Mode of Action on Individual Energetics Determines Population Response

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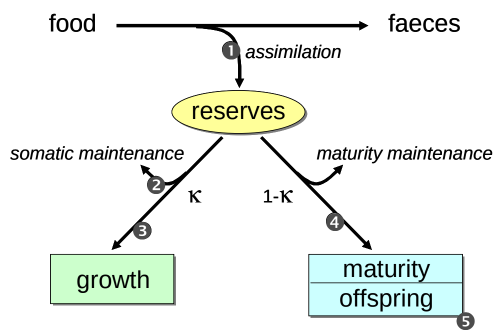
INTRODUCTION

The theory of Dynamic Energy Budgets (DEB) describes individual growth, development and reproduction based on simple rules for metabolic organisation. Effects of toxicants can be understood as a change in energetic parameters (DEBtox, Fig. 1)

Effects on individuals translate to effects on populations. Identifying the energetics-based mode of action is crucial for extrapolation to population responses, especially under food limitation.

EXAMPLES

Three life-cycle data sets are shown in Fig. 2, revealing different modes of action. Intrinsic rate of population increase is calculated using the Euler equation. Food level is a parameter in DEB (Fig. 1); thus effects of food limitation can easily be explored using simulations (Jager *et al.*, 2004).



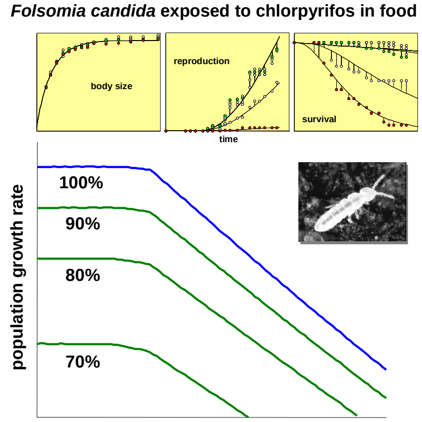
❶ assimilation
❷ maintenance costs
❸ growth costs
❹ reproduction costs
❺ hazard to embryo

Figure 1. Schematic outline of DEBtox with modes of action

❺ *Hazard to embryo*

Chlorpyrifos does not affect growth, but decreases reproduction by directly affecting the embryo. Food limitation is additive to toxicant stress. (Data from Crommentuijn *et al*., 1997).

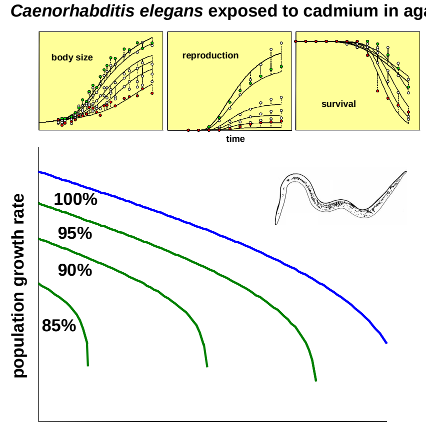
Folsomia candida **exposed to chlorpyrifos in food**



❶ *Assimilation from food*

Cadmium decreases assimilation of energy from food, affecting growth and sexual reproduction. Food limitation and toxicant stress are synergistic. (Data from Alda Álvarez *et al*., 2005).

Caenorhabditis elegans **exposed to cadmium in agar**



❷ *Maintenance costs*

Aldicarb increases the maintenance costs. Food limitation increases the effects of this compound, above a certain concentration. (Data provided by Jodie Wren, CEH, UK).

Caenorhabditis elegans **exposed to aldicarb in agar**

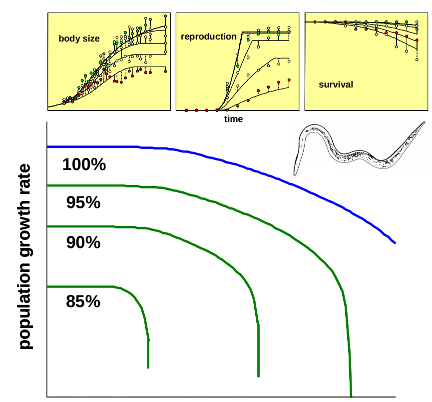


Figure 2. Life-cycle toxicity tests, demonstrating different modes of action, and predicted effects under limiting food levels (green lines).

VALIDATION OF LIMITING FOOD

To validate the extrapolation, we use the data set presented in Fig. 3 (Heugens, 2003). Reproduction and survival where monitored daily, body size and internal concentrations only at the end of the experiment.

Although the basic trend is preserved, the model predictions deviate in several aspects from the response based on the data:

1. Less effect of food level in the controls: *D. magna* is able to decrease the body size at first reproduction.
2. Effect of cadmium is more pronounced at limiting food than predicted: algal food concentration also affects bioavailability.

Daphnia magna **exposed to cadmium, three food levels**

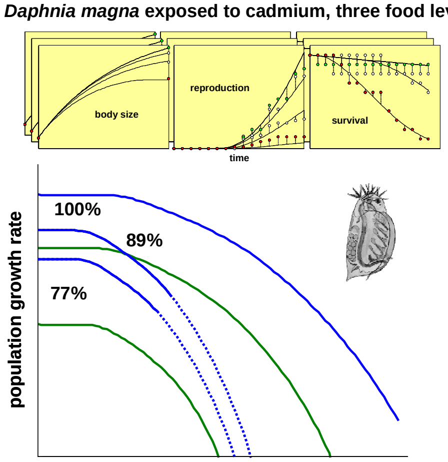


Figure 3. Life-cycle test with Daphnia magna *at three food levels. Blue lines are population response from the actual data, green lines are model predictions.*

CONCLUSIONS

- Life-cycle experiments can be used to make predictions for population effects.
- Population response depends on life-history characteristics of the organism and mode of action of the toxicant.
- DEB-based modelling helps to understand the process of toxicity, and allows for educated extrapolation to the field.

References:
Alda Álvarez *et al*. (2005). Acc. Funct. Ecol.
Crommentuijn *et al.* (1997). In: Ecological Risk Assessment of Contaminants in Soil.
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Jager et al. (2004). Environ. Sci. Technol. 38 :2894.

More information:
http://www.bio.vu.nl/thb/deb

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