Trade-offs between growth and reproduction in a long-lived plant

Julien Papaix, Valentin Journé, Hendrik Davi, Emily Walker, Etienne Klein, Francois Courbet, Francois Lefèvre, Sylvie Muratorio

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evolution MONTPELLIER 2018
August 19-22, 2018
Montpellier, France

Wed, 22 August
S-69 Evolutionary Physiology

Trade-offs between growth and reproduction

Example with a long-lived plant

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PhD Student, INRA URFM, Avignon

INRA SCIENCE & IMPACT

Acknowledgements

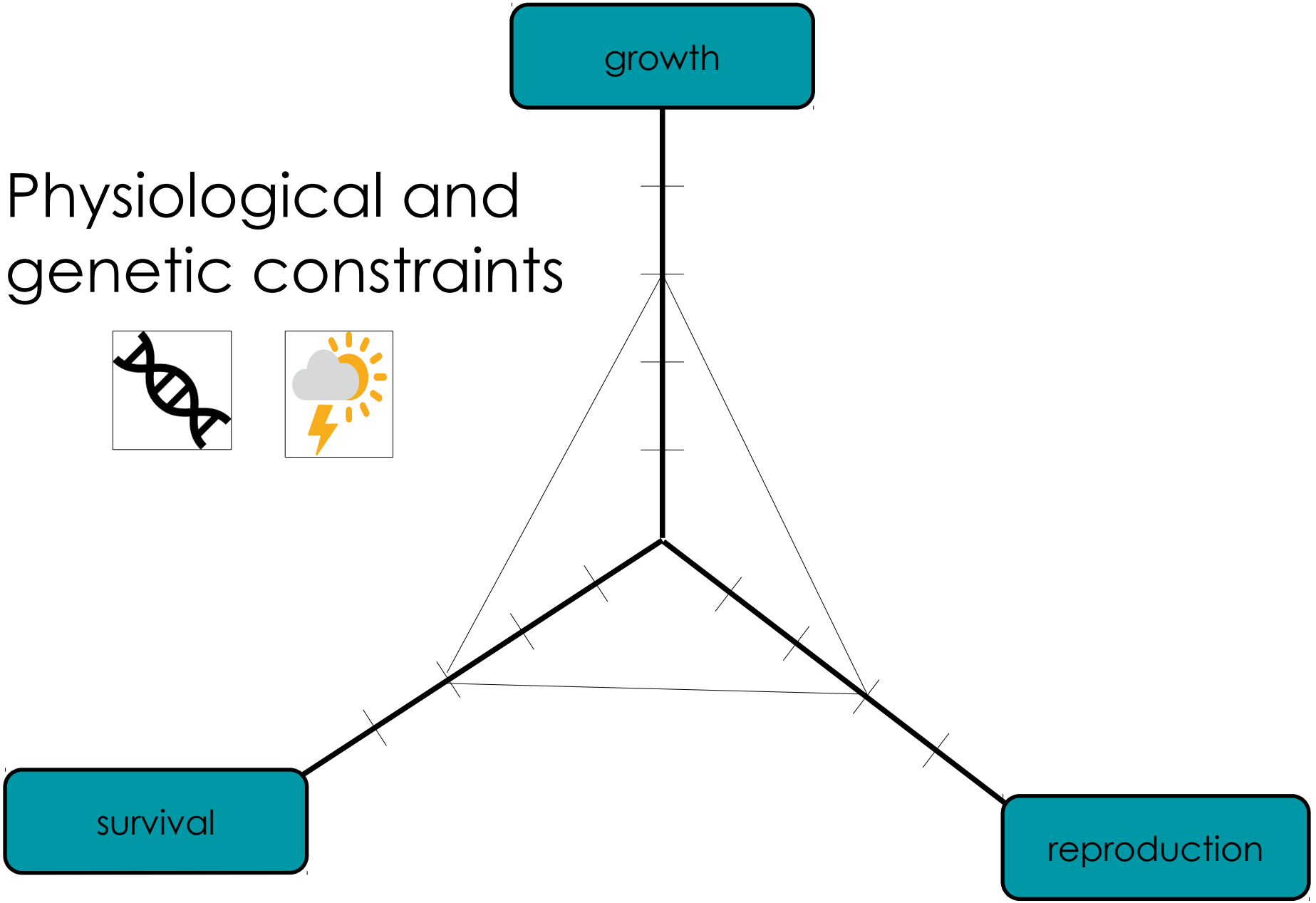
Funding:

RÉGION SUD PROVENCE ALPES CÔTE D'AZUR

INRA SCIENCE & IMPACT

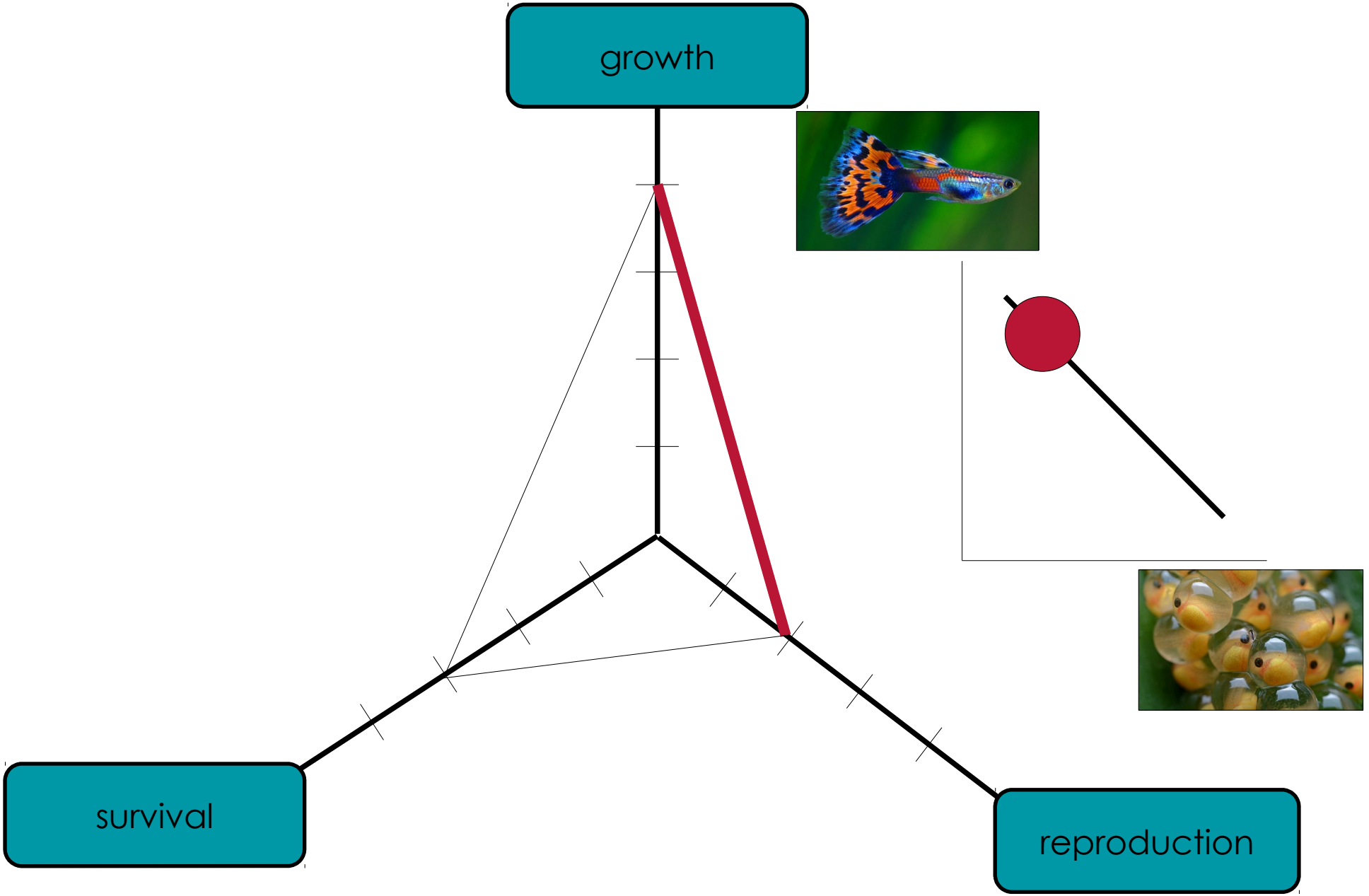
Collaborators:

Context



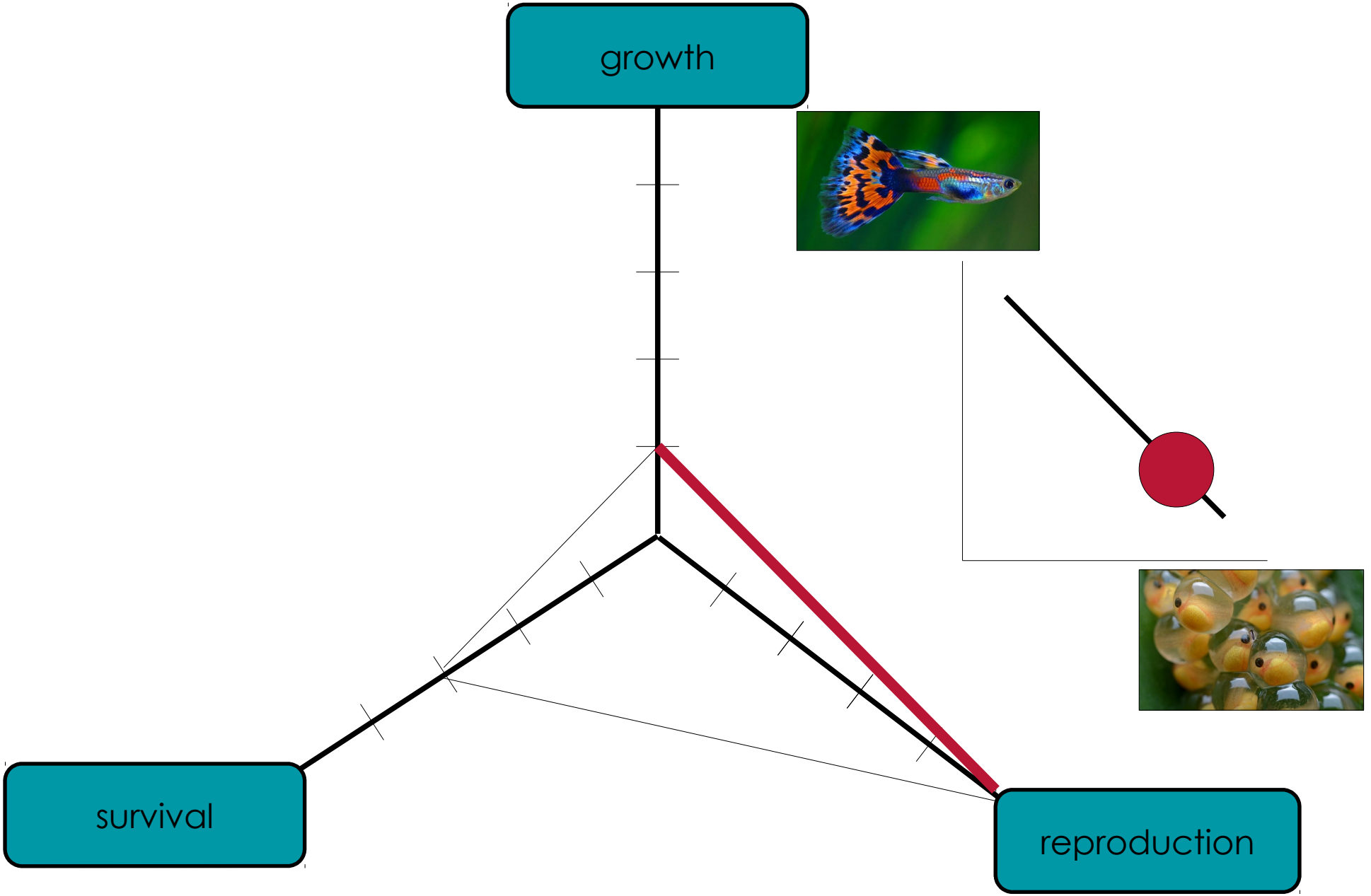
Adapted from Cody 1966

Context



Reznick, 1983
Adapted from Cody 1966

Context



Reznick, 1983
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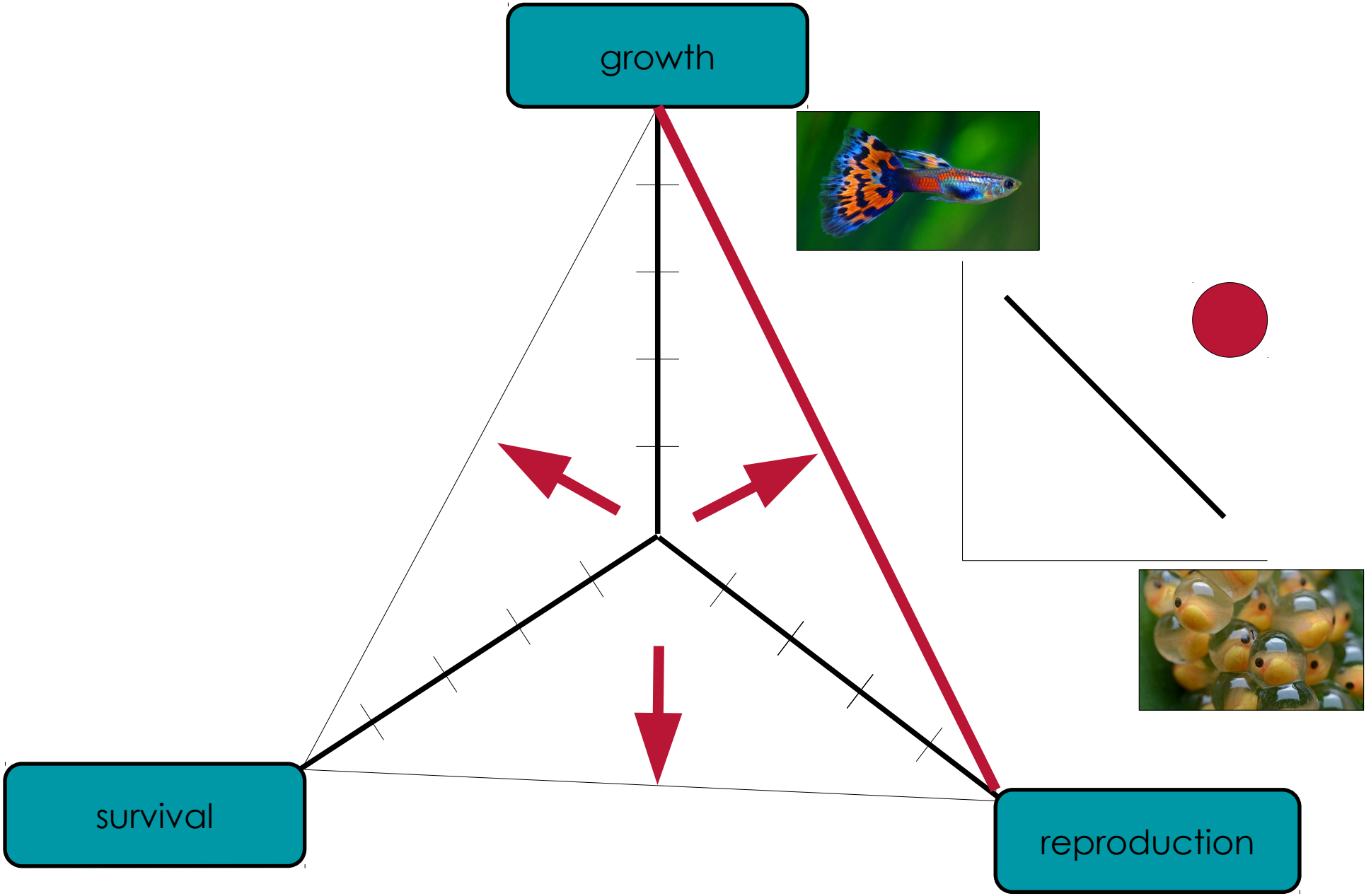
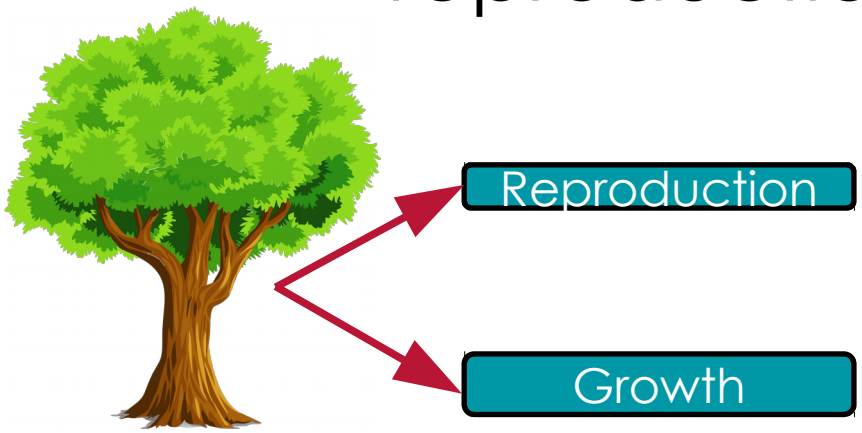
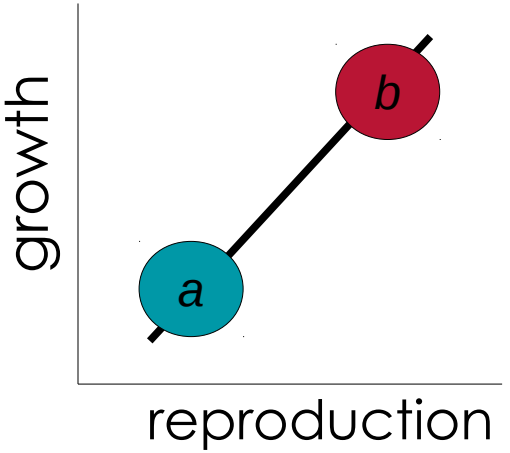


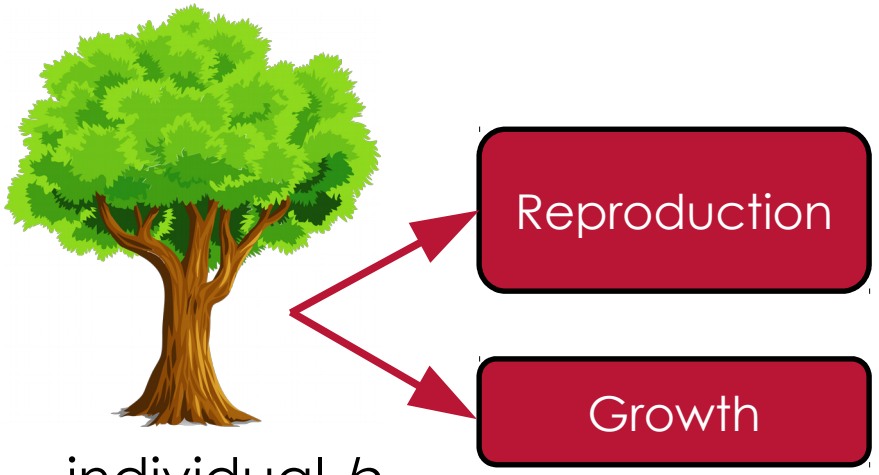
Reznick, 1983
Adapted from Cody 1966

How to measure trade-off between growth and reproduction ?



individual *a*

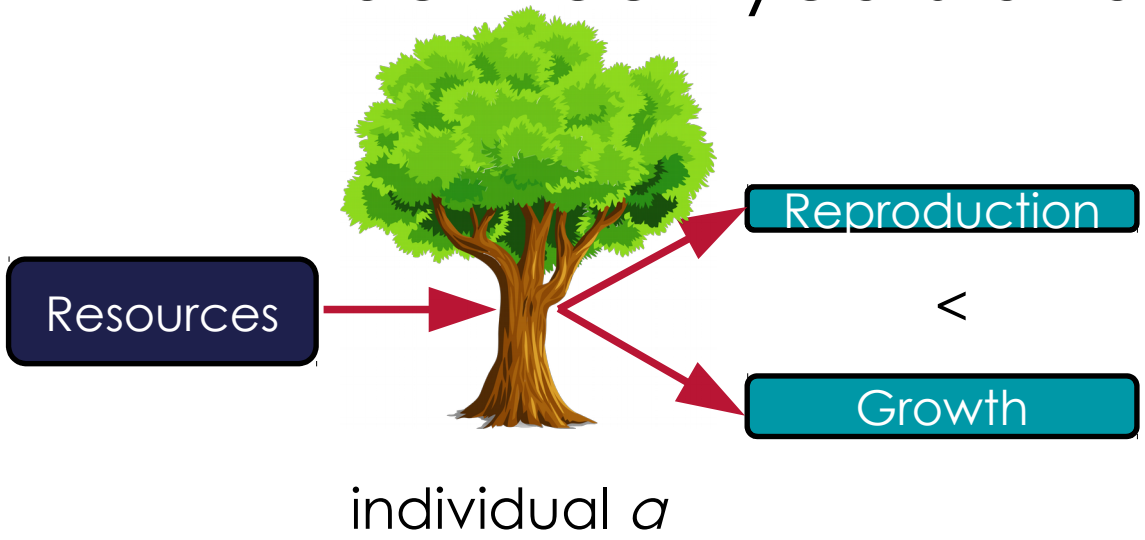




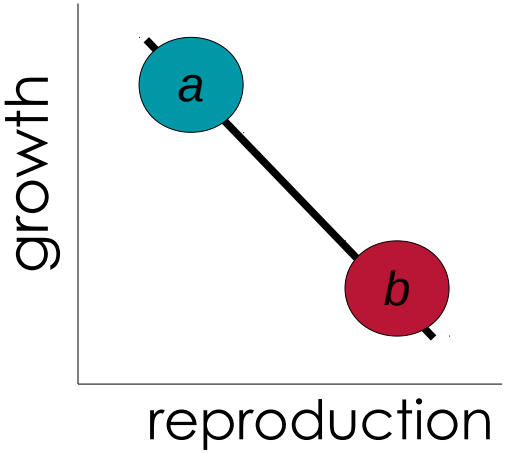
individual *b*

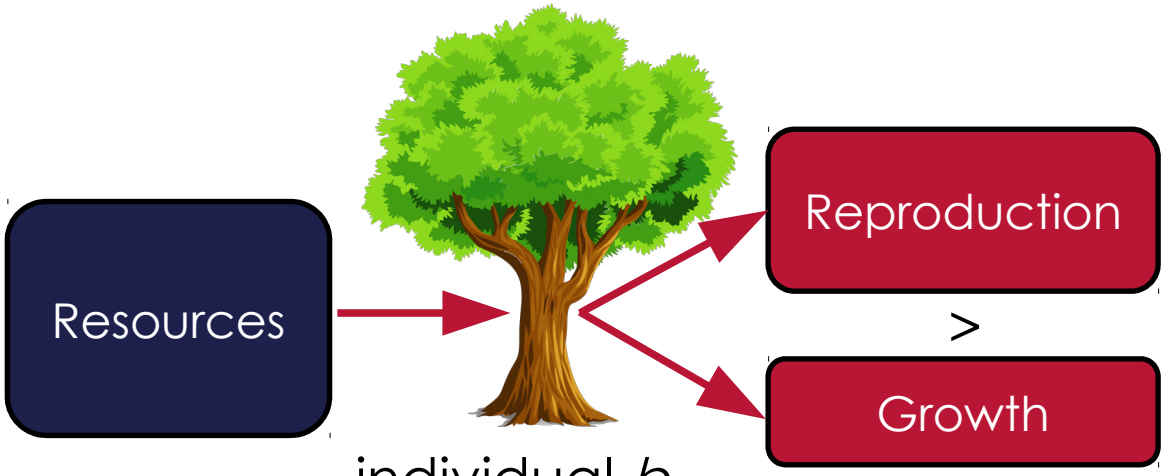
(Reznick, 1985; Reznick et al., 2000; Roff, 2000)

Difficulties to estimate resources … variation between years and individuals



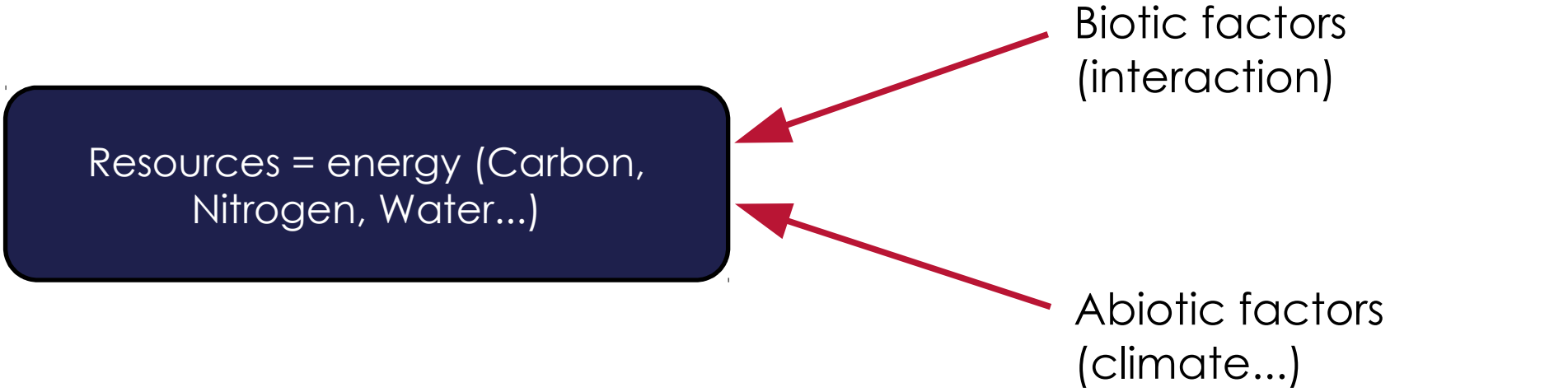
individual *a*





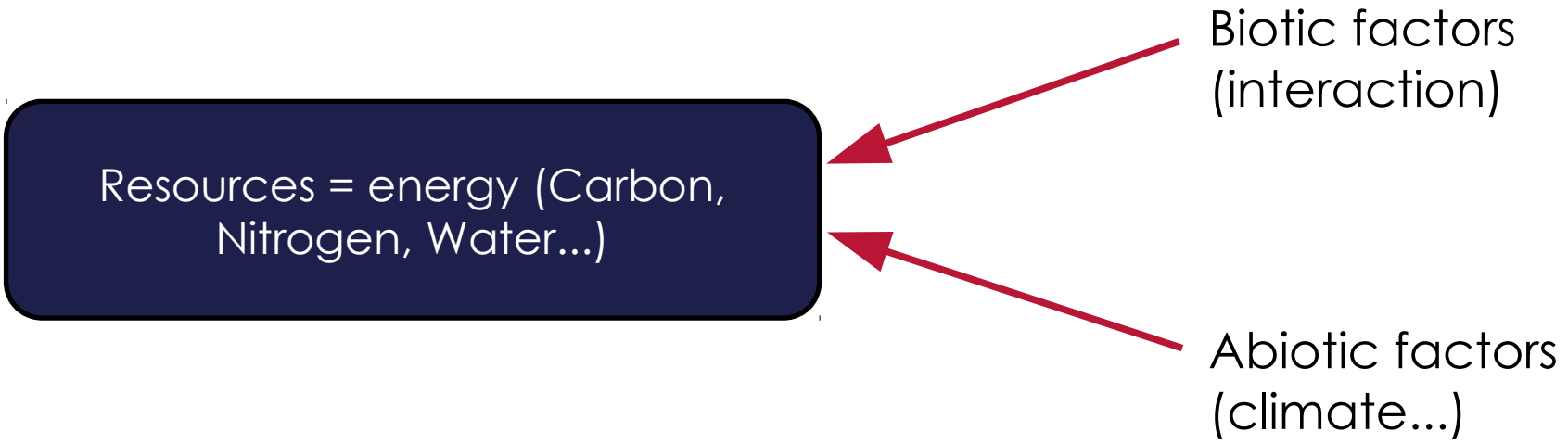
individual *b*

Need to integrate physiology

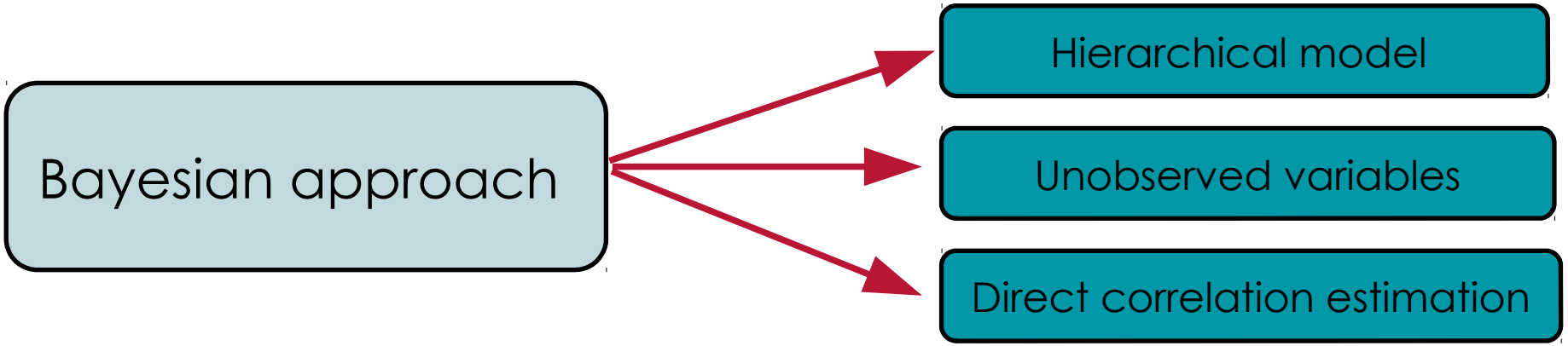


Stearns, 1989; Zera & Harshman, 2001

Context



Stearns, 1989; Zera & Harshman, 2001



Roff & Fairbairn, 2007; Worley et al., 2003

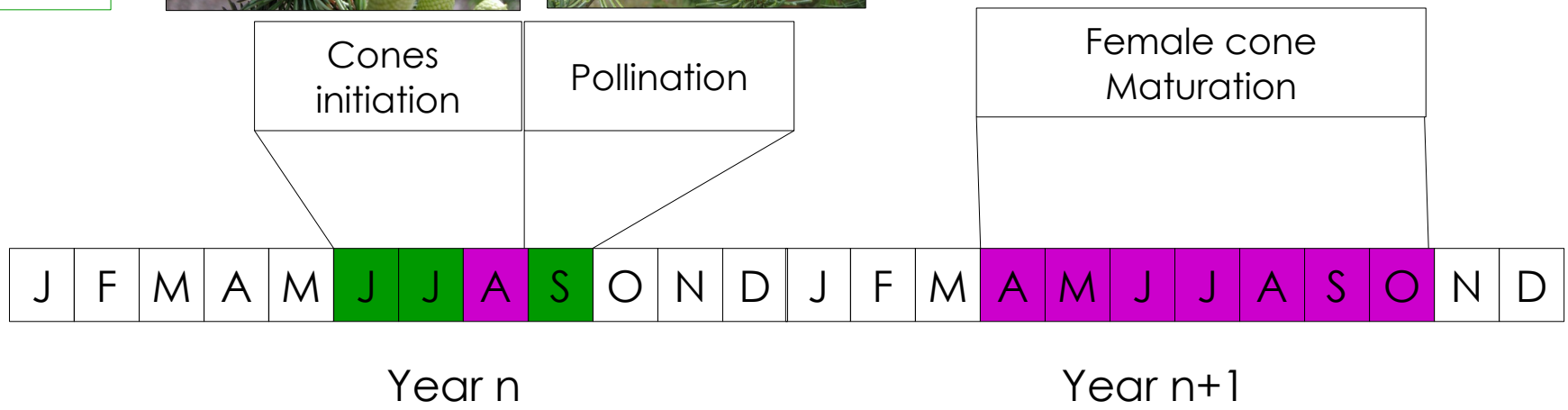
Material and Methods

- The species :
  Cedrus atlantica
- Conifer

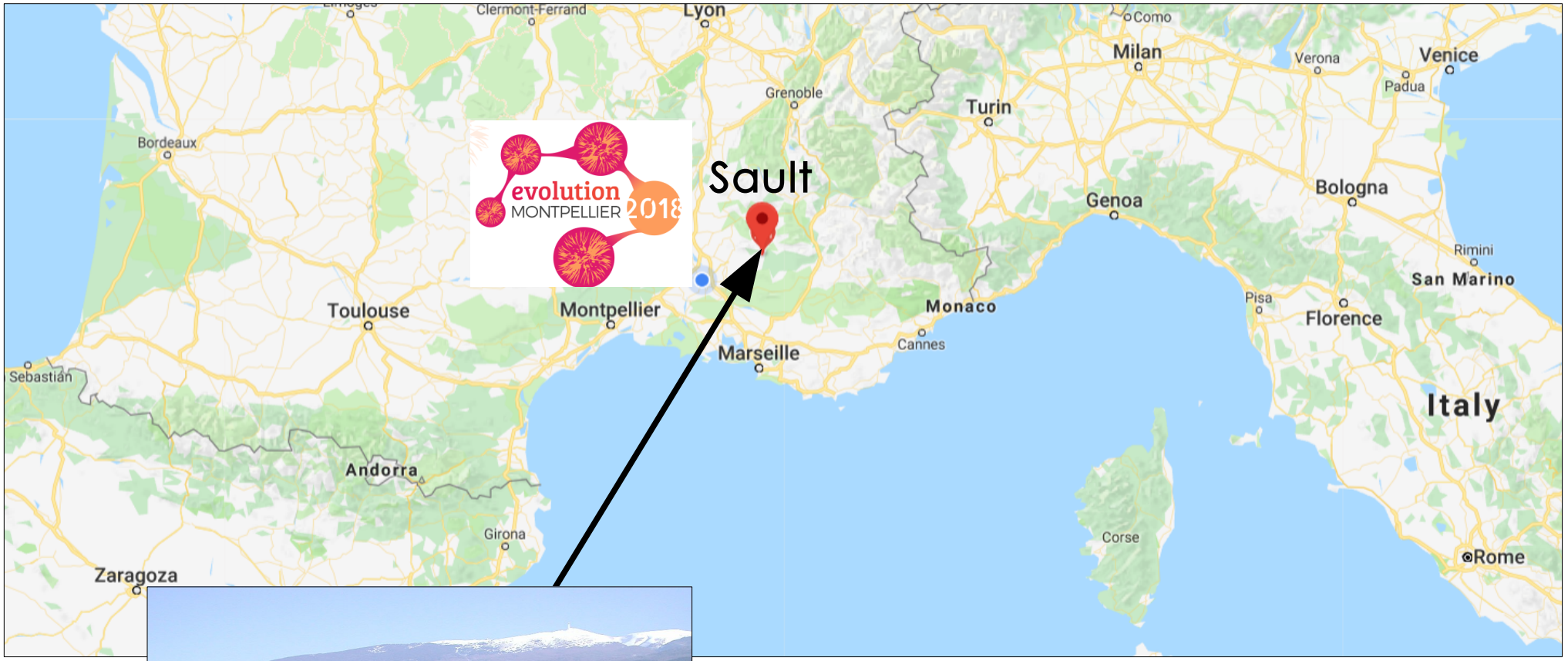
Patterns of resource allocation during reproduction

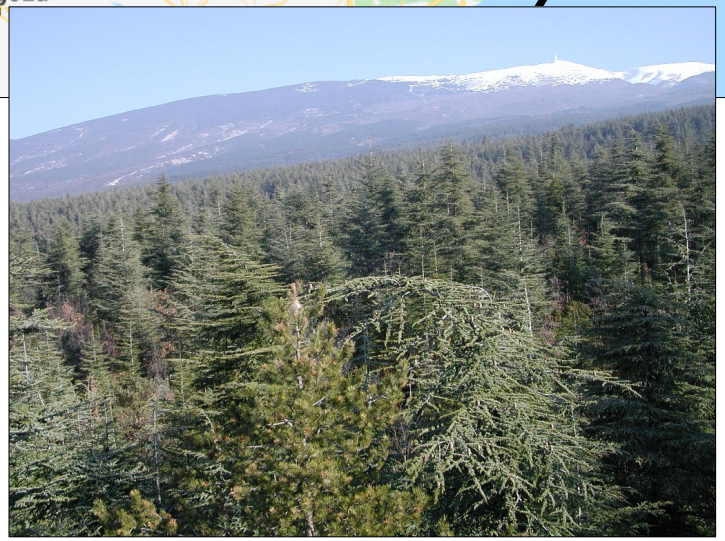
Female reproduction ♀

Male reproduction ♂

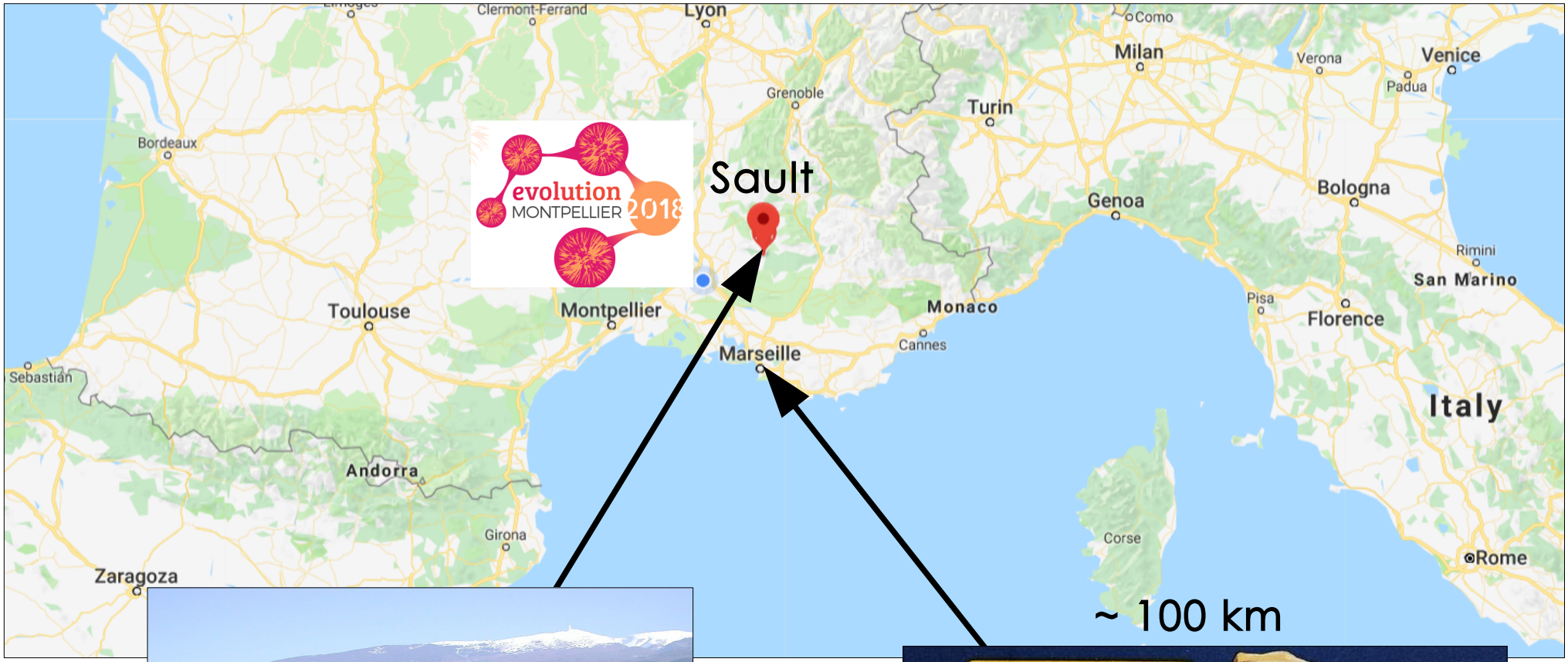


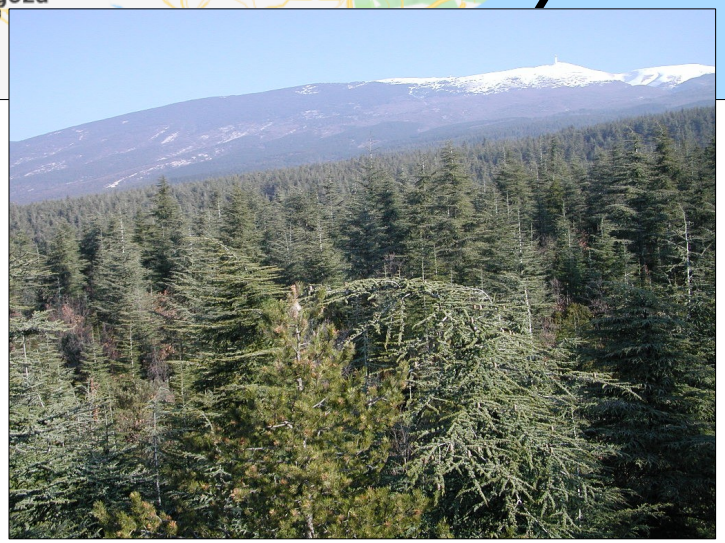
Material and Methods





Material and Methods





~ 100 km

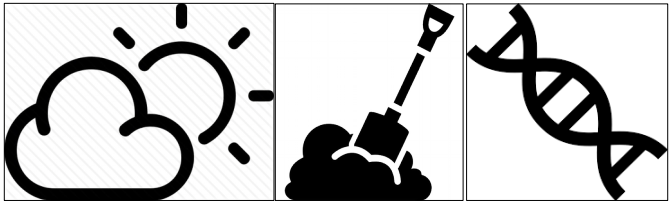
*Boy ! A Marseillaise-style RICARD

Material and Methods

Plantation with two density populations

250 stems/ha = low density

1200 stems/ha = high density



Even aged populations !

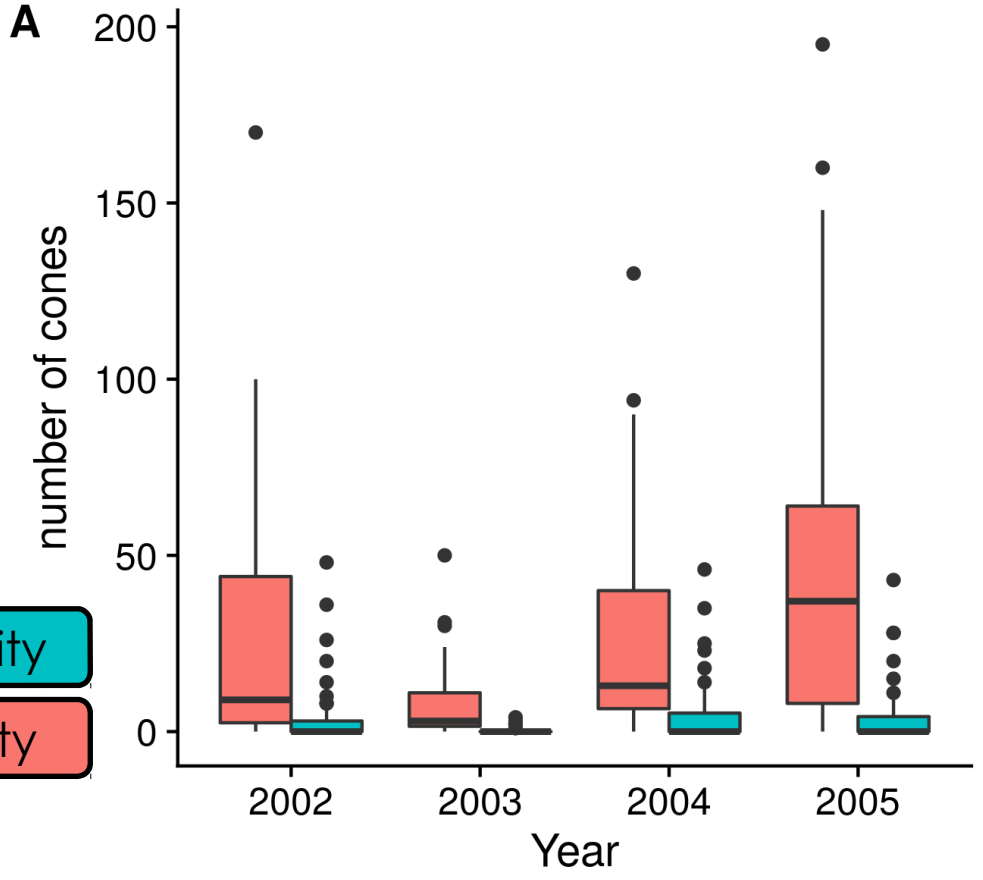
Material and Methods

Observation during 4 years

Female cones quantity

high density

low density



Material and Methods

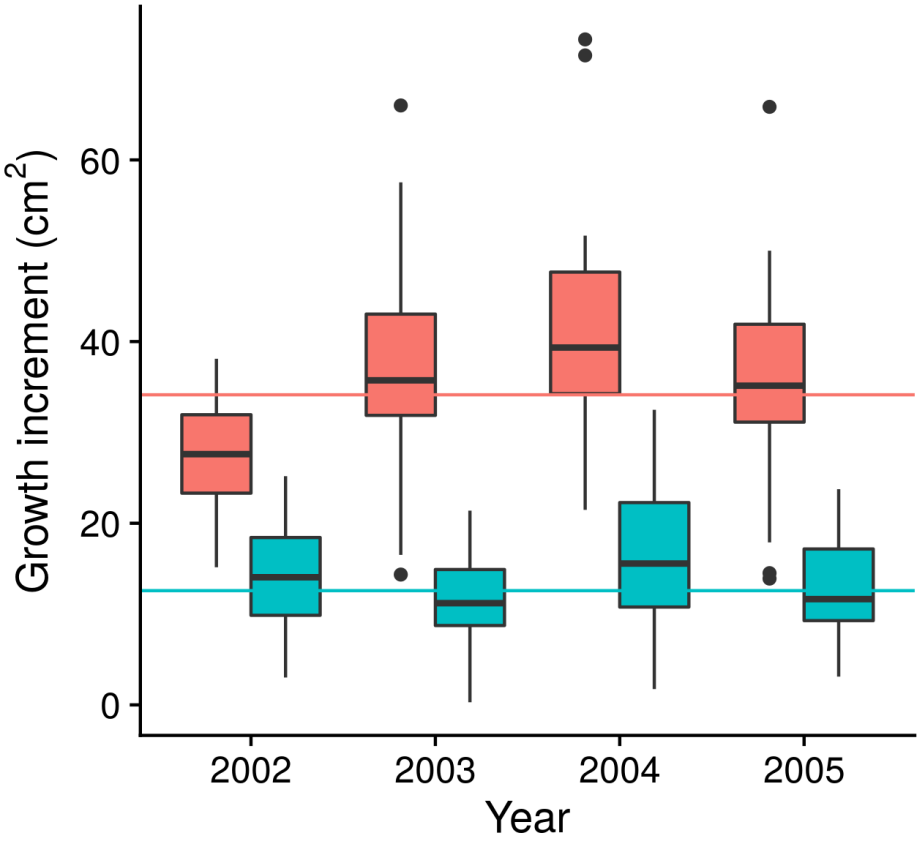
Observation during 4 years

Female cones quantity

Male pollen index

Material and Methods

Observation during 4 years



Growth increment

high density

low density

Material and Methods

Observation during 4 years

Female cones quantity

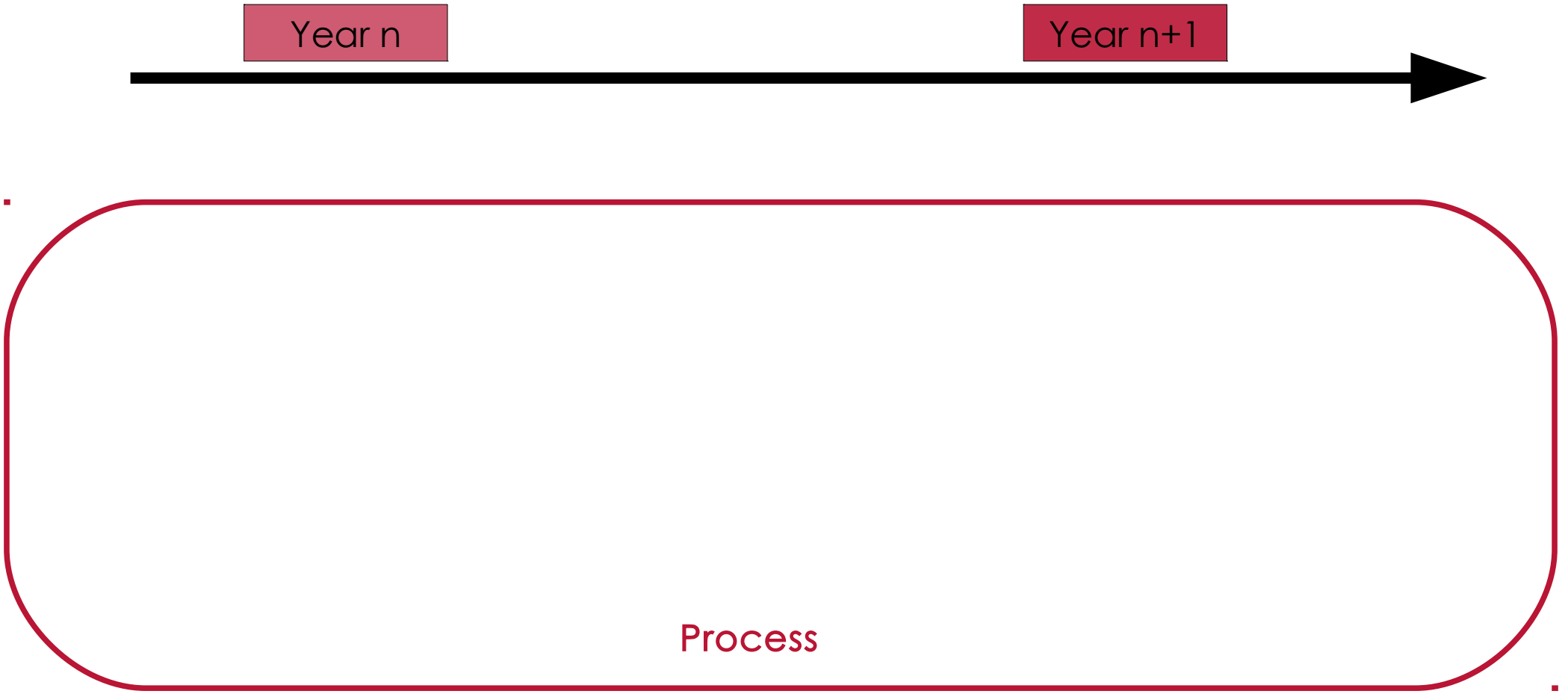
Male pollen index

Growth increment

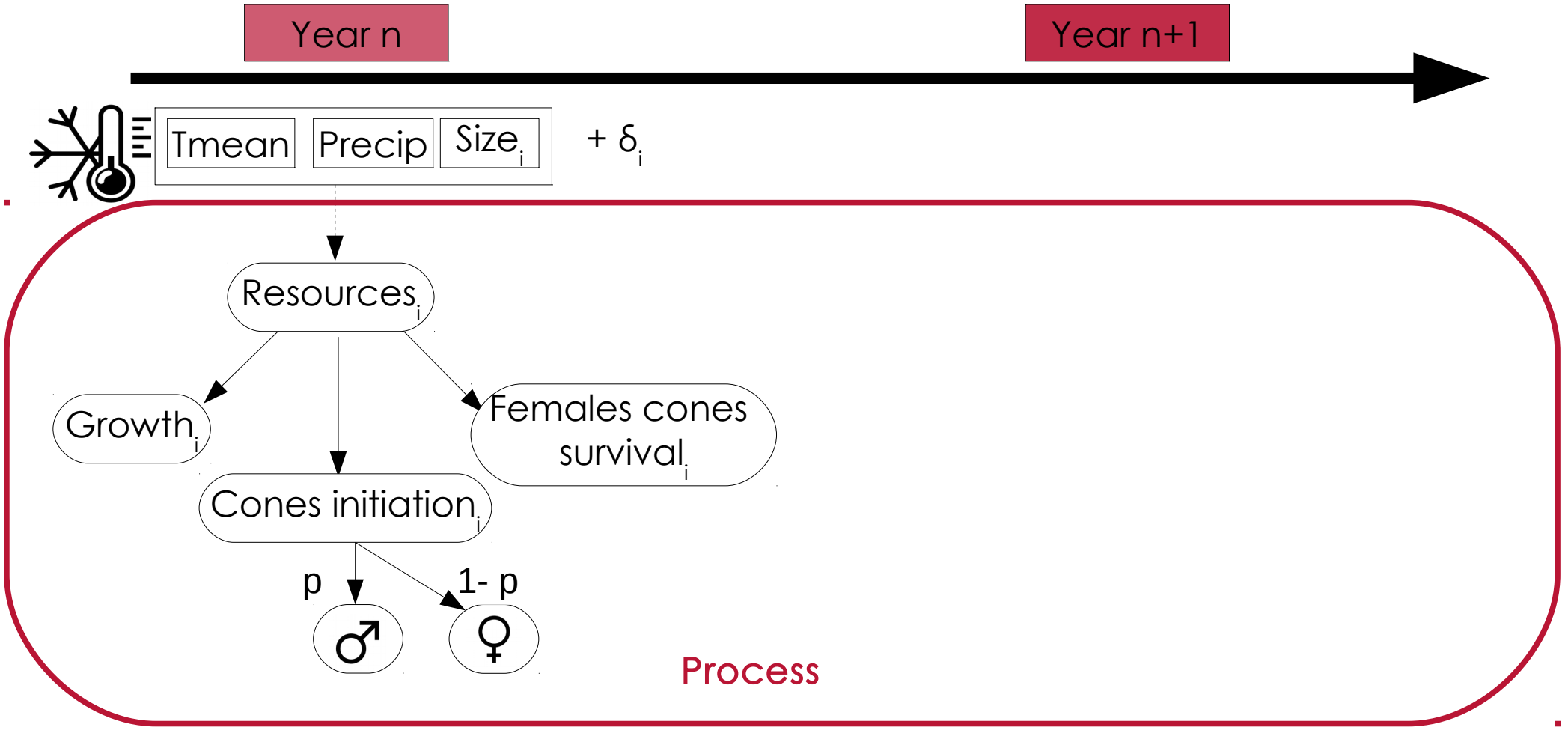
Reproduction

Growth

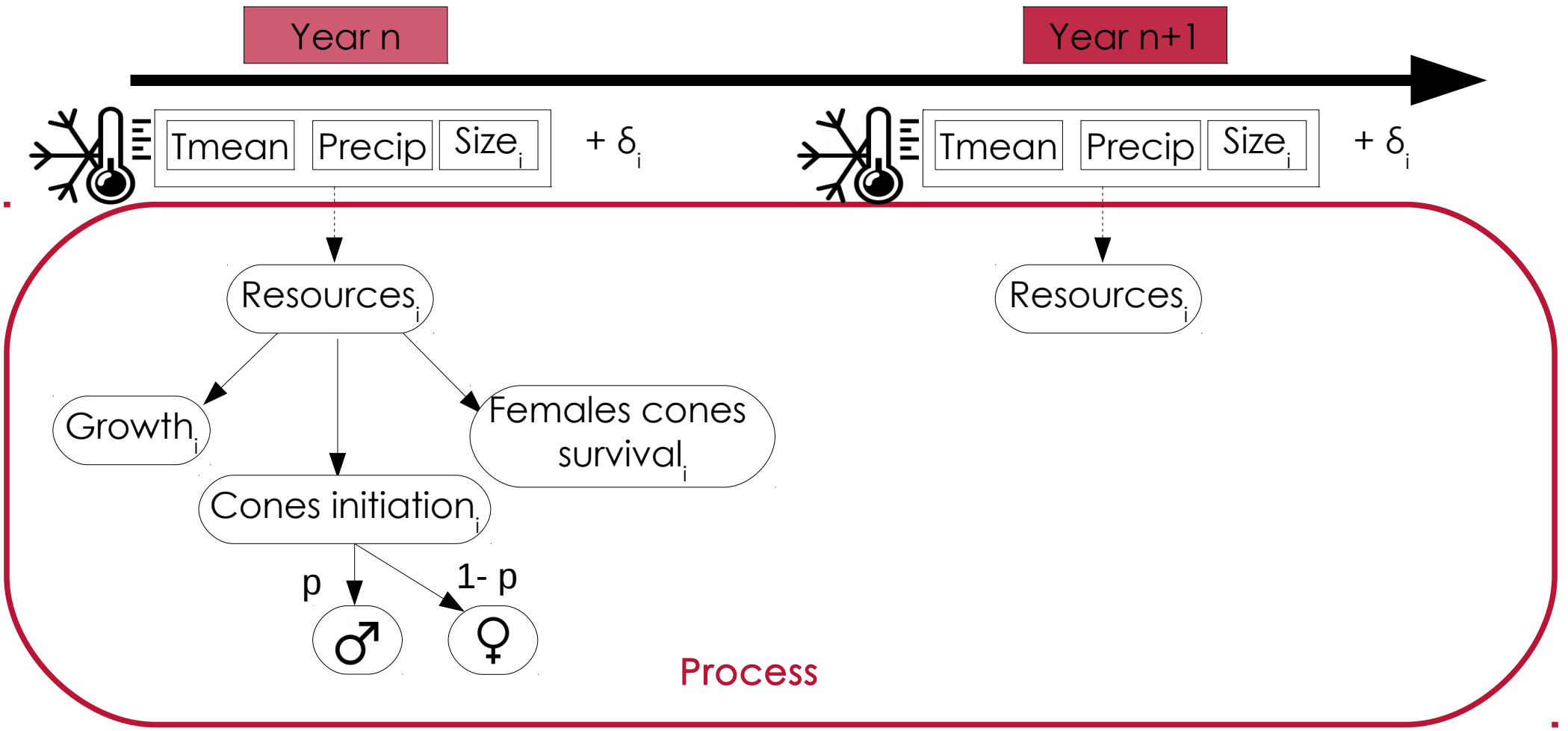
Material and Methods



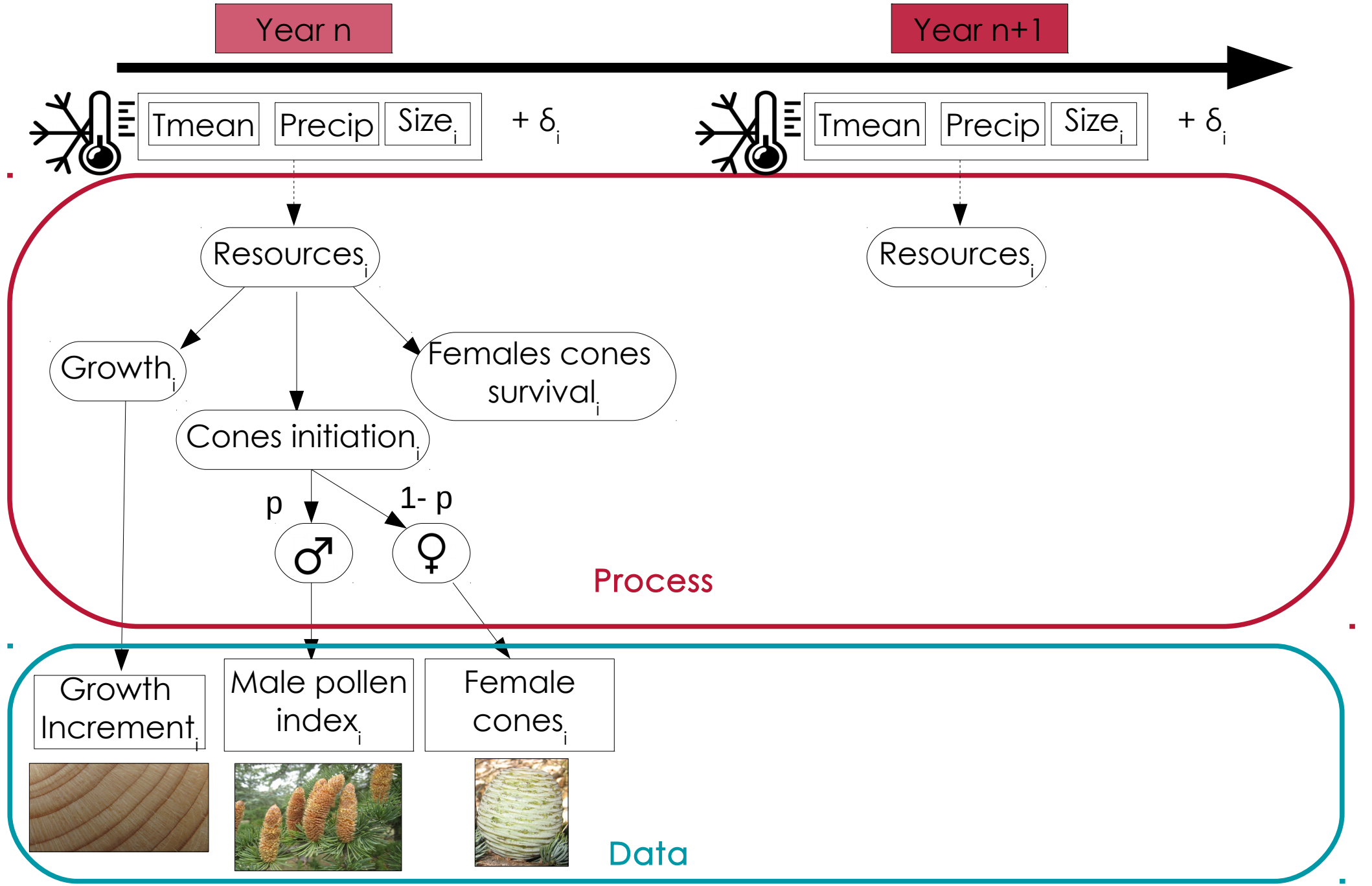
Material and Methods



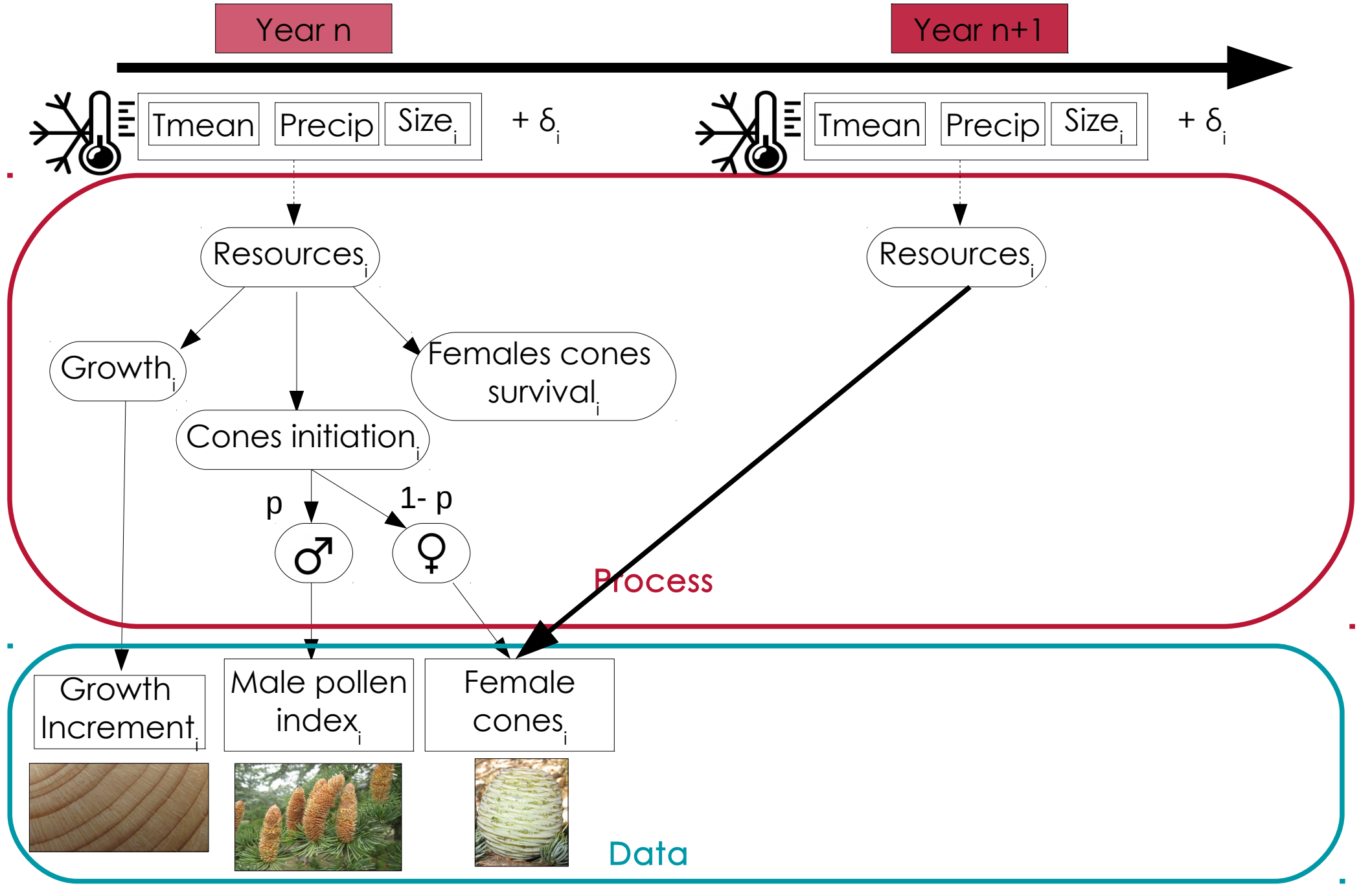
Material and Methods



Material and Methods



Material and Methods



Material and Methods

Allocation of resources to 3 energetic sinks

- $Growth_{i,n} = \gamma * Resources_{i,n} + \varepsilon_{1,i}$
- $Cones\ Initiated_{i,n} = X_{i,n} * (\beta_1 * Resources_{i,n} + \varepsilon_{2,i})$
- $Females\ cones\ survival_{i,n} = \beta_0 + \beta_2 * Resources_{i,n} + \varepsilon_{3,i}$

X: Probability to reproduce

ε: Residual term

Estimation of trade-off

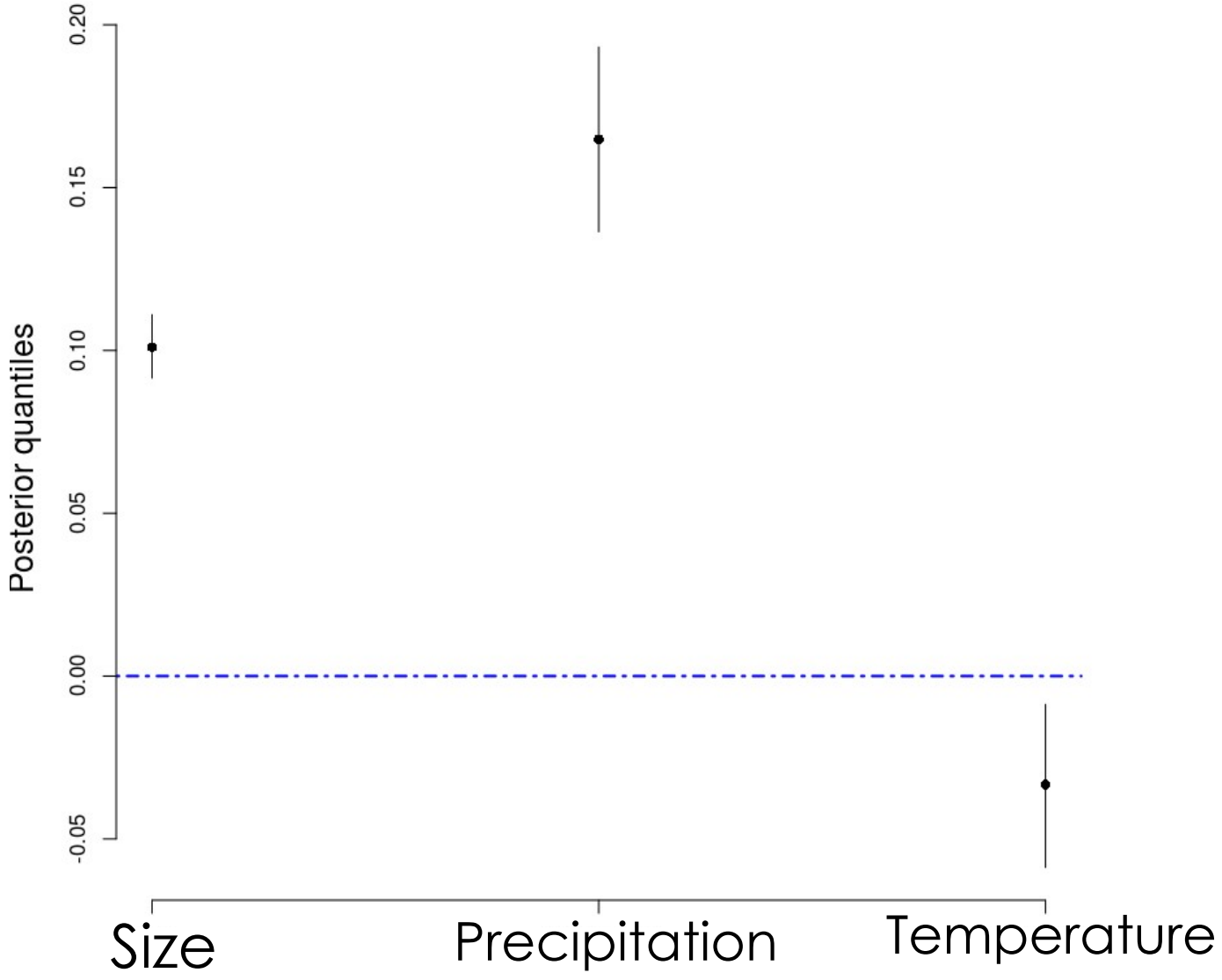
$$\begin{pmatrix} \varepsilon_{1,i} \\ \varepsilon_{2,i} \\ \varepsilon_{3,i} \end{pmatrix} \sim \text{Multivariate Normal } (0, \Sigma)$$

$$\begin{pmatrix} \sigma_{1,1} & \cdots & \cdots \\ \sigma_{1,2} & \sigma_{2,2} & \cdots \\ \sigma_{1,3} & \sigma_{2,3} & \sigma_{3,3} \end{pmatrix}$$

Define correlation coefficient

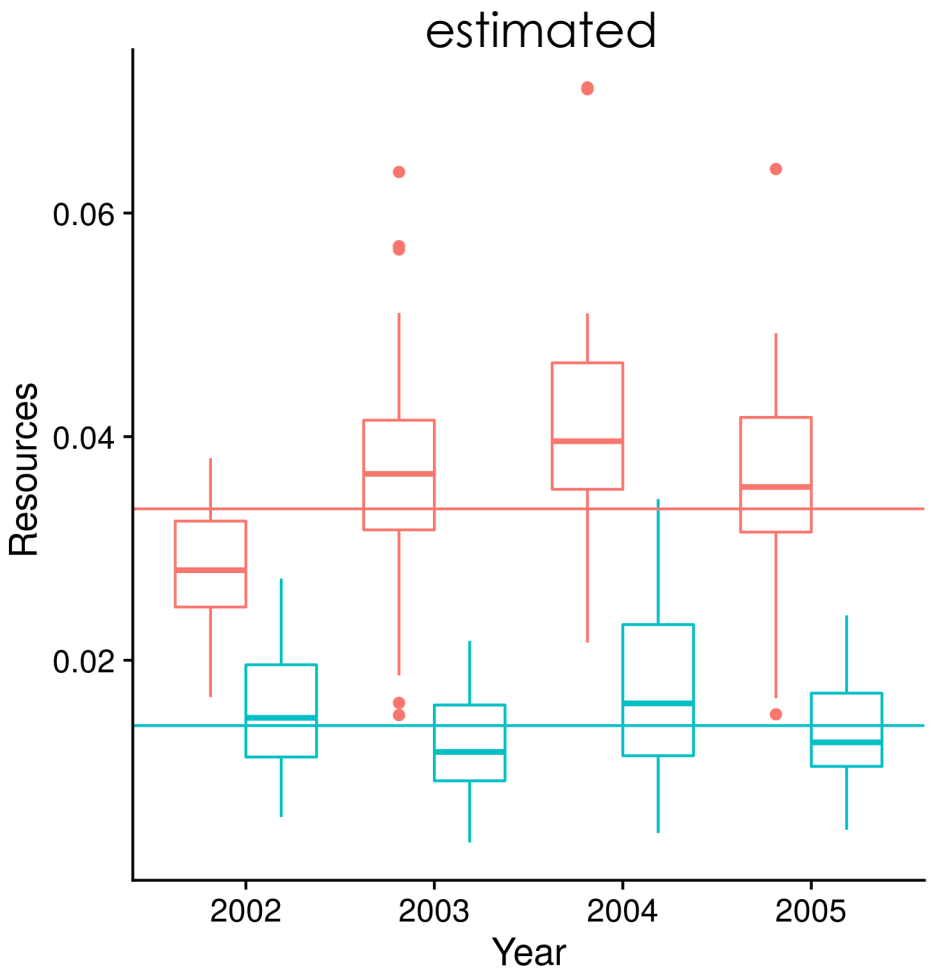
$$\rho_{x,y} = \frac{\sigma_{x,y}}{\sigma_{x,x} * \sigma_{y,x}}$$

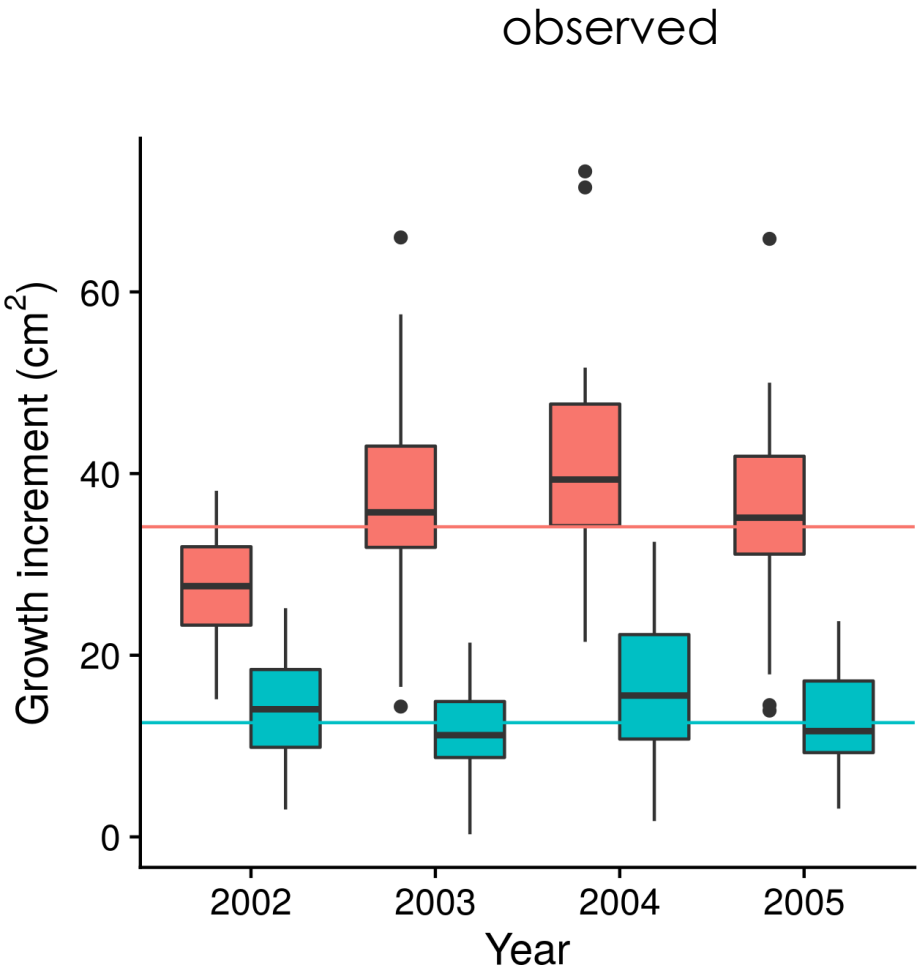
Effects of Climate and Size on resources



Results

Resources vary among years and competition levels



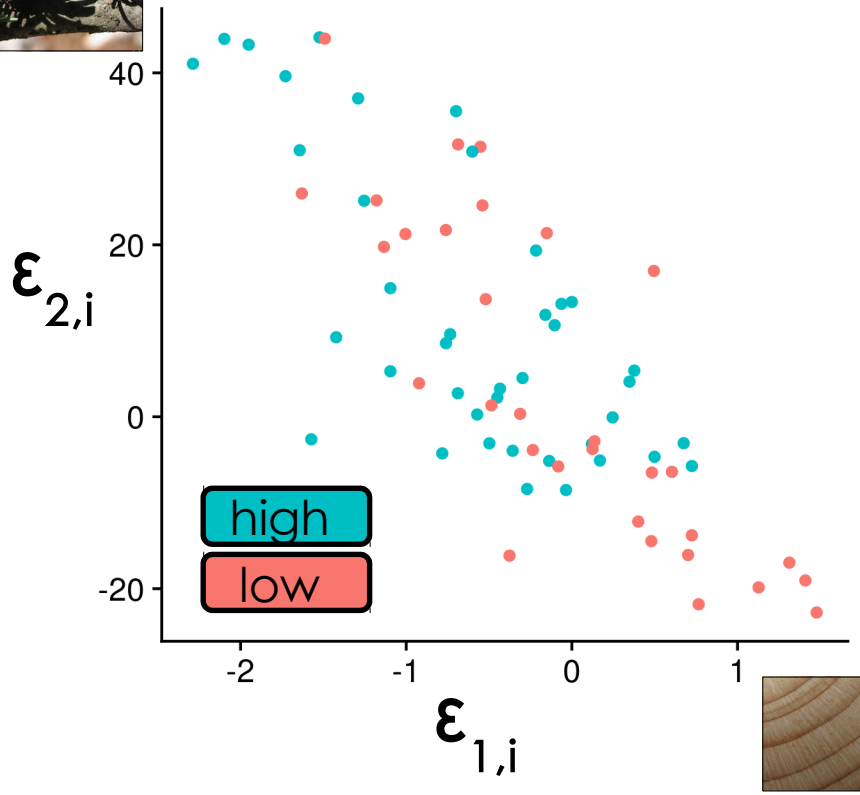


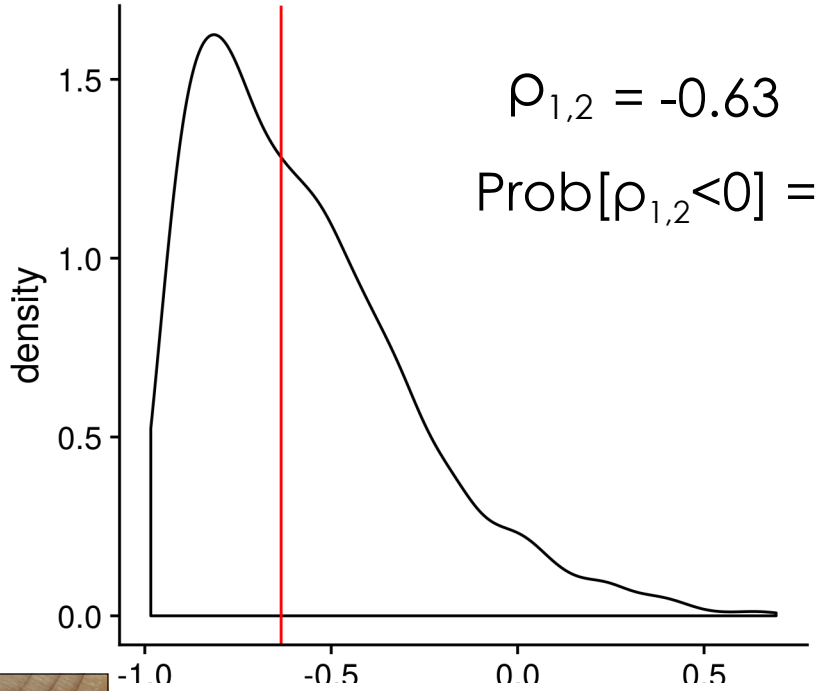
high density

low density

Results

Negative correlation between Growth and Cones initiated

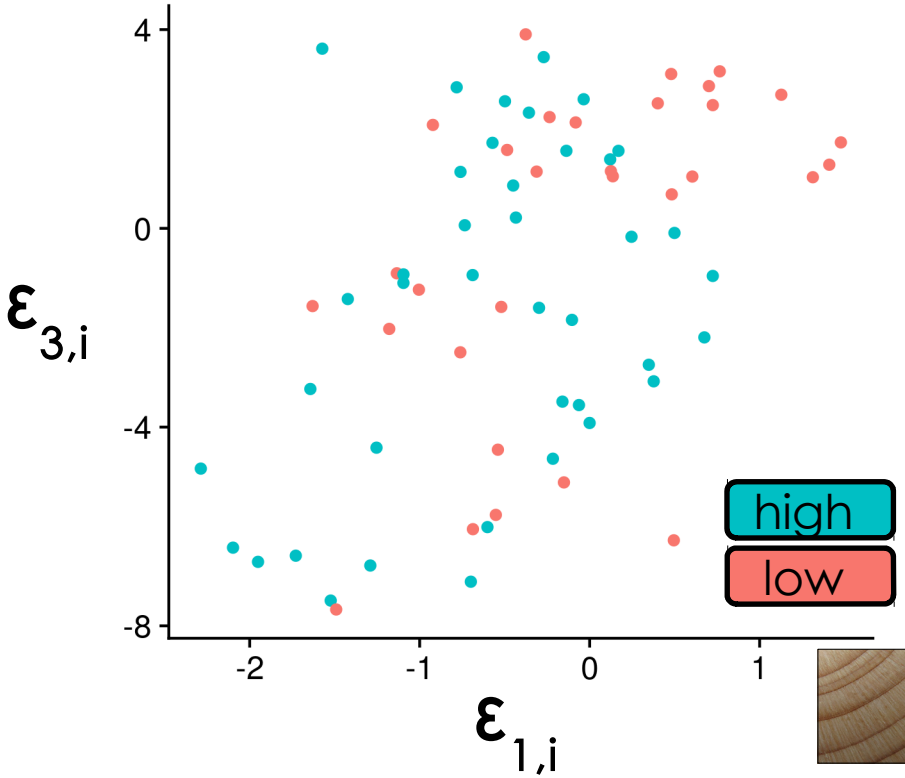


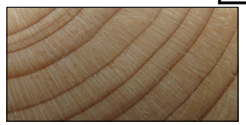


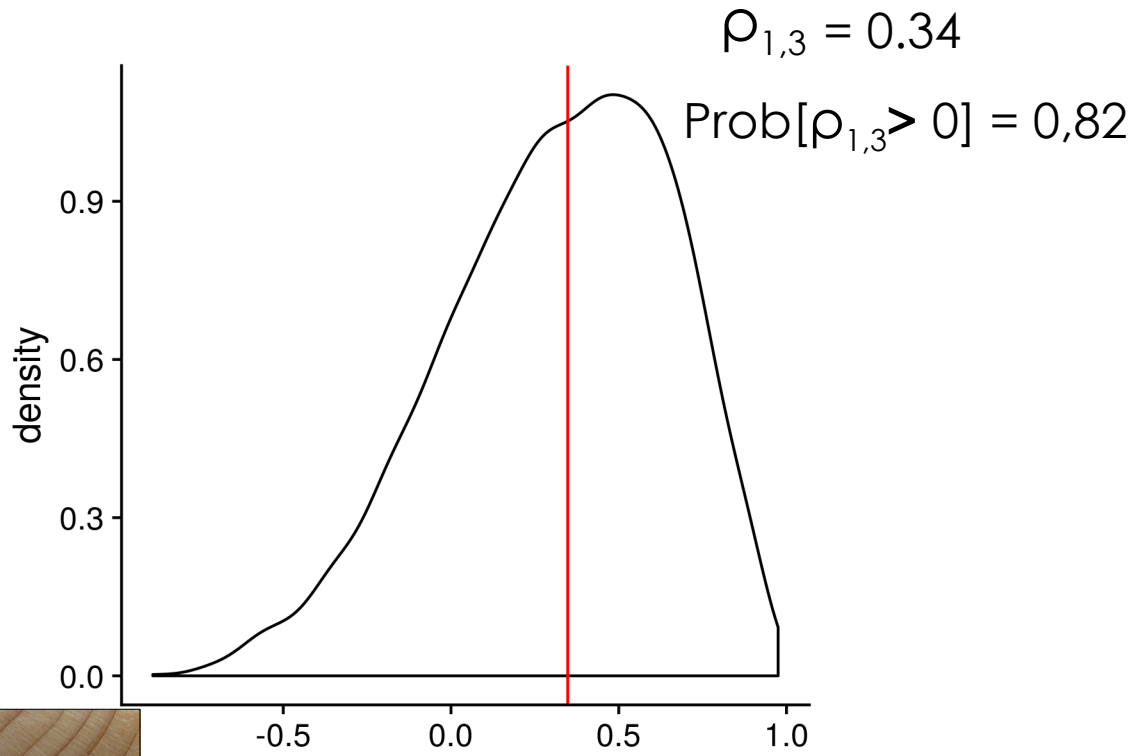
- Growth$_{i,n}$ = γ * Resources$_{i,n}$ + $\varepsilon_{1,i}$
- Cones Initiated$_{i,n}$ = X$_{i,n}$ * (β_1 * Resources$_{i,n}$ + $\varepsilon_{2,i}$)

Results

Positive correlation between Growth and Female cones survival



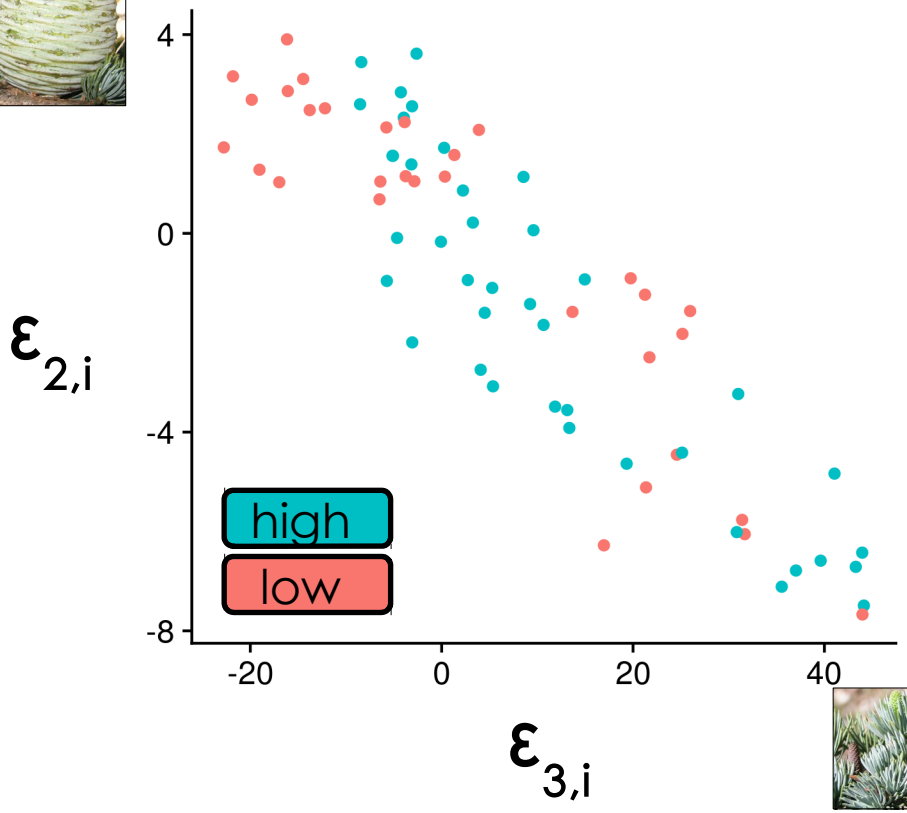


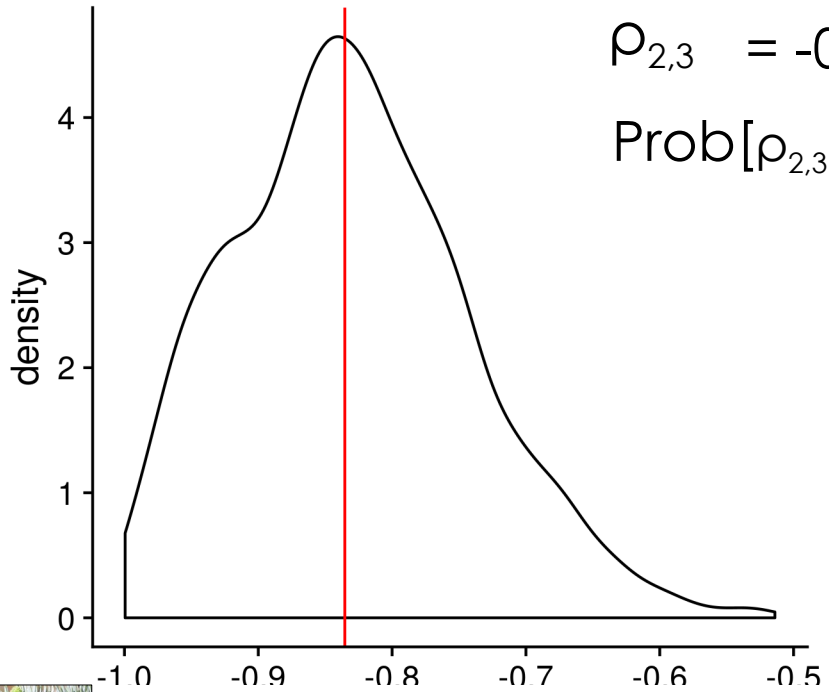


- $Growth_{i,n} = \gamma * Resources_{i,n} + \varepsilon_{1,i}$
- $Females\ cones\ survival_{i,n} = \beta_0 + \beta_2 * Resources_{i,n} + \varepsilon_{3,i}$

Results

Negative correlation between Cones initiated and Female cones survival





$\rho_{2,3} = -0.84$

$Prob[\rho_{2,3} < 0] = 1$

- $Cones\ Initiated_{i,n} = X_{i,n} * (\beta_1 * Resources_{i,n} + \varepsilon_{2,i})$
- $Females\ cones\ survival_{i,n} = \beta_0 + \beta_2 * Resources_{i,n} + \varepsilon_{3,i}$

Discussion

1) Clear trade-off between growth and reproduction at initial stage (**negative** correlation)

2) Positive variation of growth and cone survival (**positive** correlation)

3) Current year of reproduction impact future reproduction (**negative** correlation)

Discussion

1) Clear trade-off between growth and reproduction at initial stage (**negative** correlation)

2) Positive variation of growth and cone survival (**positive** correlation)

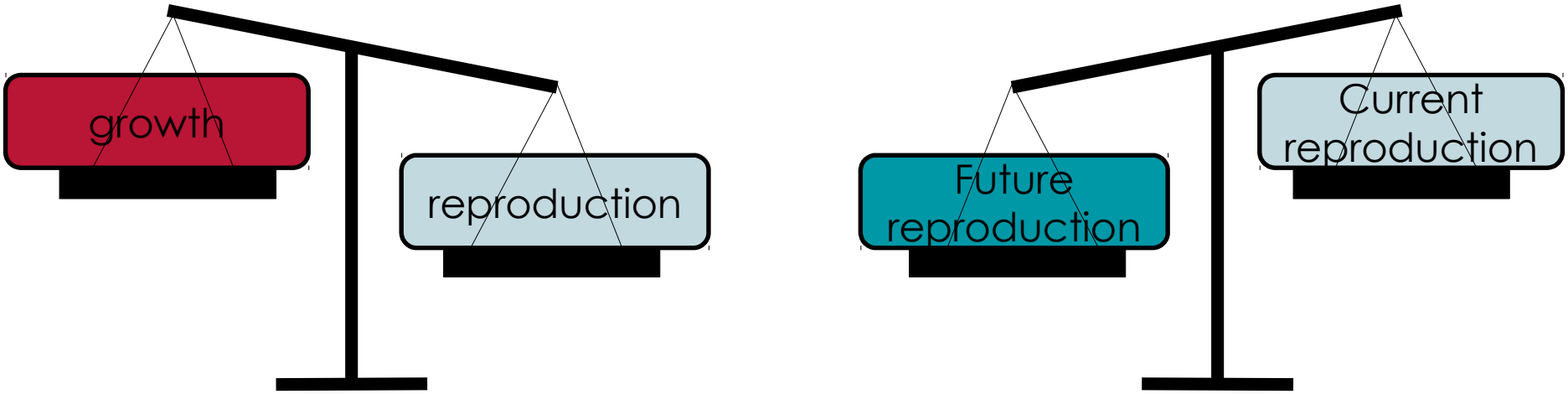
3) Current year of reproduction impact future reproduction (**negative** correlation)

- Same trend for both populations: density did not impact all three relations identified

Discussion

Why trees produces variable quantities of seeds?

Several hypothesis exists (e.g. resource matching, resources switching...) (Kelly & Sork, 2002; Pearse et al, 2016)



Not only one hypothesis

Discussion

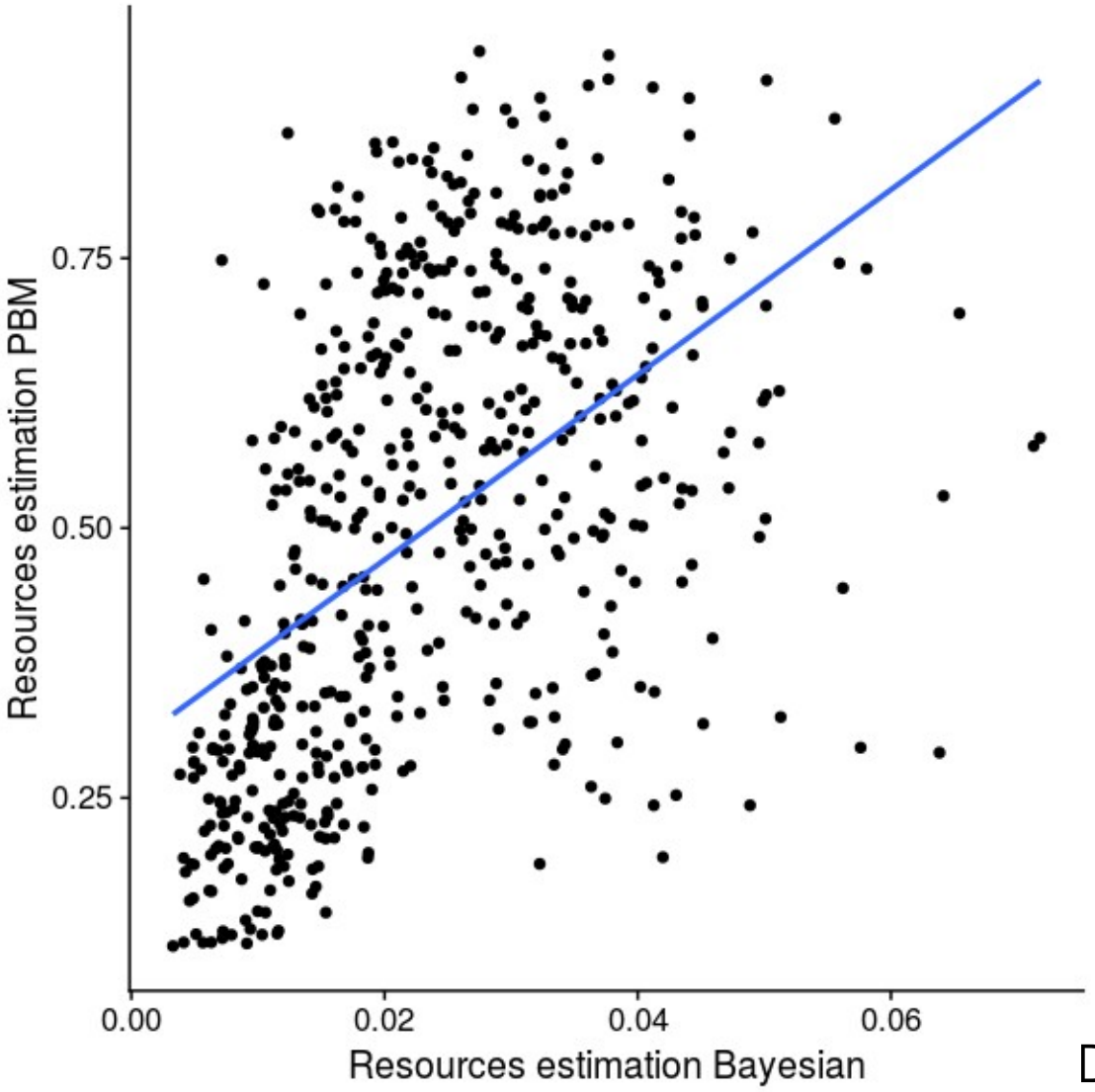
- Evolution is needed to understand ecological phenomenon : Why trees produces variable quantities of seeds ?
- Mechanistic approach for trade-off investigation : a touch of physiology allows a better understanding of evolution

Discussion

Variation of resources : depending of climate, tree size and density

- Growth Increment drives the level of resources
- How to simulate resources?
- Integration of more physiological process?

Comparison of resources estimated with an ecophysiological model



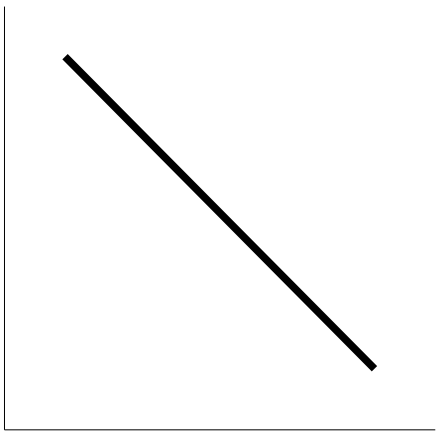
Dufrêne et al., 2005

- We combined **physiology** and **evolution**

- We found evidence for growth-reproduction **trade-offs** in trees

More information ?

Valentin.journe@inra.fr



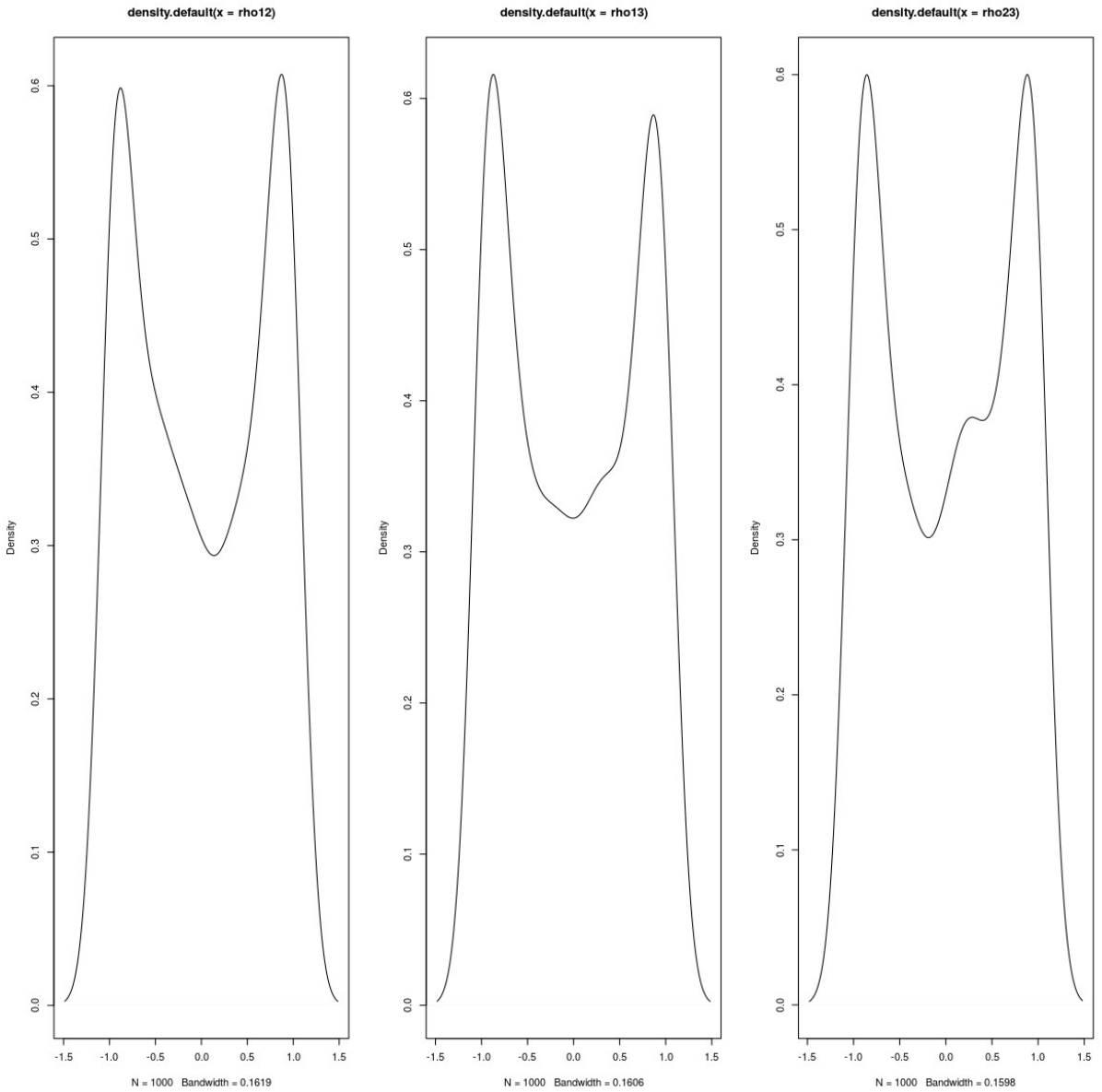
@Valentin_Journe

Supp

- Initialized Males $cones_{i,t}$ = Phenotypic $gender_{i,t}$ * Initialized $cones_{i,t}$
- Notations convert into Multinomial observation

$$\begin{cases} M_{i,t} = 0 \Rightarrow IMC_{i,t}^{\text{obs}} = [1,0,0,0,0] \\ M_{i,t} = 1 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,1,0,0,0] \\ M_{i,t} = 2 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,0,1,0,0] \\ M_{i,t} = 3 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,0,0,1,0] \\ M_{i,t} = 4 \Rightarrow IMC_{i,t}^{\text{obs}} = [0,0,0,0,1] \end{cases}$$

Supp

- Initialized Males $cones_{i,t}$ = Phenotypic $gender_{i,t}$ * Initialized $cones_{i,t}$
- Notations convert into Multinomial observation
- Link Initialized Males cones (observed) to latent variable Initialized Males cones in the process model

Prior for correlation : inverse Wishart