DEB2025 DEB practical course

May 26 – June 3, Heraklion, Crete, Greece

This advanced 8-day course on Dynamic Energy Budget (DEB) theory is designed to train participants in estimating DEB model parameters for their species and applying DEB theory in different contexts. Trainees will come together in Heraklion and interact with experienced scientists actively involved in applying DEB to their own research. The teaching team will deliver insightful lectures on applications of the theory across various fields, including environmental quality management, ecology, fisheries, and population dynamics. Beyond the coursework, this program fosters networking and strengthens international collaboration, making it an excellent platform for knowledge exchange and professional growth.

DEB2025 Team

Lecturers

André Gergs (A.G.), Mike Kearney (M.K.), Sebastiaan (Bas) Kooijman (S.K.), Romain Lavaud (R.L.), Konstadia (Dina) Lika (D.L.), Gonçalo Marques (G.M.), Nina Marn (N.M.), Roger Nisbet (R.N.), Charlotte Récapet (C.R.), Tânia Sousa (T.S.), Tan Tjui-Yeuw (T.T-Y.), Jaap van der Meer (J.vdM)

Leaders Discussion Groups

Romain Lavaud/Roger Nisbet; Nina Marn/Charlotte Récapet; Mike Kearney; Tan Tjui-Yeuw/Orestis Stavrakidis-Zachou; Gonçalo Marques

Assistants DEB-in practice and AmP workshops

Gonçalo Marques, Dina Lika, Romain Lavaud, Charlotte Récapet, Bas Kooijman, Nina Marn, Urban Dajcman, Evridiki Klagkou, Maria Lagunes, Diogo F. Oliveira, Orestis Stavrakidis-Zachou

Plenary Discussion chairs

Mike Kearney (1st Plenary); Roger Nisbet (2nd Plenary)

AmP presentations chair

Mike Kearney

Onsite Support

Dina Lika, Evridiki Klagkou, Orestis Stavrakidis-Zachou

Timekeepers

Dina Lika, Romain Lavaud (who will ring a bell to call the time).

Course schedule by day

Monday 26 May

09:00-10:00	"Welcome and Tele-course Summary" (D.L, R.L.)
10:00-11:00	"Overview of Typified DEB models & Tools" (D.L.)
11:00-11:30	Break
11:30-12:45	"DEB and the ecological niche" (M.K.)
12:45-14:00	Lunch
14:00-16:00	DEB in practice "DEB model Simulations" (M.K.)
16:00-16:30	Break
16:30-17:30	"Life: from molecules to system earth" (S.K)
17:30-18:30	Discussion groups

Tuesday 27 May

09:00-10:00	"Accelerations and evolution of acceleration" (S.K.)
10:00-11:00	Discussion groups
11:00-11:30	Break
11:30-12:45	DEB in practice "AmP Parameter Estimation" (D.L)
12:45-14:00	Lunch
14:00-15:00	AmP projects: Setting up (N.M.)
15:00-16:00	AmP projects
16:00-16:30	Break
16:30-18:30	AmP projects

Wednesday 28 May

09:00:10:00	"DEB and environmental limits" (M.K.)
10:00-11:00	Discussion Groups
11:00-11:30	Break
11:30-12:45	"Synthesizing Units" (G.M.)
12:45-14:00	Lunch
14:00-16:00	DEB in practice "Running DEB models in NicheMapR" (M.K.)
16:00-16:30	Break
16:30-18:30	AmP projects

Thursday 29 May

09:00-10:00	"DEB in ecotoxicology" (R.N.)
10:00-11:00	"Patterns in parameter values" (S.K.)
11:00-11:30	Break
11:30-12:45	DEB in practice "DEB tools to trait based ecology" (T.T-Y.)
12:45-14:00	Lunch
14:00-15:00	Plenary Discussion (M.K.)
15:00-16:00	Reconstruction (R.L.)
16:00-16:30	Break
16:30-18:30	AmP projects

Friday 30 May

09:00-10:00	"Lessons learned in ecotoxicology crossing scales of organization" (R.N.)
10:00-11:00	Discussion Groups
11:00-11:30	Break
11:30-12:45	"DEB theory and evolutionary theories on life-history" (C.R.)
12:45-14:00	Lunch
14:00-15:00	“Respiration and macro-chemical reaction equations in practice” (G.M.)
15:00-16:00	"Parameter Identifiability" (D.L.)
16:00-16:30	Break
16:30-18:30	AmP projects

Saturday 31 May

09:00-10:00	"Intraspecific variation in a DEB framework" (C.R.)
10:00-11:00	Discussion Groups
11:00-11:30	Break
11:30-12:45	"DEB modules and applications" (N.M. & R.L.)
12:45-14:00	Lunch
14:00-15:00	"Multivariate DEB models" (G.M.)
15:00-16:00	AmP projects
16:00-16:30	Break
16:30-18:30	AmP projects

Sunday 1 June

Day off

Monday 2 June

09:00-11:00 "Canonical community" (J.vdM.)
11:00-11:30 Break
11:30-12:45 Discussion Groups
12:45-14:00 Lunch
14:00-15:00 "The Structure of DEB theory" (T.S.)
15:00-16:00 AmP projects
16:00-16:30 Break
16:30-17:30 "Thermodynamics of life" (T.S.)
17:30-18:30 Plenary Discussion (R.N.)

Tuesday 3 June

09:00-11:00 DEB in practice "Ecotoxicology workshop" (A.G.)
11:00-11:30 Break
11:30-12:45 DEB in practice "Ecotoxicology workshop" (A.G.)
12:45-14:00 Lunch
12:00-16:00 AmP presentations
16:00-16:30 Break
16:30-18:00 AmP presentations
18:00-18:30 Q&A / Closing remarks

AmP projects (13 H)

Objective: estimate parameters for “multiple models that share parameters and are fitted to multiple data sets” using 1 food, 1 reserve, 1 structure DEB model for an animal. In addition to the task and learning objectives outlined below, the AmP workshop will also be used to provide Matlab and DEBtool training and basics in statistical and numerical methods for those who have an interest in it.

Tasks

- Create a "predict_my_pet" file specific to your project animal.
- Utilize the "run_my_pet" function to estimate parameter values for your project animal.
- Calculate and analyze over 100 implied properties for your project animal.

Tasks will be further outlined based on participant level and objectives during the “AmP projects: setting up” on Tuesday, 27 May. It is very important to come prepared with both a discussion topic and compiled physiological data (with references) on an animal of your choice. The specific tasks defined here will form the basis for the following 13 hours of project time.

Learning objectives

- Develop the ability to generate user-defined predictions for an animal's length, weight, respiration, and reproduction using multiple models.
- Acquire skills to estimate parameters using diverse sets of data.
- Analyze and evaluate goodness of fit by assessing the distance and accuracy of predictions compared to observed data.
- Demonstrate an understanding of the biological context by discussing the goodness of fit in relation to phylogenetic and ecological factors.

Assessment

Alone or in a small group present the findings (up to 7 min/person). This will be on the final day of the course (Tuesday, 03 June).

Animals used for each Project

First Name	Animal (Latin Name)	Animal (English Name)	GitHub Name	In AmP

Discussion Groups

Please find any DEB related paper in the DEB zotero library (you can access PDFs for free when you are a member).

6/7 participants per group discussion. The chair(wo)man will appoint a reporter, who will summarize the discussion during the plenary discussions. In each scheduled hour, 2 participants have 10 min to expose the problem and question(s) that they submitted in preparation for the course, followed by a 10 min discussion per presentation. In the remaining time (some 20 min per hour) we will discuss a topic related to DEB theory:

TOPIC 1 (May 26, 27 & 28): TBA

TOPIC 2: (June 09,10 & 12) TBA

Plenary Discussions (2 H)

The reporters of the discussion groups report at the plenary session for 5 min each, leaving some 30 min for discussion with all the participants simultaneously.

AmP presentations (3.5 H)

On the final day (June 3), participants can briefly present their results, issues, and next steps, and will receive feedback from the teaching team. If time permits, we will compare the parameter values and provide a concise summary of the findings.

Lecture contents (20 H)

Michael Kearney

Lecture 1: “DEB, functional traits and the ecological niche”

This lecture will introduce a way of thinking about the ecological niche that focuses on individuals as thermodynamic systems, linking theory about heat and water exchange (biophysical ecology) with DEB theory. It will discuss the concept of ‘functional traits’ viewed through this perspective.

Download slides

Lecture 2: “DEB and environmental limits”

This lecture will work through some examples of coupling biophysical ecology and DEB theory in practice and discuss perspectives that this provides for understanding environmental limits.

References

Kearney, M.R., Enriquez-Urzelai, U., 2022. A general framework for jointly modelling thermal and hydric constraints on developing eggs. Methods in Ecology and Evolution. https://doi.org/10.1111/2041-210X.14018

Bas Kooijman

Lecture 1: “Life: from molecules to system earth”

- This lecture discusses conceptual aspects of links between the molecular and system earth levels of life and the role of individuals.
- Limitations of mathematical modeling are discussed in the light of scales in space and time.
- Ideas are presented on the evolution of the central metabolism and how they can be used to delineate metabolic modules between molecules and individuals.
- Mass and energy balances at the population level can structure canonical communities in ways that respect the syntrophic nature of life on earth.
- Geochemical recycling processes shaped the evolution of life; examples are given.

References:

Meer, J. van der, Hin, V. Oort, P. van & Wolfshaar, K.E. van der 2022
A simple DEB-based ecosystem model. Cons. Physiol. 10: coac057
Kooijman, S.A.L.M., Lika, K., Augustine, S., Marn, N. & Kooi, B.W. 2020
The energetic basis of population growth in animal kingdom. Ecol. Mod, 428: 109055
Kooijman, S.A.L.M. & Troost, T.A. 2007
Quantitative steps in the evolution of metabolic organization as specified by the Dynamic Energy Budget theory. Biol. Rev 82: 1-30
Meer, J. van der 2016
A paradox in individual-based models of populations. Cons. Physiol. 4 cow023
Kooijman, S.A.L.M. & Hengeveld, 2005
The symbiotic nature of metabolic evolution.
In: Reydon & Hemerik (eds): current themes in Theoretical Biology. Springer
Kooijman, S.A.L.M. 2004
On the coevolution of life and its environment.
In: Schneider et al (eds): Scientists Debate Gaia; the next century. Cambridge, Mass
Kooijman, S.A.L.M, Auger, P., Poggiale, J.C. & Kooi, B.W. 2003
Quantitative steps in symbiogenesis and the evolution of homeostasis. Biol. Rev. 78: 435-463
Nisbet, R.M., Muller, E.B., Lika, K. & Kooijman, S.A.L.M. 2000
From molecules to ecosystems through Dynamic Energy Budget models. J. Anim. Ecol. 69: 913-926

Lecture 2: “Acceleration and the evolution of acceleration”

- I will review the 5 different types of metabolic acceleration that have been delineated so far.
- The most frequently occurring type, the Morph-type, structures the DEB models that are used in AmP.

- The key is how surface areas (assimilation) relate to volumes (maintenance).
- Definitions and examples will be given for each type.

References:

Add-my-Pet database:
https://www.bio.vu.nl/thb/deb/deblab/add_my_pet/
Marques, G.M., Lika, K., Pecquerie, L., Domingos, T. & Kooijman, S.A.L.M. 2018
The AmP project: Comparing Species on the Basis of Dynamic Energy Budget Parameters. PLOS Comp. Biol. 14: e1006100
Kooijman, S.A.L.M. 2014
Metabolic acceleration in animal ontogeny: An evolutionary perspective. J. Sea Res. 94: 128-137

Lecture 3: “Patterns in Parameter values”

- Building on my acceleration lecture, I will review 4 other general patterns in DEB parameter values that have been found so far.
- Apart from the physical co-variation rules, waste-to-hurry shaped Kleiber's 3/4-rule.
- Patterns found in sharks show, however, why the body-size scaling of respiration is a poor predictor for other traits.
- The supply-demand and altricial-precocial spectra are discussed.
- Ideas are presented for why mammals evolved from altricial to precocial, while birds did so in the opposite direction.

References

Add-my-Pet database:
https://www.bio.vu.nl/thb/deb/deblab/add_my_pet/
Augustine, S., Lika, K. & Kooijman, S.A.L.M. 2022
The comparative energetics of the chondrichthyans reveals universal links between respiration, reproduction and life span. J. Sea Res. 185: 102228
Kooijman, S.A.L.M. & Augustine, S. 2022
The comparative energetics of the cephalopods: they neither grow nor reproduce fast. J. Sea Res. 184: 102205
Kooijman, S.A.L.M., Lika, K., Augustine, S. & Marn, N. 2021
Multidimensional scaling for animal traits in the context of dynamic energy budget theory. Cons. Physiol. 9: coab086
Lika, K., Augustine, S. & Kooijman, S.A.L.M. 2019
Body size as emergent property of metabolism. J. Sea Res. 143:8-17
Augustine, S., Lika, K. & Kooijman, S.A.L.M. 2019
Altricial-precocial spectra in animal kingdom. J. Sea Res. 143: 27-34
Augustine, S., Lika, K. & Kooijman, S.A.L.M. 2019
Why big-bodied animal species cannot evolve a waste-to-hurry strategy. J. Sea Res. 143: 18-26
Marques, G.M., Lika, K., Pecquerie, L., Domingos, T. & Kooijman, S.A.L.M. 2018

The AmP project: Comparing Species on the Basis of Dynamic Energy Budget Parameters. PLOS Comp. Biol. 14: e1006100
Kooijman, S.A.L.M. & Lika, K. 2014
Resource allocation to reproduction in animals. Biol. Rev. 89: 849-859
Lika, K, Augustine, S., Pecquerie, L. & Kooijman, S.A.L.M. 2014
The bijection from data to parameter space with the standard DEB model quantifies the supply-demand spectrum. J. Theor, Biol. 354: 35-47
Kooijman, S.A.L.M. 2014
Metabolic acceleration in animal ontogeny: An evolutionary perspective. J. Sea Res. 94: 128-137
Kooijman, S.A.L.M. 2013
Waste to hurry: Dynamic Energy Budgets explain the need of wasting to fully exploit blooming resources. Oikos 122: 348-357
Kooijman, S.A.L.M 1986
Energy budgets can explain body size relations. J. Theor. Biol. 121: 269-282

Romain Lauvaud

Lecture 1 " Tele-course Summary "

Opening remarks, orientation
Summary of tele-course
Core principles of DEB theory

Lecture 2 “Reconstruction”

Using DEB models to reconstruct environmental forcings and traits
Fitting methods to reconstruct environmental conditions
“True model inversion” methods

Kooijman, S.A.L.M. 2010
Dynamic energy budget theory for metabolic organisation. Cambridge university press.
Lavaud, R., Rannou, E., Flye-Sainte-Marie, J., Jean, F., 2019.
Reconstructing physiological history from growth, a method to invert DEB models. Journal of Sea Research, 143, pp.183-192.
Pecquerie, L., Fablet, R., De Pontual, H., Bonhommeau, S., Alunno-Bruscia, M., Petitgas, P. and Kooijman, S.A., 2012.
Reconstructing individual food and growth histories from biogenic carbonates. Marine Ecology Progress Series, 447, pp.151-164.Freitas, V., Cardoso, J.F., Santos, S., Campos, J., Drent, J., Saraiva, S., Witte, J.I., Kooijman, S.A. and Van der Veer, H.W., 2009.
Reconstruction of food conditions for Northeast Atlantic bivalve species based on Dynamic Energy Budgets. Journal of Sea Research, 62(2-3), pp.75-82.

Dina Lika

Lecture 1: "Overview of Typified DEB models & Tools"

- Standard DEB model
- Isomorphy, V1-morphy
- Types of DEB parameters
- Typified DEB models
- Extensions of DEB models
- Tools for simulating individual dynamics in constant and varying food/temperature

Lecture 2: “Parameter Identifiability”

- Structural and practical identifiability
- Quantifying accuracy of parameters of deterministic models
- Model plasticity
- Handling non- identifiable parameters
- Confidence intervals

Gonçalo Marques

Lecture 1: “Synthesizing Units”

- What are SUs good for?
- One more conservation: conservation of time
- One example on how to estimate fluxes with SUs

Lecture 2: “Multivariate DEB models”

- When to multiply State variables?
- Multiple substrates
- Multiple reserves
- Multiple structures
- Multiple modules

Required visualization: Multivariate DEB Models

Lecture 3: “Respiration and macro-chemical reaction equations in practice”

TBA

Nina Marn

Lecture 1: “DEB Modules and Applications”

TBA

Roger Nisbet

Lecture 1: “Dynamic Energy Budget theory in ecotoxicology”

• Ecotoxicology: effects of toxic substances on living organisms at multiple levels of ecological organization
• Why develop general theory? Too many chemicals, organisms, environments
• Toxicokinetics (TK) and toxicodynamics (TD)
• Modeling triad: DEB/TK/TD
• DEB-based modeling of lethal effects: damage and survival (GUTS)
• DEB-based modeling of sublethal effects: physiological modes of action (pMoA)
• Practical challenges

Reference:
Jager T (2019). Making Sense of Chemical Stress. Application of Dynamic Energy Budget Theory in Ecotoxicology and Stress Ecology. Leanpub: https://leanpub.com/debtox_book.

Lecture 2: “Lessons learned in ecotoxicology crossing scales of organization”

DEB as “pivot” linking sub-organismal biology to higher levels of ecological organization
• Individual-to-population: DEB-IBM (connects with DEB-in-Practice: "Importance of toxicants' Mode of Actions to predict population outcomes”)
• Adverse Outcome Pathways (AOP)
• AOP-to-DEB: challenges in linking AOP to pMoA in DEB theory
• So much more needed!

References:
B. Martin et al. (2014). Limitations of extrapolating toxic effects on reproduction to the population level. Ecological Applications, 24, pp. 1972–1983.
C.A. Murphy et al. (2018). Incorporating Suborganismal Processes into Dynamic Energy Budget Models for Ecological Risk Assessment, Integrated Environmental Assessment and Management, DOI: 10.1002/ieam.4063

Charlotte Récapet

Lecture 1: "DEB theory and evolutionary theories on life-history"

Learning outcomes

After this lecture, you should be able to

- Explain the main theories/explanations on life-history variation among animals
- Discuss the generality of their application (interspecific vs. intraspecific, specific taxa or environmental conditions) and the strength of their empirical support
- Interpret empirical life-history patterns and theories in the light of DEB theory

Topics

life-history strategies, evolutionary trade-offs, alternative tactics, r and K-selected species, supply-demand spectrum, pace-of-life syndrome, waste-to-hurry strategy

References

- Stearns 1992. The evolution of life histories. Oxford University Press, Oxford
- Ricklefs and Wikelski 2002. The physiology/life-history nexus. *Trends Ecol. Evol.*, 17, 462–468.
- Royauté, Berdal, Garrison, et al. 2018. Paceless life? A meta-analysis of the pace-of-life syndrome hypothesis. *Behav Ecol Sociobiol* 72, 64
- Montiglio, Dammhahn, Messier, and Réale 2018. The pace-of-life syndrome revisited: the role of ecological conditions and natural history on the slow-fast continuum. *Behav. Ecol. Sociobiol.*,72, 116.
- Lika, Augustine, Pecquerie, and Kooijman 2014. The bijection from data to parameter space with the standard DEB model quantifies the supply–demand spectrum. *Journal of theoretical biology*, 354, 35-47.

Lecture 2: “Intraspecific variation in a DEB framework”

Learning outcomes

After this lecture, you should be able to

- Explain the relevance of mechanistic approaches for integrating genetic and environmental variation
- Predict qualitatively the phenotypic differences resulting from variation in DEB parameters and environmental variables
- Understand the advantages and limits of different approaches to estimate intraspecific variation in DEB parameters, from sub-species to individuals
- Illustrate the ecological impact of intraspecific variation using examples from aquatic species

Topics

gene-by-environment interactions, plasticity, micro-evolution, evolutionary constraints

References

- Koch & De Schamphelaere 2020. Estimating inter-individual variability of dynamic energy budget model parameters for the copepod nitocra spinipes from existing life-history data. *Ecol. Model.* 431, 109091
- Roff 1996. The evolution of threshold traits in animals. *Q. Rev. Biol.* 71(1), 3-35
- Nisbet et al. 2016. Integrating ecological insight derived from individual-based simulations and physiologically structured population models. *Ecol. Model.* 326, 101-112
- Monaco 2019. Predicting the performance of cosmopolitan species: dynamic energy budget model skill drops across large spatial scales. *Marine Biol.* 166, 14
- Jager 2013. All individuals are not created equal; accounting for interindividual variation in fitting life-history responses to toxicants. *Environ. Sci. Technol.* 47, 3, 1664-1669
- Lika et al. 2020. The use of augmented loss functions for estimating dynamic energy budget parameters. *Ecol. Model.* 428, 109110
- Sadoul et al. 2020. Multiple working hypotheses for hyperallometric reproduction in fishes under metabolic theory. *Ecol. Model.* 433, 109228

Tânia Sousa

Lecture 1: “The Structure of DEB Theory”

Building on Sousa et al. (2008), here we show that DEB theory can be built from 1) the fundamental thermodynamic constraints that all processes obey mass and energy conservation but lead to entropy production, 2) a physical assumption of quite general applicability, that local flows are proportional to differences in intensive variables (and, hence, total flows are proportional to surface areas), 3) a biological assumption, that cells are metabolically very similar, independently of the organism or its size, and, 4) in a “systems theory” type of approach, an application of Occam’s razor, in always choosing the simplest possible formulation of a mathematical theory (minimize the number of state variables; choose linear over non-linear functions; minimize the number of parameters).

Having condensed DEB theory in this compact definition, we then show how these fundamental assumptions lead to the strong and weak homeostasis principles, and then to partitionability of reserve dynamics and the reserve dynamics itself. With this, we obtain the von Bertallanfy growth curve and Kleiber’s rule, for intra- and inter-specific comparisons.

Sousa, T., T. Domingos, S. A. L. M. Kooijman, 2008, From empirical patterns to theory: A formal metabolic theory of life, Philosophical Transactions of the Royal Society of London B 363: 2453–2464

Lecture 2: “Thermodynamics of life”

Metabolism: The effect of temperature
Aggregated chemical reactions
Mass, energy, and entropy balances in organisms.

Jaap van der Meer

Lecture 1: “Canonical community”

TBA

DEB-in-Practice contents (11 H)

"DEB model Simulations" - Mike Kearney

Simulating the DEB model for different species using online simulators
http://bioforecasts.science.unimelb.edu.au/app_direct/deb_sea/
http://bioforecasts.science.unimelb.edu.au/app_direct/deb/

"AmP Parameter Estimation" - Dina Lika

Learning objectives

- Understand and apply the concept of fitting multiple models, which share parameters, to multiple data sets, which may differ in dimensions, in a single parameter estimation.
- Be able to prepare the 4 AmP source files to do the AmP parameter estimation.
- Learn how to configure and customize the options for running the parameter estimation procedure.
- Develop skills for evaluating the quality of parameter estimates and model fit by comparing simulated and observed data, assessing goodness-of-fit.

DEB parameter estimation: https://debportal.debtheory.org/docs/AmPestimation.html
Data types: https://debportal.debtheory.org/docs/AmPestimation.html#Data
Spurdog: Squalus acanthias entry:
http://www.bio.vu.nl/thb/deb/deblab/add_my_pet/entries_web/Squalus_acanthias/Squalus_acanthias_res.html

Data Sheet: for filling out the example entry and going over each step of the estimation procedure:

"AmP project Setting Up" - Nina Marn

- Know the difference between core DEB theory assumptions and auxiliary theory assumptions
- Know how to navigate the AmP database and associated resources to find user-defined predictions for you type of data
- Description of files

"Running DEB models in NicheMapR" - Mike Kearney

NicheMapR, R, R Studio as well as the R.matlab package

The link below is ~40 meg and is the output of the microclimate model for one of the examples – people could download that if they want to save some time because it takes ages to download the data needed for that simulation from the web (just because of the weird nature of the connection to the database rather than it being a lot of data).

https://www.dropbox.com/s/qnb21x24etunpni/micro_baton_rouge_2017_2020.Rda?dl=0

Download zip folder with files for working

NicheMapR_tidal_sandflat_simulation.html
NicheMapR_tidepool_simulation.html

"DEB tools to trait based ecology" - Tan Tjui-Yeuw

AmPtool: https://amptool.debtheory.org/docs/index.html
Templates we will work with are in https://github.com/add-my-pet/SI
AmP Ecology coding: http://www.bio.vu.nl/thb/deb/deblab/add_my_pet/AmPeco.html
Survivor plot of empirical data
Survivor function
Plotting DEB traits and parameters in practice

"Ecotoxicology workshop" - Andre Gergs

During the workshop, I will provide a very brief introduction into (aquatic) ecotoxicology and the use of DEB models for evaluating chronic toxicity studies. We will work with a data set where water fleas (*Daphnia magna*) were exposed to different concentrations of silver nanoparticles.

Learning objectives

- Familiarize with basics concepts of aquatic ecotoxicology and simplified TK-TD models, including scaled damage dynamics, chemical stress and physiological modes of action.
- Being able to handle a toxicity data set in an AmP estimation environment.
- Learn how to configure the options for running the parameter estimation procedure for different physiological modes of actions.
- Develop skills for identifying likely physiological modes of actions and evaluating the goodness-of-fit.

Reads:
For an introduction to the use of the standard DEB model in ecotoxicological analyses, see:
Jager et al. https://doi.org/10.1016/j.ecolmodel.2022.110187

The experiment with *Daphnia magna* and silver nanoparticles has been published by Mackevica et al. https://doi.org/10.1016/j.aquatox.2015.01.023

Participant discussion topics

Participant List