FACULTY OF BIOSCIENCE ENGINEERING

Implementing realistic biological variability in an individual-based Dynamic Energy Budget model

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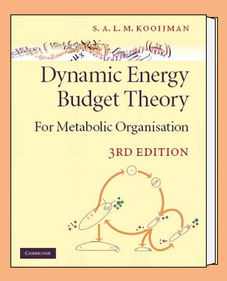
Introduction

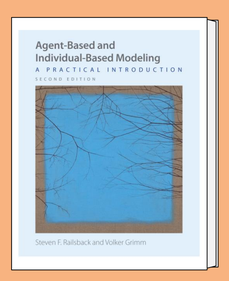
DEB-IBM

- Allows for extrapolation of individual-level energetic effects to populations



DEB[1]

+



IBM[2]

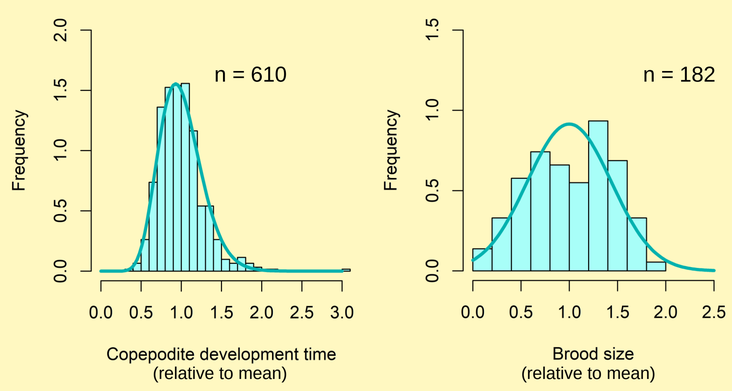
Species: *Nitocra spinipes*

- Brackish water copepod
- Worldwide distribution
- Ecotoxicological test species*
- DEB parameters available[3]

* - OECD ENV/JM/MONO(2014)17
- ISO 14669:1999
- ISO/TS 18220:2016

Inter-individual variability

- Integral in population resilience
- Data available for *N. spinipes*:

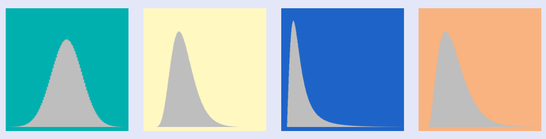


Challenge: How can variability in DEB parameters be estimated from variation in data?

What parameters?

$\{\dot{F}_m\}$ κ_X $[E_G]$ κ $\dot{k}_J$
$\{\dot{p}_{Am}\}$ $[\dot{p}_M]$ $\dot{v}$ $\{\dot{p}_T\}$ E_H^p
κ_R E_H^b E_H^j

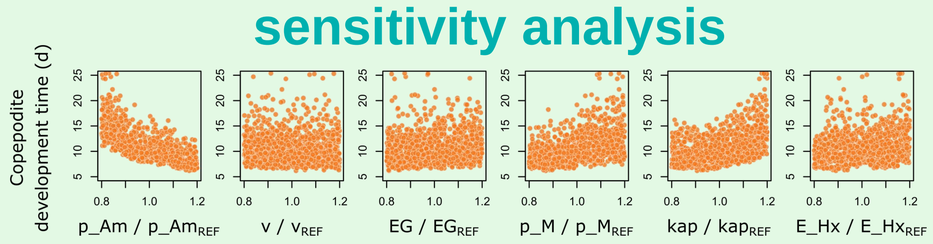
What probability distributions?



What scale of variation?

Methods

Variance based global sensitivity analysis



Monte Carlo simulations with all parameters uniformly distributed (+/- 20%) around their respective reference value from the preceding parameter estimation[3]

$$S_i = \frac{V_{X_i}\left(E_{X_{\sim i}}(Y|X_i)\right)}{V(Y)}$$

The first-order effect indices S_i[4] (always between 0 and 1) indicate how much of the output variance $V(Y)$ can be directly attributed to each respective input parameter X_i

Compare common distribution types

Gaussian

vs.

Log-normal

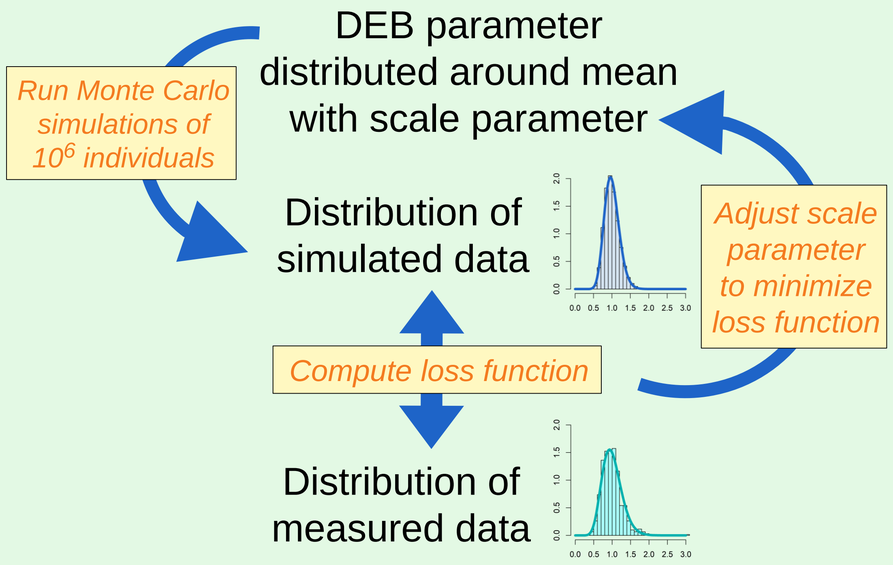
vs.

Log-logistic

vs.

Gamma

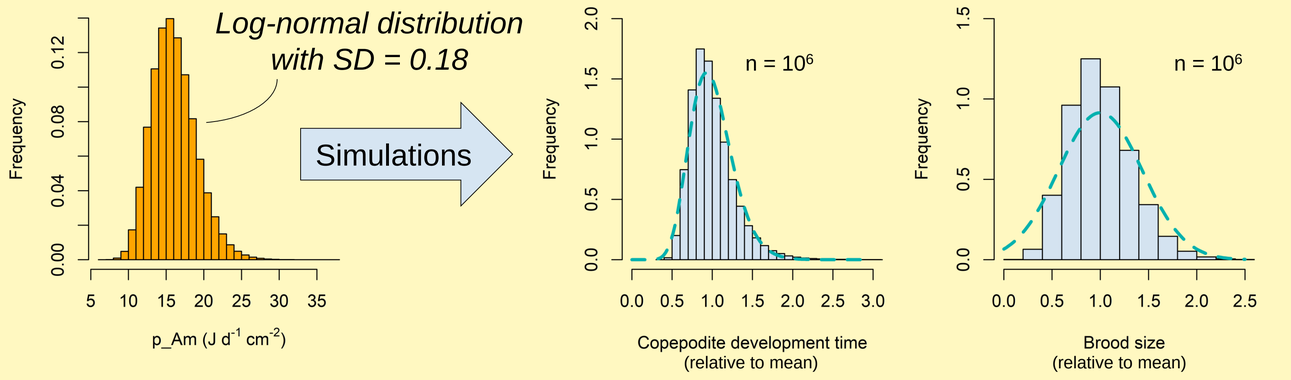
Optimisation algorithm for scale parameter



Results & Discussion

Parameter	$\{\dot{p}_{Am}\}$	$\dot{v}$	$[E_G]$	$[\dot{p}_M]$	κ	E_H^x
S_i Dev. time	0.44	0.003	0.03	0.06	0.36	0.06
S_i Brood size	0.42	0.001	0.01	0.11	0.39	0.05

- Observed endpoints are most sensitive to the maximum assimilation rate $\{\dot{p}_{Am}\}$
- Drawing $\{\dot{p}_{Am}\}$ from a log-normal distribution with an optimised scale parameter (SD) led to the best possible approximation of the variation in real data



Conclusions

- Variability in DEB parameters can be estimated from experimental data
- Adding variability to a single parameter provided a good approximation of observed variation in measured data and can easily be implemented in the IBM

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References

[1] Kooijman, S.A.L.M., *Dynamic Energy Budget Theory For Metabolic Organisation*. 3rd ed. 2010, Cambridge: Cambridge University Press
[2] Railsback, S.F. and V. Grimm, *Agent-based and Individual-based Modeling: A Practical Introduction*. 2nd ed. 2019, New Jersey: Princeton University Press
[3] Koch, J. and K.A.C. De Schamphelaere, *Two Dynamic Energy Budget Models for the Harpacticoid Copepod Nitocra spinipes.* Journal of Sea Research, 2018
[4] Saltelli, A., et al., *Variance Based Sensitivity Analysis of Model Output. Design and Estimator for the Total Sensitivity Index*. Computer Physics Communications, 2010. 181(2): p. 259-270

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