Dynamic modeling of physiological processes related to energy management in Gammarus fossarum

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Dynamic modeling of physiological processes related to energy management in crustaceans: a case study with *Gammarus fossarum*

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1- Introduction

- Response to a contamination of high biological organization levels (population and ecosystem) determined by **alterations of individual fitness**.
- Individual performance governed by energy allocation to physiological processes ➔ **DEB theory** to formalize energy allocation to key physiological functions [1].
- In crustaceans, **spawning synchronized with molt and non continuous energy allocation to oocytes** through adulthood [1] ➔ assumption of a permanent continuous energy allocation to reproduction all along the life not valid.
- *Gammarus fossarum* extensively used in ecotoxicology for many years: development of a chronic sub-lethal toxicity test [2] with endpoints in relation to reproductive success (molt, fecundity, …).
- **Water temperature** as the key environmental factor controlling the duration of the reproductive cycle and many markers studied in relation with energy processes (digestive enzymes [3], oocytes' surface [4] and feeding rate [5]).

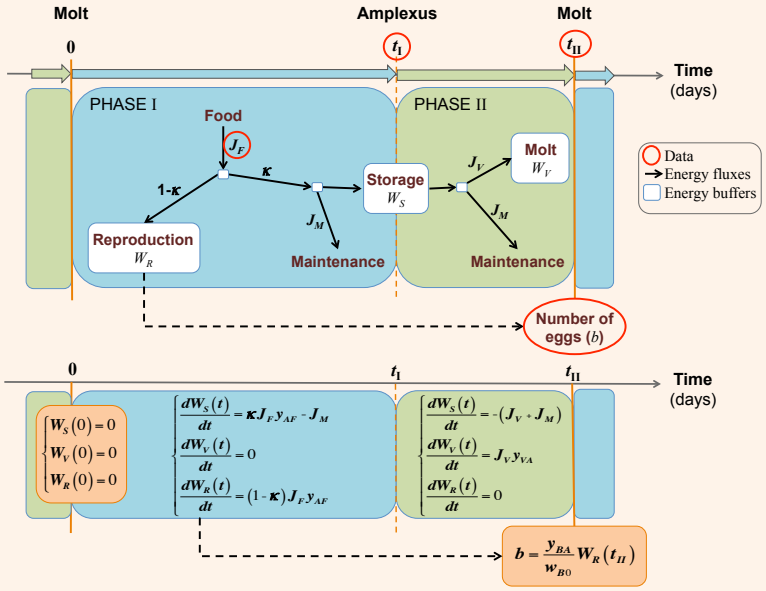
➡ **Aims**: **(1) to develop a mechanistic DEB-based model to describe the energy allocation during a reproductive cycle of *G. fossarum* at different temperatures;**
(2) to show the predictive power of this model and to illustrate how it can be used under stress conditions.

2- Material & Methods

Biological and physiological characteristics of *G. fossarum*

- Reproductive and molt cycles perfectly synchronized.
- Two successive phases reproductive cycle [2]:
  - ➔ Phase I (from molt to amplexus position, t_I days): feeding – vitellogenesis
  - ➔ Phase II (from amplexus to next molt, t_{II} days): stop feeding – synthesis of molt structures
- Effects of temperature on feeding rate and duration of the reproductive cycle [5].

Schematic diagram of biomass fluxes and associated DEB-based model



Data

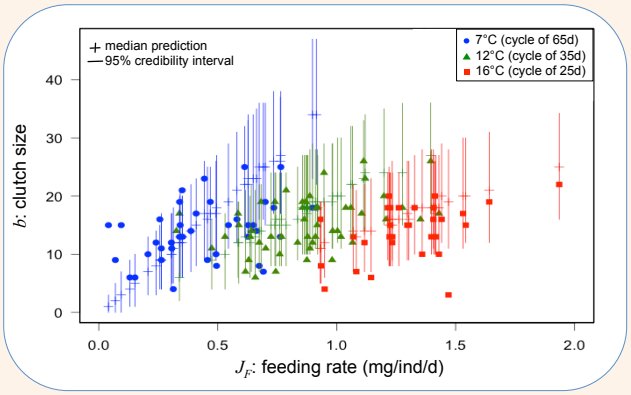
- Reproduction of 124 females fed *ad libitum* at three temperatures (7, 12, 16°C): b_{obs}
- Duration of the two reproductive phases according to temperature: $t_{I,obs}$ and $t_{II,obs}$
- Individual measurement of female size
- Feeding rate according to size and temperature: $J_{F,obs}$
- Reproduction of 70 females under different food conditions at 14°C

Parameter estimation

- Fixed parameters: w_{B0} = 0.045 mg [6], y_{BA} = 0.95 [1], y_{AF} = 0.3 [7]
- Stochastic links: $b_{obs} \sim \mathcal{P}(b)$; $t_{Iobs} \sim \mathcal{N}(t_I, \sigma_I)$; $t_{II} \sim \mathcal{N}(t_{IIobs}, \sigma_I)$; $J_F \sim \mathcal{N}(J_{F,obs}, \sigma_0)$
- Bayesian inference: three MCMC with *rjags*

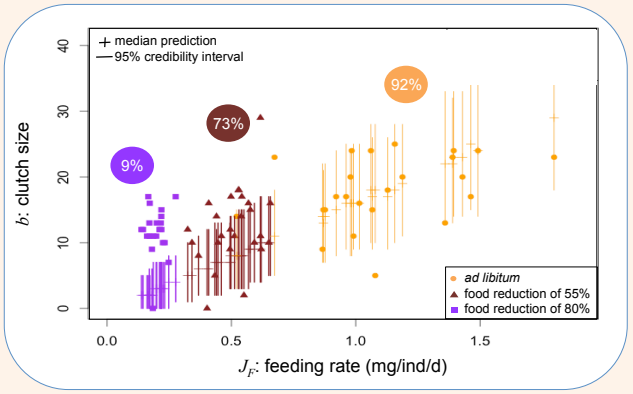
3- Results

Reproduction according to feeding rate (*ad libitum*) at different temperatures



➔ κ = 0.88 [0.86-0.89] : 12% of ingested energy allocated to reproduction
➔ 83% of data in credibility intervals

Model validity and application under food limited conditions at 14°C



➔ Validity: 92% of other *ad libitum* data in credibility intervals of model predictions
➔ Application: the more food is restricted, the more reproduction is under-estimated

4- Discussion - Conclusion

- DEB formalism to describe the energy allocation processes of a crustacean for which reproduction occurs in a discrete way during successive molts
- Effect of body size and temperature, the key abiotic and biotic factors, on reproductive cycle and feeding rate taken into account
- In *ad libitum* condition, "only" around 12% of ingested energy allocated to reproduction
- In food restricted stress condition, energy allocation modified to privilege reproduction
- First step for a more realistic description of energy allocation during the lifespan of organisms exposed to pollution

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