

Assessing the impact of anthropogenic pressures on temperate eels using Genetics & Evolutionary ecology-based model for eels (GenEveel)

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EABX (Aquatic ecosystems and global changes) - Research unit team PMA (diadromus fish)

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1. Introduction

► Spatial patterns in life history traits and geographic attributes of temperate eels at different spatial scales:



European eel (*A. anguilla*)



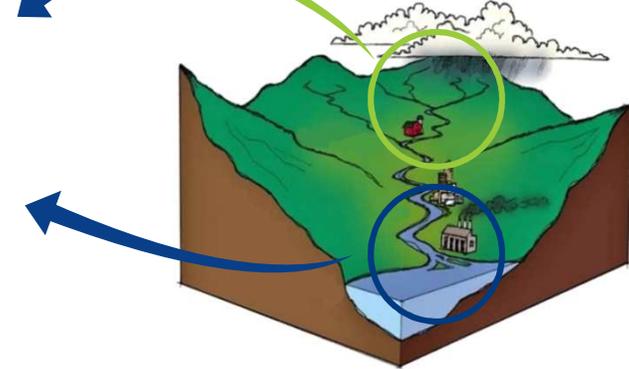
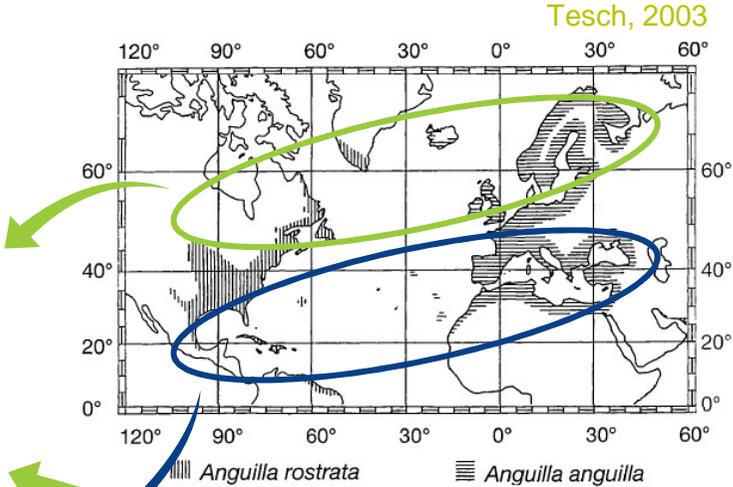
American eel (*A. rostrata*)



Japanese eel (*A. japonica*)

Density ↘↘
 Sex-ratio ♀♀
 Growth rate ↘↘
 Length-at-silvering ↗↗

Density ↗↗
 Sex-ratio ♂♂
 Growth rate ↗↗
 Length-at-silvering ↘↘



1. Introduction

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European eel (*A. anguilla*)



American eel (*A. rostrata*)

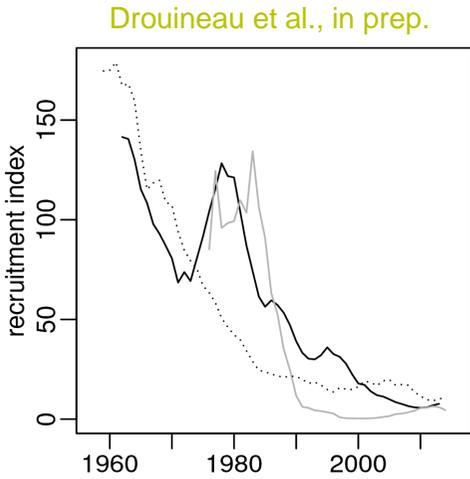


Japanese eel (*A. japonica*)

■ Troublesome for population dynamics models

- Density ↘↘
- Sex-ratio ♀♀
- Growth rate ↘↘
- Length-at-silvering ↗↗

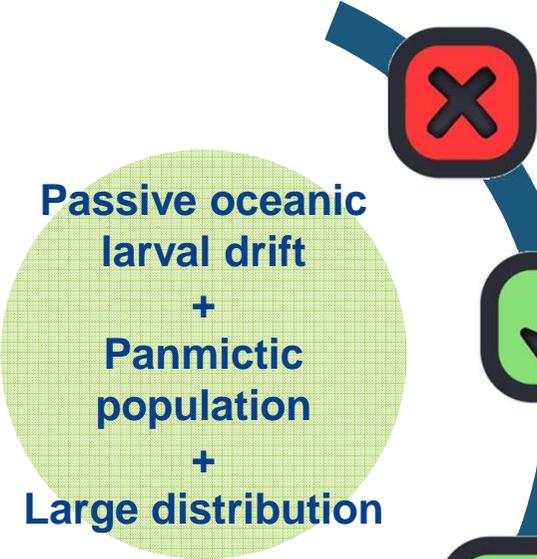
- Density ↗↗
- Sex-ratio ♂♂
- Growth rate ↗↗
- Length-at-silvering ↘↘



■ Need to understand the origin of phenotypic variability to quantify the impact of anthropogenic pressures

1. Introduction

► Adaptation mechanisms to cope with environmental heterogeneity:



Passive oceanic larval drift
+
Panmictic population
+
Large distribution

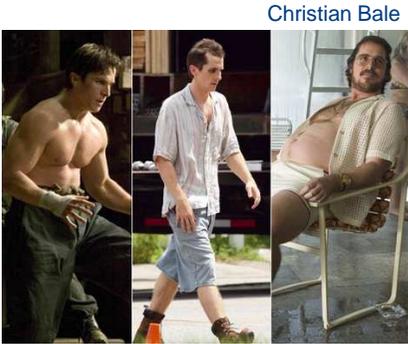
Als et al., 2011
Bonhommeau et al., 2010
Kettle & Haines, 2006
Palm et al., 2000



Local adaptation: measures the match between adaptive genetic variation and environmental variation.



Phenotypic plasticity:
Different phenotypes expressed by a single genotype in different environments.

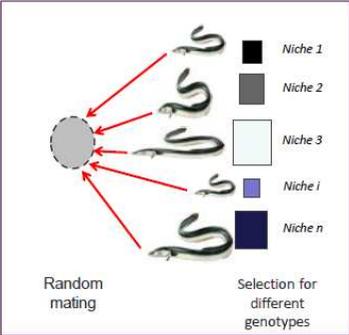
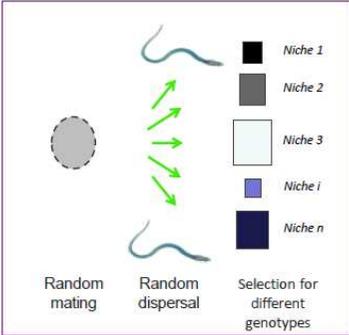


Christian Bale



Spatially varying selection:
Local selection acting on genetic polymorphism reshuffled every generation.

Bernatchez, 2013



Daverat et al., 2006; Davey & Jallyman, 2005; Drouineau et al., 2014; Edelyne, 2007; Geffroy & Bardonnnet, 2012; Vollestad, 1992; Boivin et al., 2015; Côté et al., 2009; 2014; 2015; Gagnaire et al., 2012; Pavey et al., 2015; Pujolar et al., 2014; Ulrik et al., 2014

1. Introduction

- ▶ Are phenotypic plasticity and genetic polymorphism adaptive responses to variable environment?
- ▶ How these adaptive responses affect the impact of anthropogenic pressures on population dynamics?



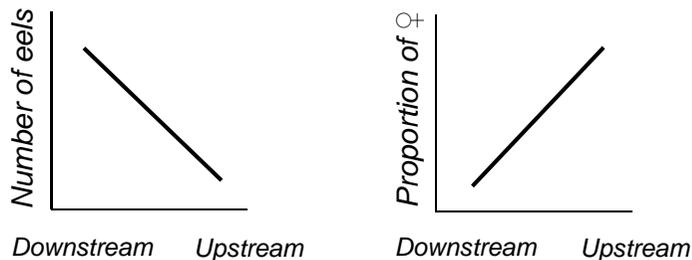
GenEveel

- Prediction of emergent life history spatial patterns:
 - Length-at-silvering
 - Sex-ratio
 - Growth habitat
 } At river catchment scale
 
- Depending on :
 - Adaptive mechanisms: Phenotypic plasticity and habitat selection maintained by genetic polymorphism
 - Environmental heterogeneity

2. GenEveel: an individual-based optimization model

► Applying **pattern-oriented modelling approach**:

(Grimm and Railsback, 2012)



	Downstream	Upstream
	↗↗	↘↘
Density		
	♂♂	♀♀
Sex-ratio		
	↘↘	↗↗
Length-at-silvering		
	↗↗	↘↘
Growth rate		
	↗↗	↘↘
Ratio of fast growing genotype		

► **Assumptions of the model:**

Geographic variations in growth ⇒ **Genetic basis**

Two types of individuals:

- Fast-growing individuals
- Slow-growing individuals

Intra-specific competition for resources ⇒ **density-dependent negative effect**

Natural mortality rate varies with **density**

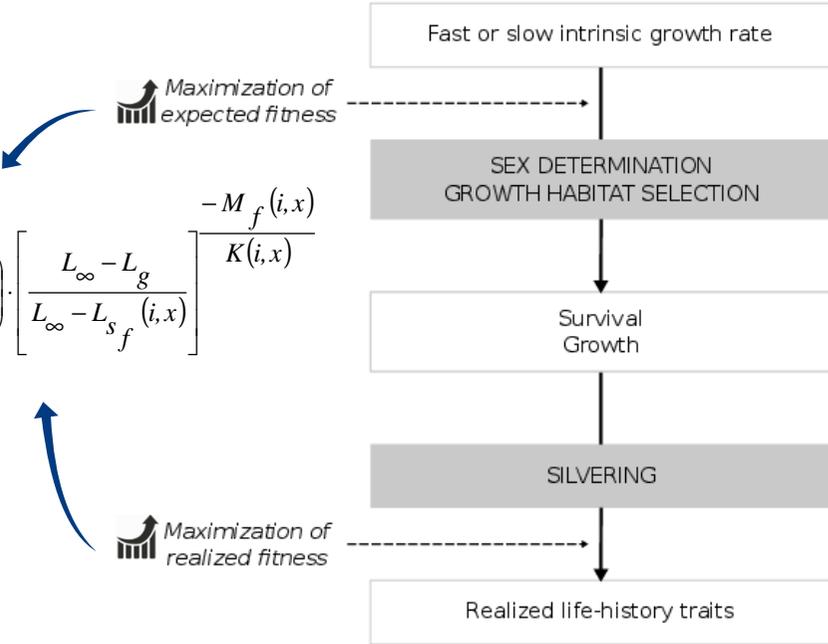


2. GenEveel: an individual-based optimization model

► Flowchart representing the fish biological pathway:

$$\pi_m(i,x) = fertility \cdot \left[\frac{L_\infty - L_g}{L_\infty - L_{s_m}(i,x)} \right] \cdot \frac{-M_m(i,x)}{K(i,x)}$$

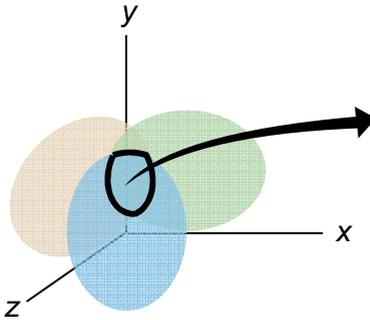
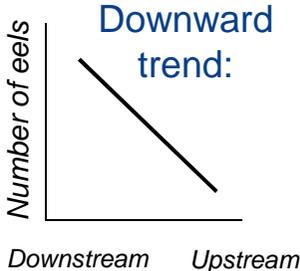
$$\pi_f(i,x) = fecundity(L_{s_f}(i,x)) \cdot \left[\frac{L_\infty - L_g}{L_\infty - L_{s_f}(i,x)} \right] \cdot \frac{-M_f(i,x)}{K(i,x)}$$



► Validation of spatial patterns:

🖨️ Test Mann-Kendall

Downstream		Upstream
↗↗	Density	↘↘
♂♂	Sex-ratio	♀♀
↘↘	Length-at-silvering	↗↗
↗↗	Growth rate	↘↘
↗↗	Ratio of fast growing genotype	↘↘



Combination of parameter values leading to reproduce the spatial patterns

► Exploration of the uncertainty and the model parameter space:

2. GenEveel: an individual-based optimization model

- ▶ All spatial patterns are mimicked in the reference simulation:

Downstream		Upstream	GenEveel
↗↗	Density	↘↘	✓
♂♂	Sex-ratio	♀♀	✓
↘↘	Length-at-silvering	↗↗	✓
↗↗	Growth rate	↘↘	✓
↗↗	Ratio of fast growing genotype	↘↘	✓

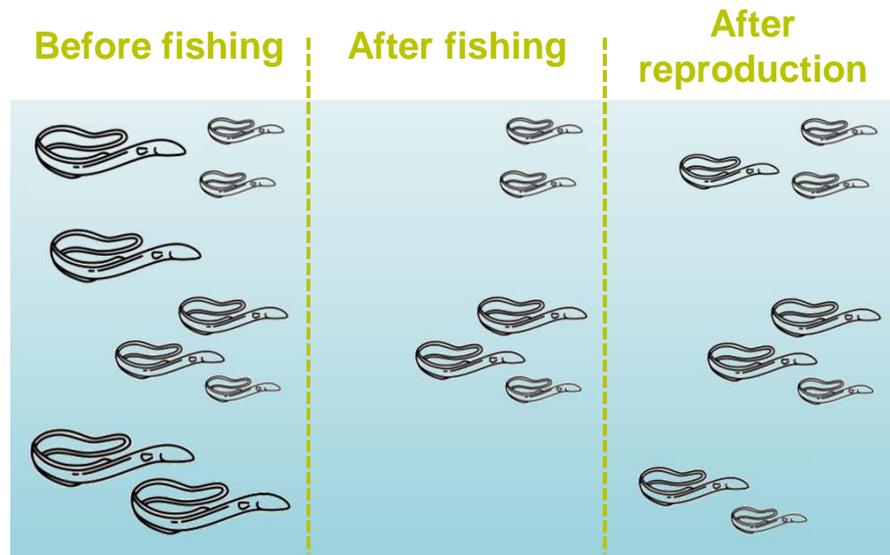
- ▶ Model exploration: patterns are mimicked when slow growers and females are not too penalized with respect fast growers and males



Phenotypic plasticity and **genotype-dependent habitat selection** maintained by **genetic polymorphism** may be **adaptive mechanisms** to deal with environmental heterogeneity (Mateo et al., 2016)

3. Impacts of anthropogenic pressures

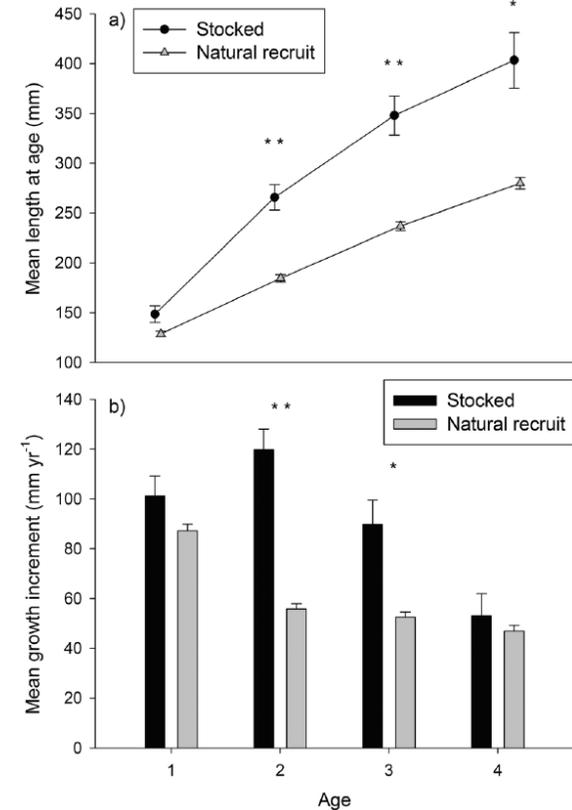
- ▶ Understanding how eels deal with occupying heterogeneous environments is key for management and conservation:



Fisheries induced evolution (Dieckmann, 2009; Bevacqua, 2012)

- For predicting how species can respond to either natural or anthropogenic changes

Stacey et al., 2015

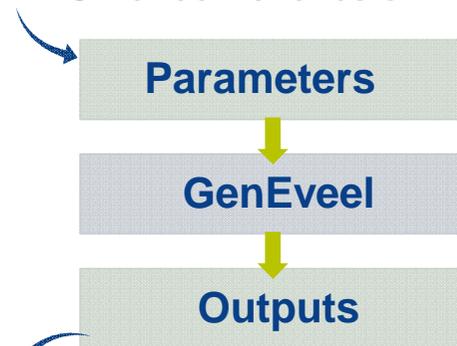


- For a better understanding of how to design conservation strategies to preserve genetic diversity (including translocation practices)

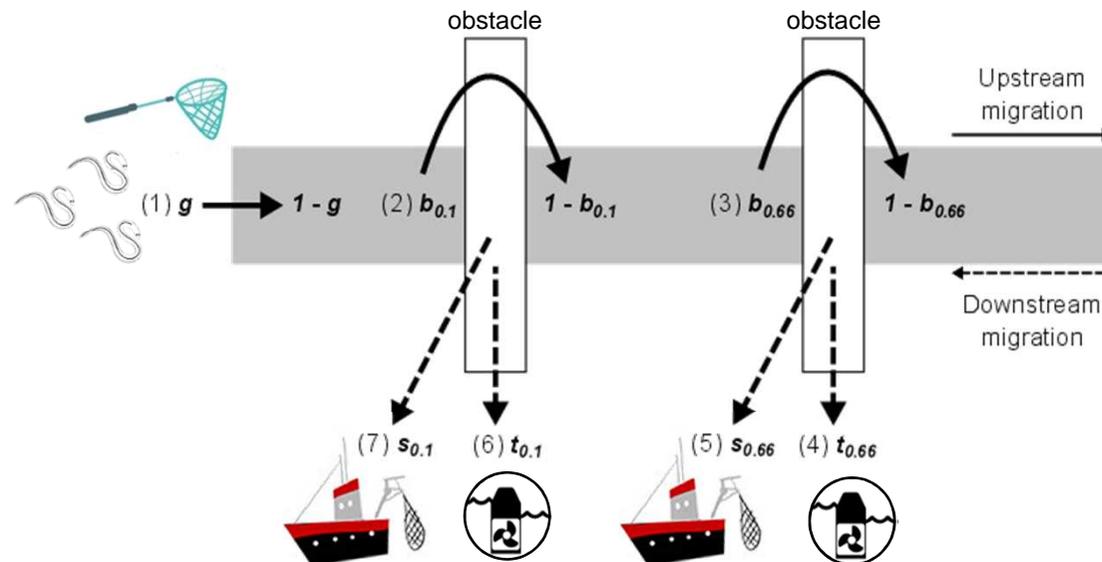
3. Impacts of anthropogenic pressures

- ▶ Explore the impacts of different anthropogenic pressures on population dynamics:

- Glass eel fishery g
- Obstacles to upstream migration b
- Turbines mortality t
- Silver eel fisheries s



- The number of escapees
- Mean length-at-silvering
- Proportion of females
- Egg production
- Proportion of slow growers



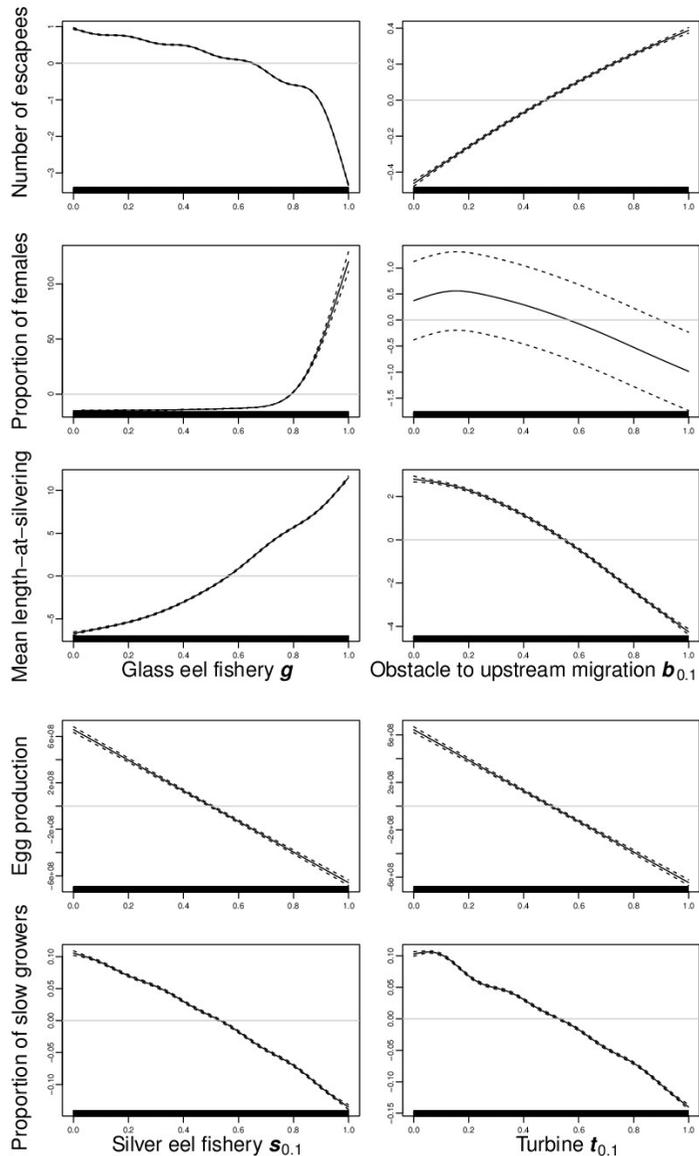
- ▶ Numerical exploration of the model and results analysis

🖨️ **Sensitivity analysis:**
exploration of the model input parameter space

🖨️ **Generalized Additive Models (GAMs):**

$$Y \sim s(g) + s(s_{0.1}) + s(s_{0.66}) + s(b_{0.1}) + s(b_{0.66}) + s(t_{0.1}) + s(t_{0.66})$$

3. Impacts of anthropogenic pressures



Greatest influence on:
Number of escapees
Proportion of females
Mean length-at-silvering

Negative effects on:
Egg production
Proportion of slow growers

Glass eel fishery g

↘↘ escapees
 ↓
 ↗↗ females

Migratory obstacle $b_{0.1}$

↘↘ females
 ↓
 ↗↗ escapees

Silver eel fishery $s_{0.1}$

↘↘ eggs
 ↓
 ⊗

Turbine $t_{0.1}$

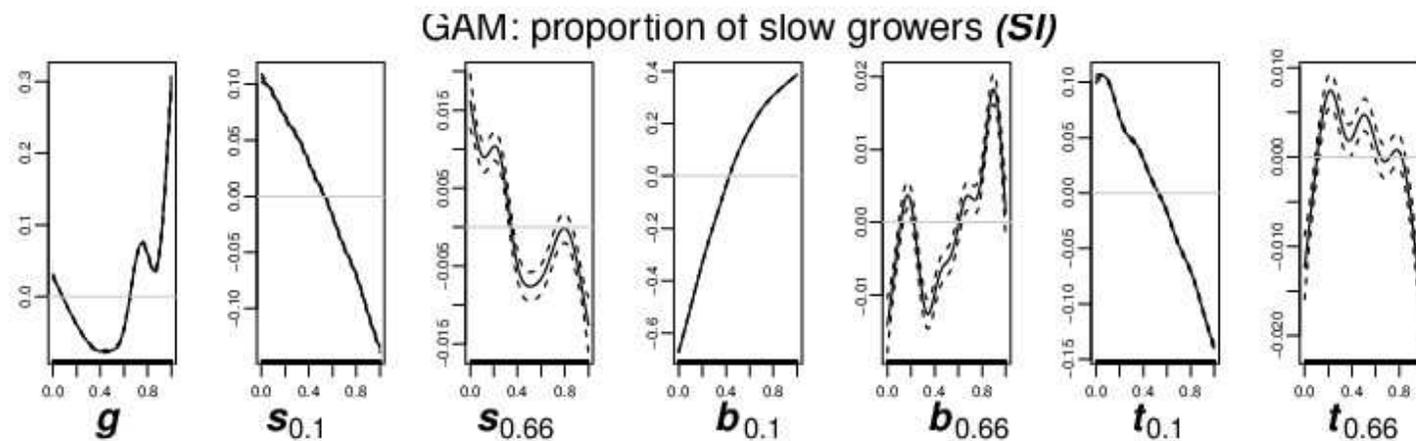
↘↘ eggs
 ↓
 ⊗



► Compensatory mechanisms that mitigates the negative effects of these pressures

3. Impacts of anthropogenic pressures

- ▶ Most pressures tend to **favour fast growers** over slow growers, and as such, **anthropogenic pressures** can be **selective pressures**:



1. Introduction

2. GenEveel

3. Anthropogenic pressures

4. Conclusions



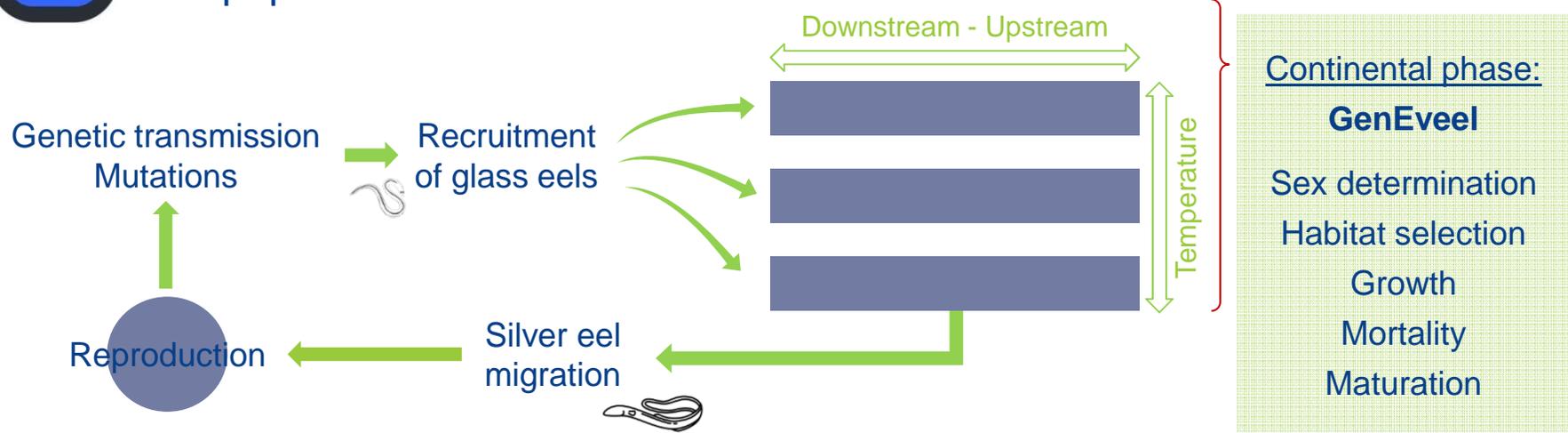
Phenotypic plasticity and **genotype-dependent habitat selection** maintained by **genetic polymorphism** may be **adaptive mechanisms** to cope with environmental heterogeneity (Mateo et al., 2016)

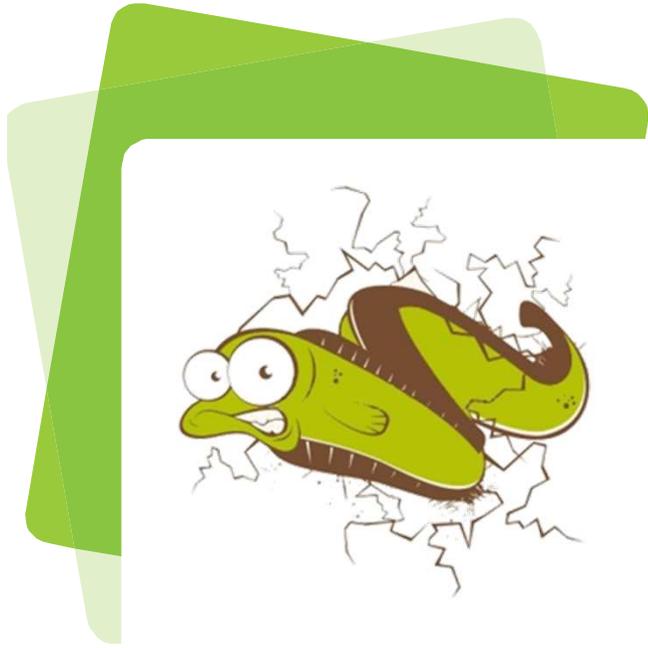


Phenotypic plasticity could act as a **compensatory mechanism** and could be **source of resilience** for the population
Anthropogenic pressures can be **selective pressures** (Mateo et al., 2017)



To validate these assumptions: multigenerational model at the scale of the population distribution area





thank you!



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