



**HAL**  
open science

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

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

### ► To cite this version:

C. Lopes, F. Mounier, S. Charles, Arnaud Chaumot, Olivier Geffard. Dynamic modeling of physiological processes related to energy management in *Gammarus fossarum*. SETAC Europe 25th Annual Meeting, May 2015, Barcelona, Spain. pp.1, 2015. hal-02602092

**HAL Id: hal-02602092**

**<https://hal.inrae.fr/hal-02602092>**

Submitted on 16 May 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

Christelle LOPES<sup>1\*</sup>, Florence MOUNIER<sup>1</sup>, Sandrine CHARLES<sup>1,2</sup>, Arnaud CHAUMOT<sup>3</sup> and Olivier GEFFARD<sup>3</sup>



Université Claude Bernard Lyon 1

<sup>1</sup>Université de Lyon, F-69000, Lyon; Université Lyon 1; CNRS, UMR5558, Laboratoire de Biométrie et Biologie Évolutive, F-69622, Villeurbanne, France

<sup>2</sup>Institut Universitaire de France, 103, bd Saint-Michel, 75005 Paris, France

<sup>3</sup>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]).



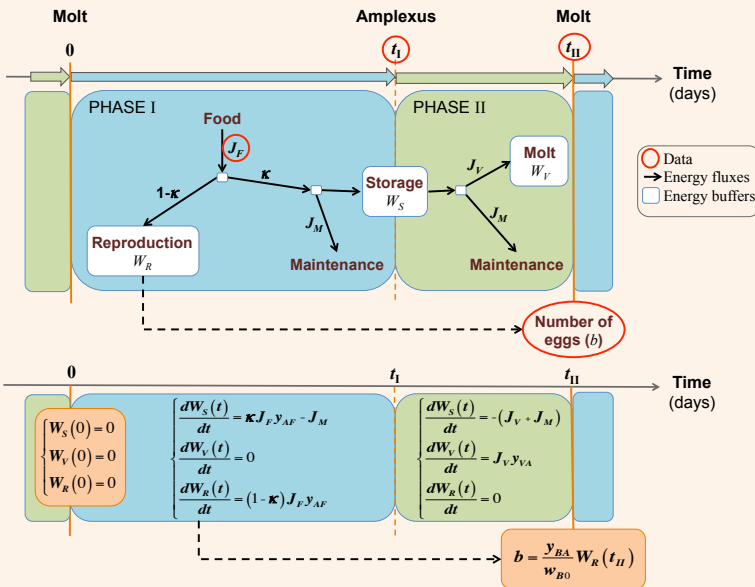
- ➔ **Aims:** (1) to develop a mechanistic DEB-based model to describe the energy allocation during a reproductive cycle of *G. fossarum* at different temperatures; (2) to show the predictive power of this model and to illustrate how it can be used under stress conditions.

## 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

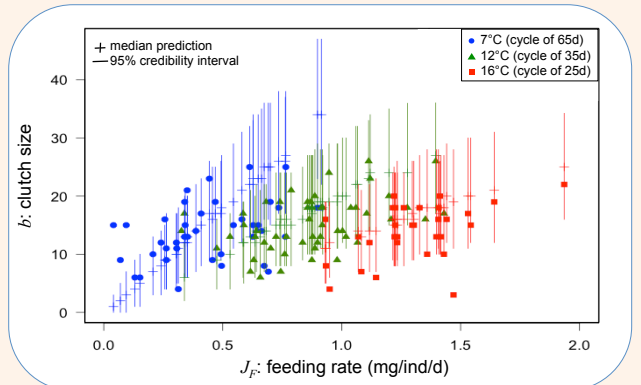
- Reproduction of 124 females fed *ad libitum* at three temperatures (7, 12, 16°C):  $b_{obs}$
- Duration of the two reproductive phases according to temperature:  $t_{I,obs}$  and  $t_{II,obs}$
- Individual measurement of female size
- Feeding rate according to size and temperature:  $J_{F,obs}$
- Reproduction 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:  $b_{obs} \sim \mathcal{P}(b)$ ;  $t_{I,obs} \sim \mathcal{N}(t_I, \sigma_I)$ ;  $t_{II,obs} \sim \mathcal{N}(t_{II}, \sigma_{II})$ ;  $J_{F,obs} \sim \mathcal{N}(J_{F,obs}, \sigma_0)$
- Bayesian inference: three MCMC with *rjags*

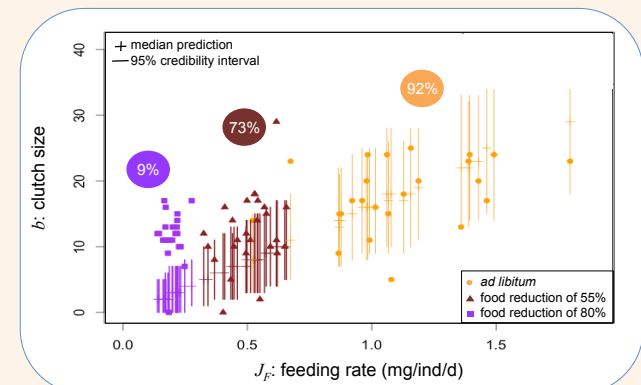
## 3- Results

### • 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] Dedouge-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] Jubaux 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] Malby 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

