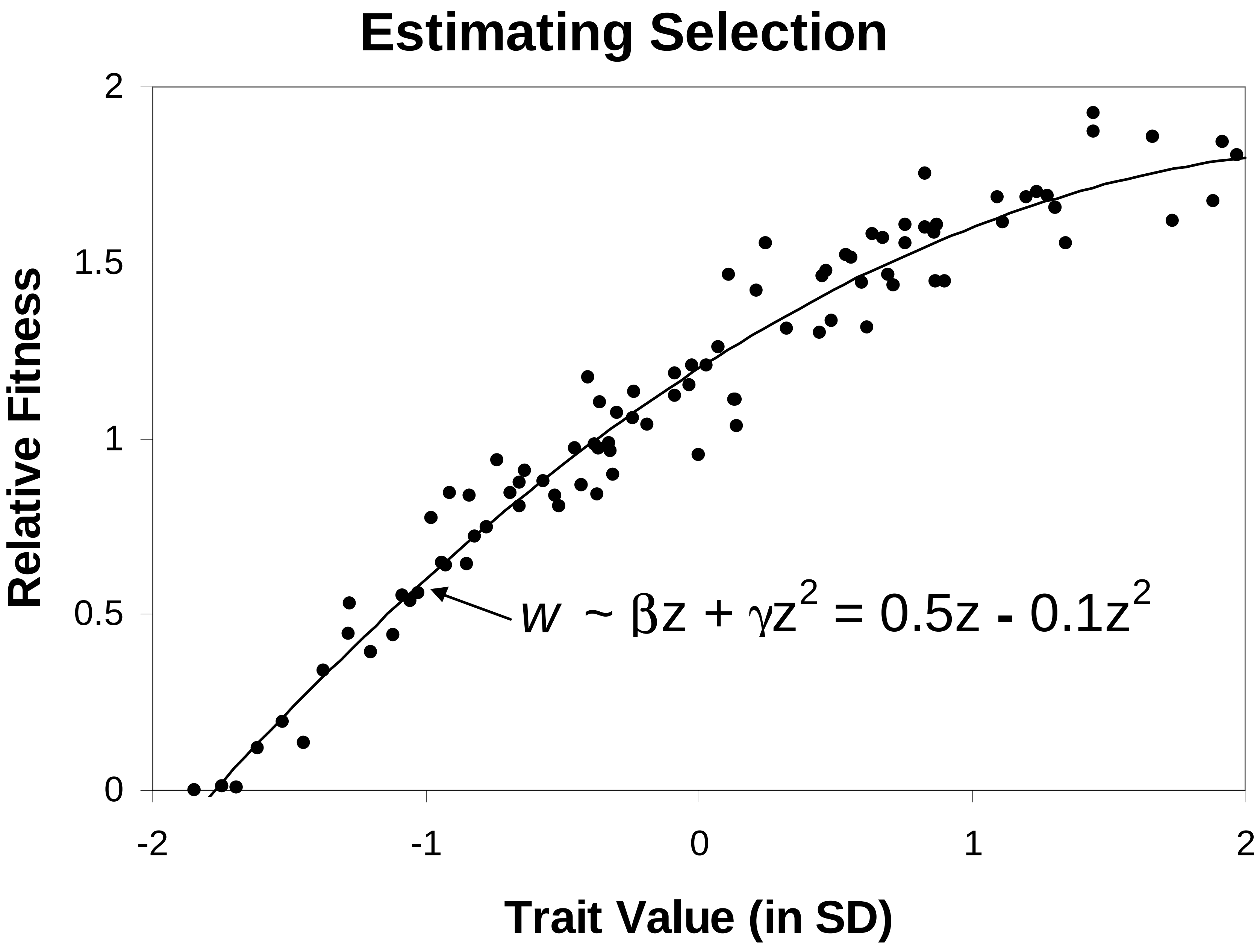
Evolutionary Constraints:
Identifying zero eigenfunctions



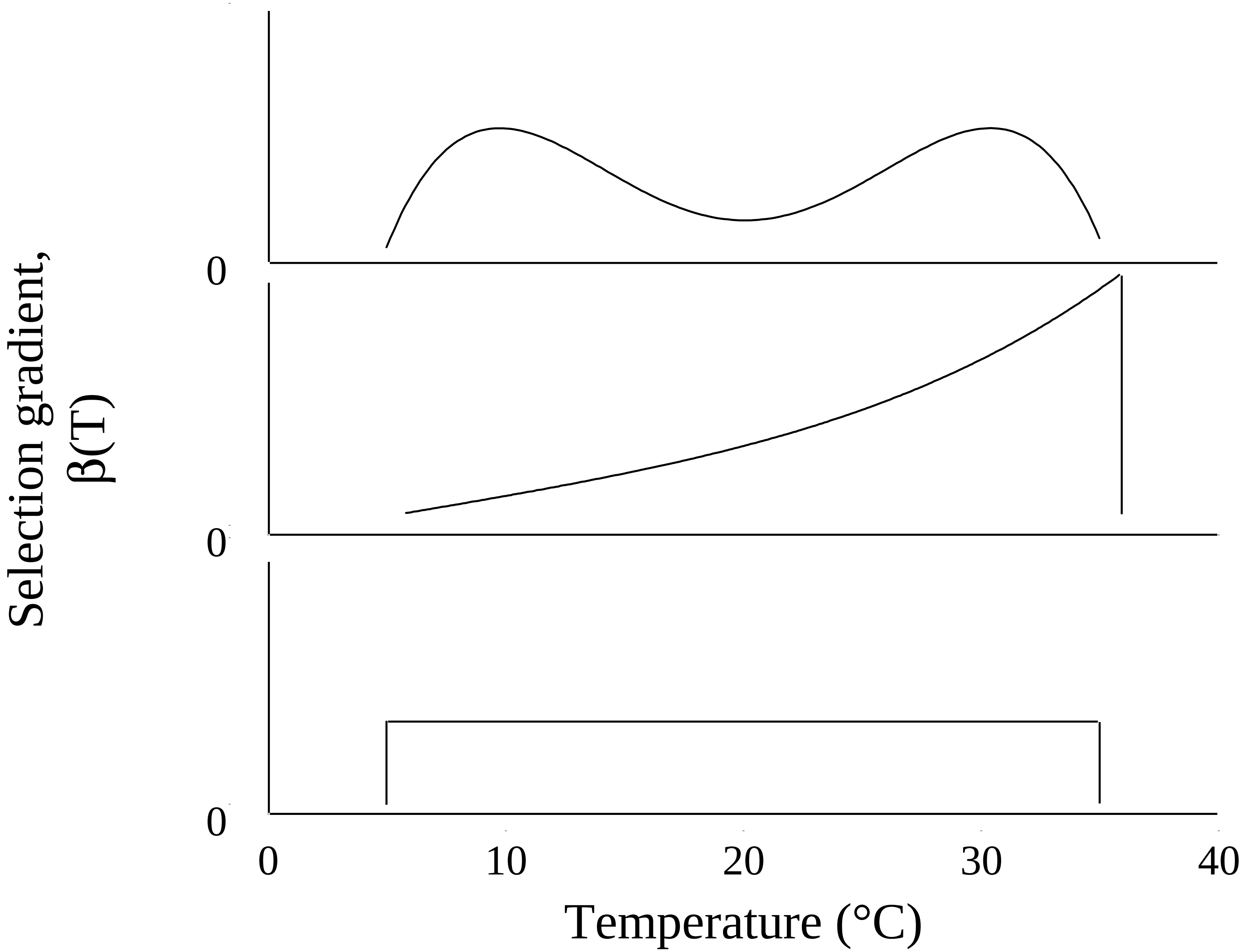
Selection and evolutionary response

- What is selection?
- Estimating selection, $\beta(s)$: an example
- Predicting evolutionary responses

$$\Delta \bar{z}(t) = \int G(t,s)\beta(s)ds$$

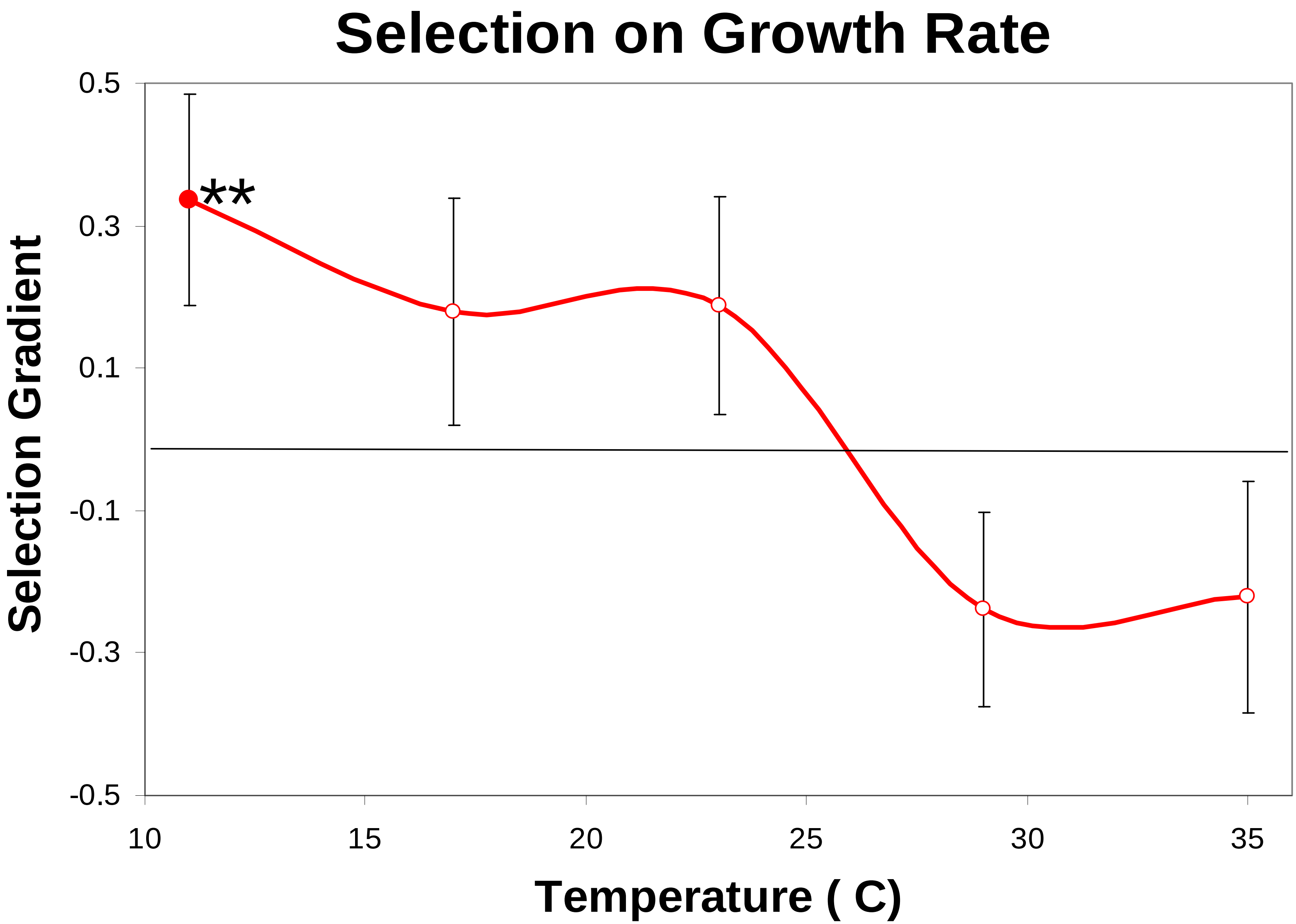


Estimating Selection
Relative Fitness
Trait Value (in SD)
2
1.5
1
0.5
0
-2
-1
0
1
2
$w \sim \beta z + \gamma z^2 = 0.5z - 0.1z^2$


Selection gradient,
β(T)
0
0
0
0
10
20
30
40
Temperature (°C)

Selection on caterpillar growth rate TPCs

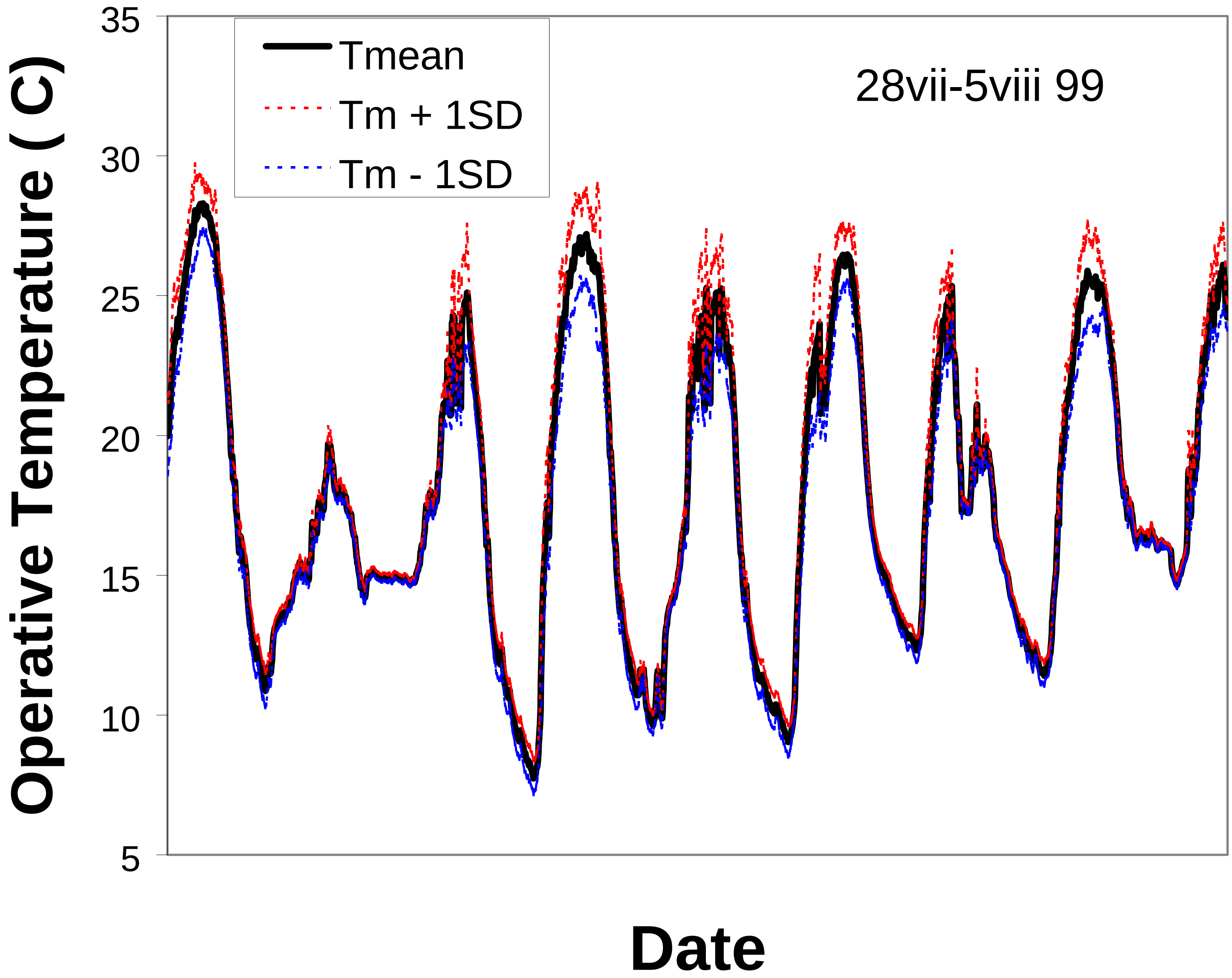
- Measure $z(T)$ for a sample of individuals in the lab --> estimate $P(T,\theta)$
- Measure fitness of those individuals in the field (survival and time to pupation; pupal mass)
- Estimate $\beta(T)$ (functional models?)

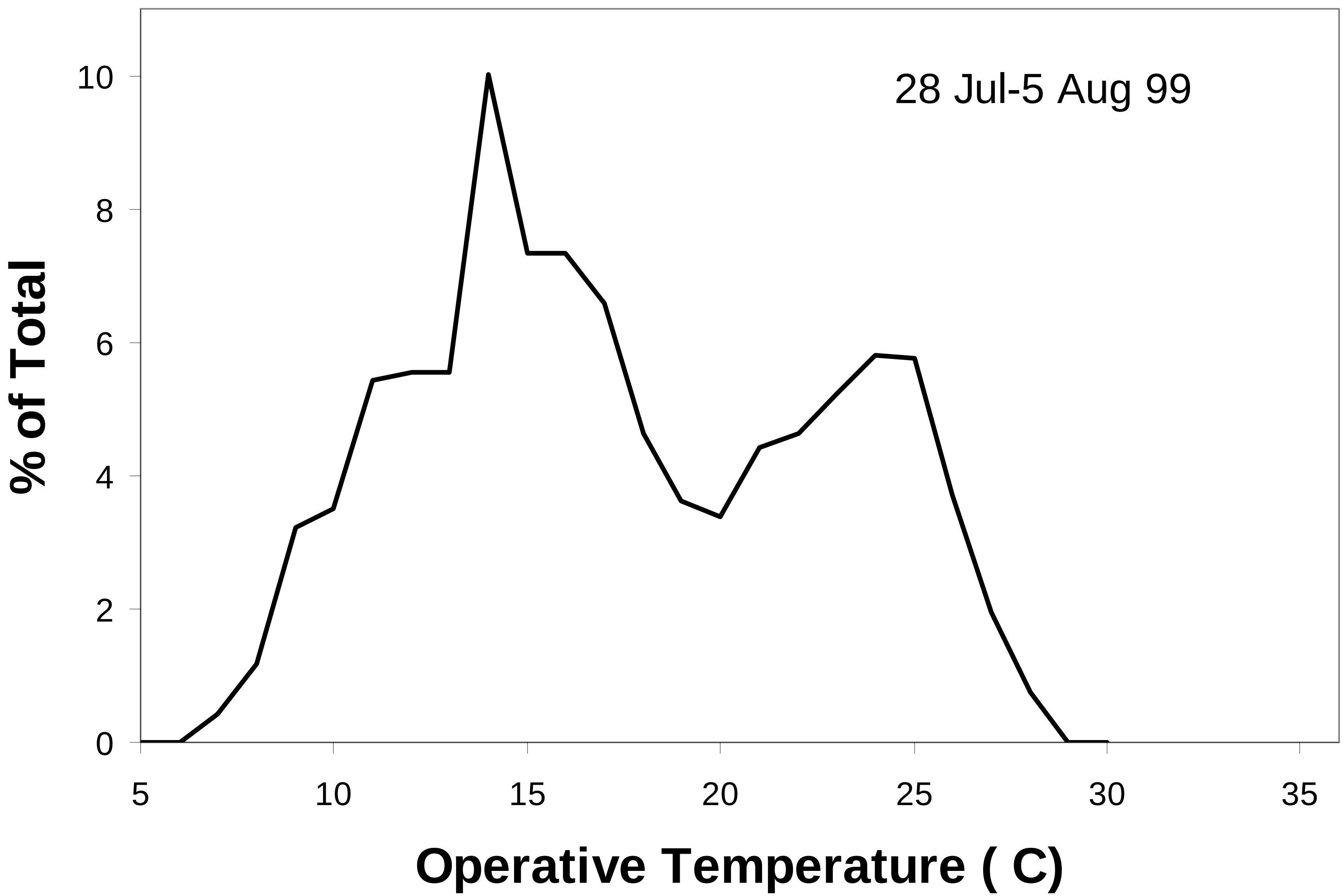


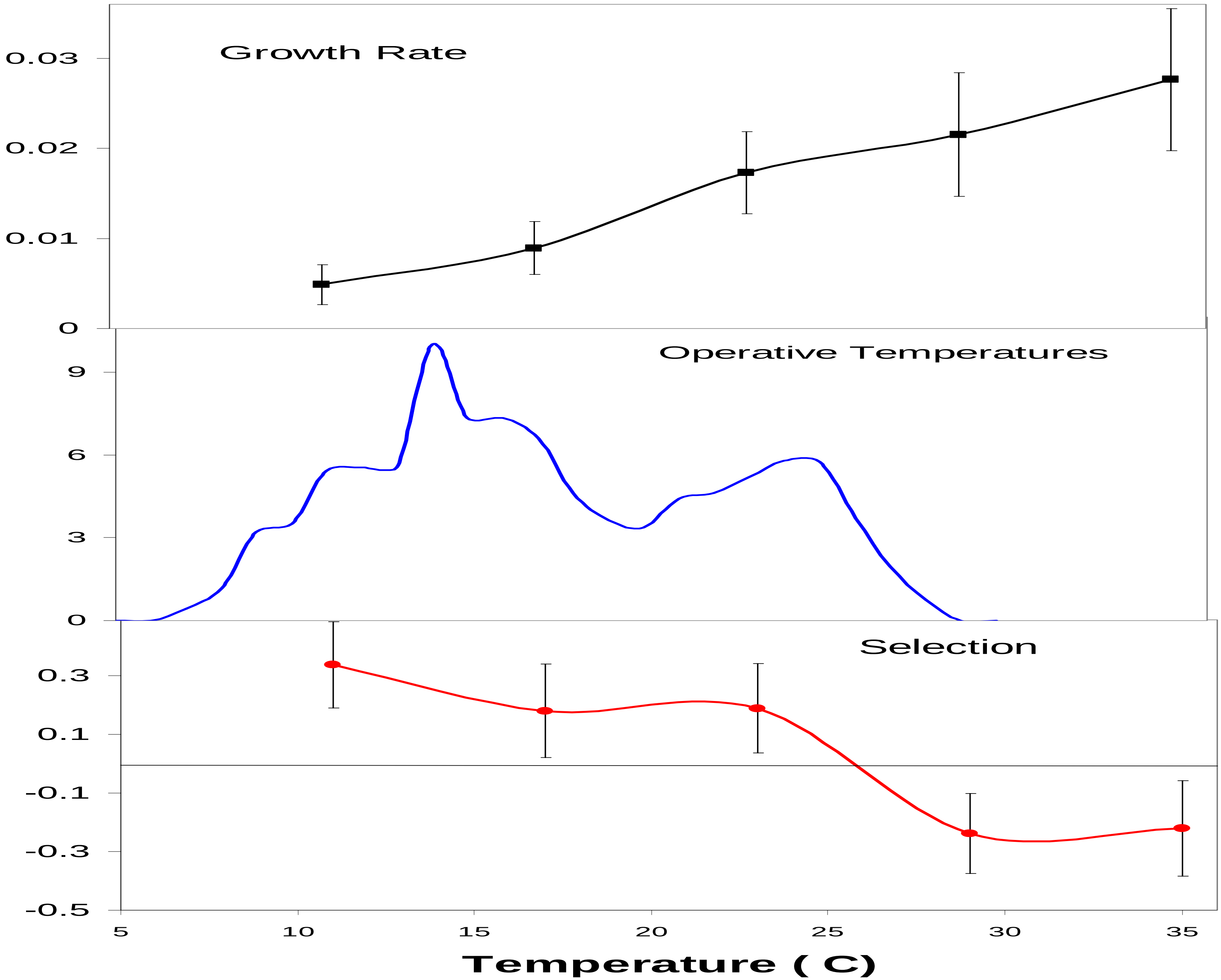
Selection on Growth Rate
Selection Gradient
Temperature (C)
0.5
0.3
0.1
-0.1
-0.3
-0.5
10
15
20
25
30
35
**

Selection on TPC and environmental temperatures:

Measuring ‘caterpillar’ temperatures


Operative Temperature (C)
35
30
25
20
15
10
5
Tmean
Tm + 1SD
Tm - 1SD
28vii-5viii 99
Date


28 Jul-5 Aug 99
% of Total
Operative Temperature (C)
0
2
4
6
8
10
5
10
15
20
25
30
35



Growth Rate
0.03
0.02
0.01
0
Operative Temperatures
9
6
3
0
Selection
0.3
0.1
-0.1
-0.3
-0.5
5
10
15
20
25
30
35
Temperature (C)

Predicting evolutionary responses

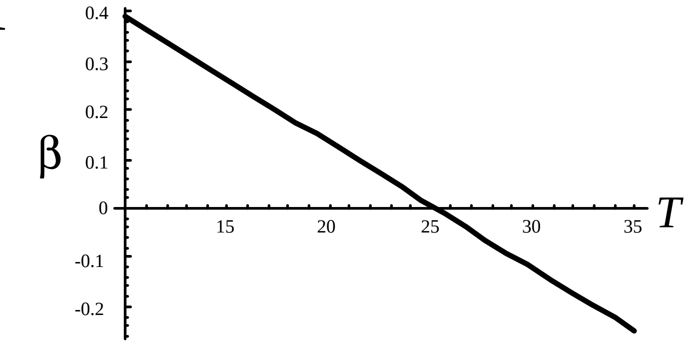
- Mean phenotype, $\bar{z}(T)$
- Genetic var-cov function, G(T,θ))
- Selection gradient function, β(T)

$$\Delta\bar{z}(t) = \int G(t,s)\beta(s)ds$$

Evolutionary Response to Selection

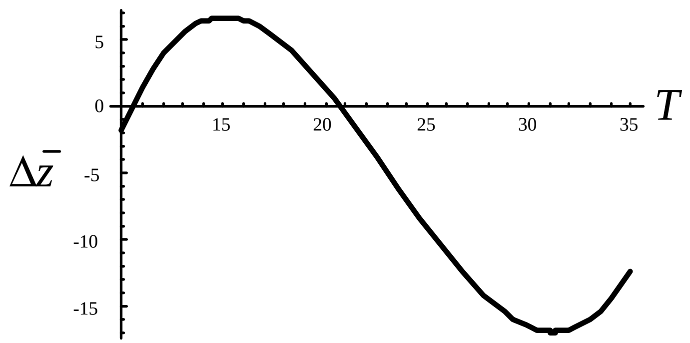
Selection

A



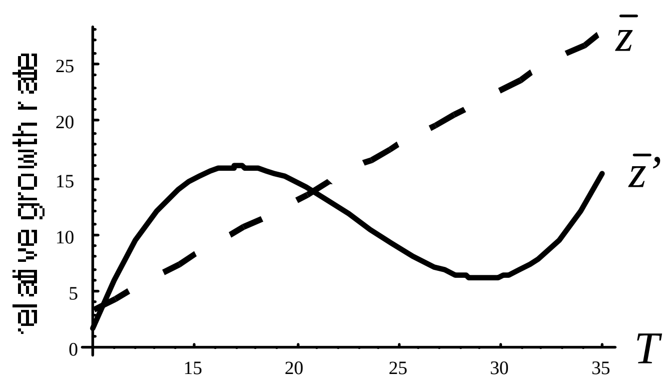
Evolutionary response

B



Evolutionary change in one generation

C



Challenges

- Estimating zero eigenfunctions
- Estimation methods for β
- Incorporating environmental information (distribution of T)
- Predicting evolutionary responses