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

C. Lopes, F. Mounier, S. Charles, Arnaud Chaumot, Olivier Geffard

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


Christelle LOPES[1]*, Florence MOUNIER[1], Sandrine CHARLES[1,2], Arnaud CHAUMOT[3] and Olivier GEFFARD[3]

[1]Université de Lyon, F-69000, Lyon; Université Lyon 1; CNRS, UMR5558, Laboratoire de Biométrie et Biologie Évolutive, F-69622, Villeurbanne, France
[2]Institut Universitaire de France, 103, bd Saint-Michel, 75005 Paris, France
[3]Irstea, UR MALY, 5 rue de la Doua, F-69626 Villeurbanne, France

***Contact: christelle.lopes@univ-lyon1.fr**


## 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]).

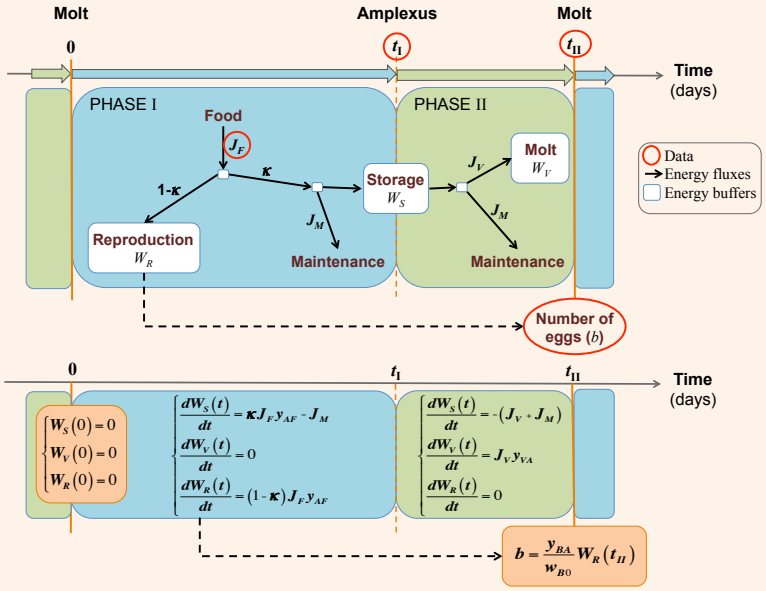
➡ **Aims**: **(1) to develop a mechanistic DEB-based model to describe the energy allocation during a reproductive cycle of *G. fossarum* at different temperatures;**
**(2) to show the predictive power of this model and to illustrate how it can be used under stress conditions.**

## 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

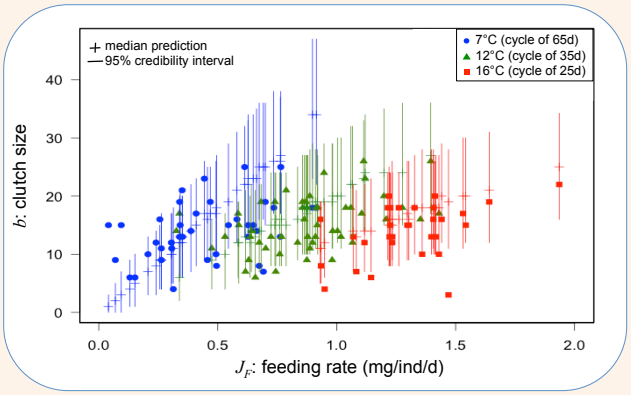
- Reproduction of 124 females fed *ad libitum* at three temperatures (7, 12, 16°C): $b_{obs}$
- Duration of the two reproductive phases according to temperature: $t_{I,obs}$ and $t_{II,obs}$
- Individual measurement of female size
- Feeding rate according to size and temperature: $J_{F,obs}$
- Reproduction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

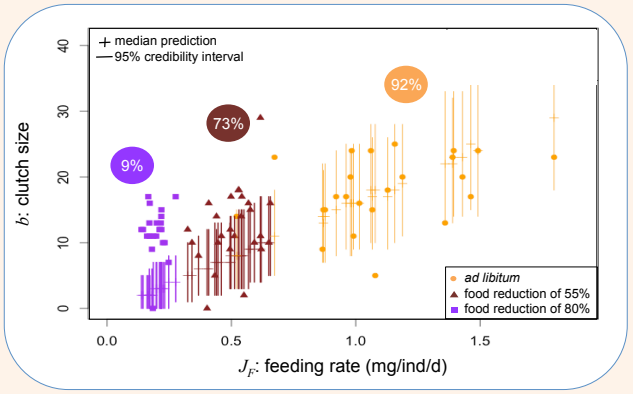
## 3- Results

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




➔ $\kappa$ = 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


**References:**

[1] Jager *et al.* (2013). DEBkiss or the quest for the simplest generic model of animal life history. *Journal of Theoretical Biology*, 328: 9-18.
[2] Geffard et al. (2010). Ovarian cycle and embryonic development in *Gammarus fossarum*: Application for reproductive toxicity assessment. *Environ. Toxicol. Chem.*, 29 (10): 2249–2259.
[3] Dedourge-Geffard *et al.* (2009). Effects of metals on feeding rate and digestive enzymes in *Gammarus fossarum*: an in situ experiment. *Chemosphere* 11:1569-1576.
[4] Jubeaux *et al.* (2012). Vitellogenin-like proteins in the freshwater amphipod *Gammarus fossarum*: Functional characterization throughout reproductive process ... *Aquat. Toxicol.*, 112-113(1), 72-82.
[5] Coulaud *et al.* (2011). *In situ* feeding assay with *Gammarus fossarum*: Modelling the influence of confounding factors to improve water quality biomonitoring. *Water Res.*, 45(19): 6417-29.
[6] Sutcliffe (1992). Reproduction in *Gammarus* (Crustacea, Amphipoda): basic processes. Freshwater forum, 2: 102-128.
[7] Maltby *et al.* (1990). Field deployment of a scope for growth assay involving *Gammarus pulex*, a freshwater benthic invertebrate. *Ecotoxicology and Environmental Safety*, 19: 292-300