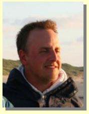
Process-Based Analysis to Extrapolate to Field Populations



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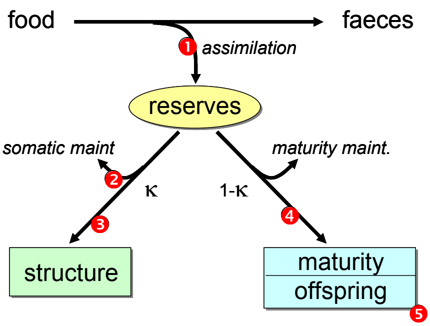
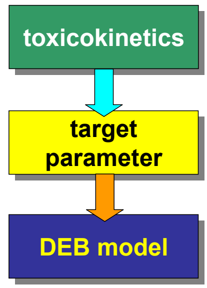
Extrapolation in risk assessment

Ecological risk assessment aims to protect field populations. Several extrapolation steps are needed to extrapolate from lab toxicity tests to the field (see fig. right). The standard approach is to apply arbitrary assessment factors on the available data (e.g. LC50s or NOECs). We demonstrate how to use process-based models to analyse life-cycle toxicity data, and how results support educated extrapolations to the field.

Laboratory	Field
short time scale	long time scale
individuals	populations
'lab' species	'wild' species
constant environment	varying environment
abundant food	(at times) food limitation
lab temperature	field temperature
…	…



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



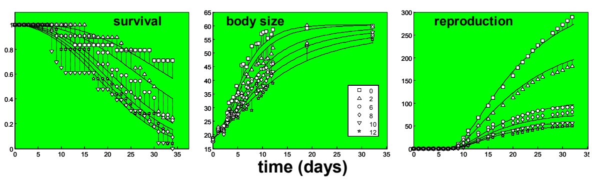
1. a one-compartment accumulation model, accounting for the effects of body size changes
2. the internal concentration changes a target parameter (e.g. maintenance costs)
3. the change in target parameter changes resource allocation, thereby affecting growth and reproduction in a specific manner

Resource allocation and DEB

Growth, development and reproduction are best understood from the perspective of resource allocation. The theory of Dynamic Energy Budgets (DEB) explains how individuals acquire and utilise energy, based on simple rules for metabolic organisation.

Toxicants affect allocation; DEBtox

Toxic effects can be understood as a disruption of allocation processes. Toxicokinetics have to be explicitly included. This approach is used to fit life-cycle data for all endpoints simultaneously (see fig. below), here for the nematode *Acrobeloides nanus*.



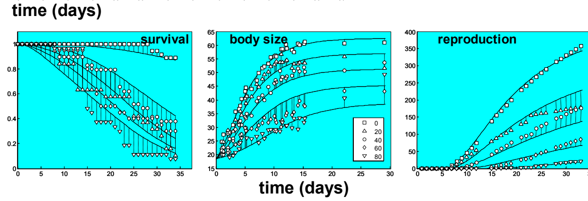
cadmium

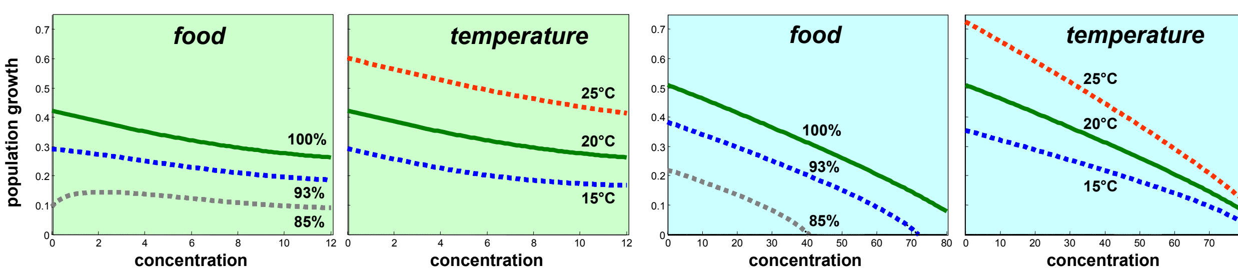
mode of action
❸ **growth costs**

Acrobeloides nanus

pentachlorobenzene

mode of action
❶ **assimilation**





How to extrapolate?

Population: Euler-Lotka eq. (assuming constant environment).
Limiting food levels: food limitation is simulated by decreasing the ingestion rate in the DEB model .
Other temperatures: temperature affects all rate constants in the DEB model (e.g. maintenance and reproduction rate) similarly.

Assuming the *intrinsic* sensitivity remains the same, we can make predictions (see fig.). The difference in response for Cd and PeCB to environmental conditions reflects the different modes of action.

Conclusions

- A process-based approach allows for educated extrapolations.
- The *intrinsic* sensitivity must be separated from the *apparent* sensitivity.
- The physiological mode of action is crucial for extrapolation to field conditions.

More information on DEB and DEBtox on our web site:
http://www.bio.vu.nl/thb/deb/

Selected papers on DEB/DEBtox

DEB basics

S.A.L.M. Kooijman (2000). Dynamic Energy and Mass Budgets in Biological Systems. Cambridge University Press.

R.M. Nisbet, E.B. Muller, K. Lika and S.A.L.M. Kooijman (2000). From molecules to ecosystems through dynamic energy budget models. *J. Anim. Ecol.* 69:913-926.

S.A.L.M. Kooijman (2001). Quantitative aspects of metabolic organization; a discussion of concepts. *Phil. Trans. R. Soc. B* 356:331-349.

DEBtox basics

S.A.L.M. Kooijman and J.J.M. Bedaux (1996). Some statistical properties of estimates of no-effects concentrations. *Water Res.* 30:1724-1728.

J.J.M. Bedaux and S.A.L.M. Kooijman (1994). Statistical analysis of bioassays, based on hazard modeling. *Environ. & Ecol. Stat.* 1:303-314.

S.A.L.M. Kooijman and J.J.M. Bedaux (1996). Analysis of toxicity tests on fish growth. *Water Res.* 30:1633-1644.

S.A.L.M. Kooijman and J.J.M. Bedaux (1996). Analysis of toxicity tests on *Daphnia* survival and reproduction. *Water Res.* 30:1711-1723.

S.A.L.M. Kooijman, A.O. Hanstveit and N. Nyholm (1996). No-effect concentrations in alga growth inhibition tests. *Water Res.* 30:1625-1632.

Critical discussions of concepts

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S.A.L.M. Kooijman, T. Jager and B.W. Kooi (2004). The relationship between elimination rates and partition coefficients of chemical compounds. *Chemosphere* 57:745-753.

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Life-cycle toxicity

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T. Jager, T. Crommentuijn, C.A.M. van Gestel and S.A.L.M. Kooijman (2004). Simultaneous modelling of multiple endpoints in life-cycle toxicity tests. *Environ. Sci. Technol.* 38:2894-2900.

O. Alda Álvarez, T. Jager, S.A.L.M. Kooijman and J.E. Kammenga (2005). Responses to stress of *Caenorhabditis elegans* populations with different reproductive strategies. *Func. Ecol.* 19:656-664.

O. Alda Álvarez, T. Jager, B. Nuñez and J. Kammenga (2006). Temporal dynamics of effects concentrations. *Environ. Sci. Technol*. 40:2478-2484.

T. Jager, T. Crommentuijn, C.A.M. van Gestel and S.A.L.M. Kooijman (2006). Chronic exposure to chlorpyrifos reveals two modes of action in the springtail *Folsomia candida*. Accepted for publication in *Environ. Pollut.*

Life-cycle ecology

T. Jager, O. Alda Álvarez, J.E. Kammenga and S.A.L.M. Kooijman (2005). Modelling nematode life cycles using dynamic energy budgets. *Func. Ecol.* 19:136-144.

T. Jager, S.A. Reinecke and A.J. Reinecke (2006). Using process-based modelling to analyse earthworm life cycles. *Soil Biol. Biochem*. 38:1-6.

Specific examples for survival data

E.H.W. Heugens, T. Jager, R. Creyghton, M.H.S. Kraak, A.J. Hendriks, N.M. van Straalen and W. Admiraal (2003). Temperature dependent effects of cadmium on *Daphnia magna*: accumulation versus sensitivity. *Environ. Sci. Technol.* 37:2145-2151.

T. Jager and S.A.L.M. Kooijman (2005). Modeling receptor kinetics in the analysis of survival data for organophosphorus pesticides. *Environ. Sci. Technol*. 39:8307-8314.