Dynamic modeling of physiological processes related to energy management in Gammarus fossarum
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To cite this version:

HAL Id: hal-02602092
https://hal.inrae.fr/hal-02602092
Submitted on 16 May 2020

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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 \( \text{DEB theory} \) 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 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 \( G. \text{fossarum} \) at different temperatures;
2. To prove 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 \( G. \text{fossarum} \):**
  - Reproductive and molt cycles perfectly synchronized.
  - Two successive phases reproductive cycle [2]:
    - Phase I (from molt to amplexus position, \( t_1 \) days): feeding – vitellogenesis
    - Phase II (from amplexus to next molt, \( t_2 \) 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); \( J_{\text{obs}} \)
  - Duration of the two reproductive phases according to temperature: \( t_1, \text{obs} \) and \( t_2, \text{obs} \)
  - Individual measurement of female size
  - Feeding rate according to size and temperature: \( J_{f} \)
  - Reproduction of 70 females under different food conditions at 14°C

• **Parameter estimation**
  - Fixed parameters: \( W_{f0} = 0.045 \text{ mg} [6], V_{\text{y0}} = 0.95 [1], V_{\text{y}0} = 0.3 [7] \)
  - Stochastic links: \( A_{\text{N}} = P(b,t_1 \to t_2) \times N(Y_{0}, \mu_{Y}, \sigma_{Y}, \sigma_{\text{ob}}), J_{\text{f}}, N(Y_{\text{ob}}, \mu_{\text{ob}}, \sigma_{\text{ob}}) \)
  - Bayesian inference: three MCMC with raps

3- Results

• **Reproduction according to feeding rate \( \text{(ad libitum)} \) at different temperatures**

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

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: