Structure of the Course


5. Physical processes in lakes. Mass balance in a system of reactors and in continuous systems.


8. Additional processes and model extensions.

Lecture 9: Goals

• Get short overview about research models.

• Learn to know some case studies of aquatic ecosystem model applications.

• Share your experience with own model development.

• Get hints for the exam.

• Give feedback about the course.
Overview of Research Models

Lake Models / Simulation Programs

- BELAMO
- SALMO
- CAEDYM

River Models / Simulation Programs

- QUAL2K
- RWQM1
- ERIMO
- Streambugs
Overview of Research Models

**BELAMO:** Biogeochemical-Ecological Lake Model

Fig. 3 from Dietzel et al. 2013 Freshwater Biology 58, 10-35
BELAMO, Model Assumptions:

- Continuous resolution of the vertical dimension, distinction of water column and two sediment layers.
- Variables: $\text{NH}_4^+$, $\text{NO}_3^-$, $\text{HPO}_4^{2-}$, $\text{O}_2$, ALG, PLR, ZOO.
- Processes: Growth, respiration and death of ALG, PLR (Planktothrix rubescens) and ZOO; aerobic and anoxic mineralization; nitrification; P-uptake of sedimenting particles.
- Variable composition/stoichiometry with respect to P.
Overview of Research Models

Measured and modelled depth profiles of Greifensee, Mieleitner and Reichert 2006

Chapter 13.1.1.
Overview of Research Models

SALMO-HR

Structure of SALMO

Overview of Research Models

SALMO-HR

Simulation Results of SALMO-HR


Simulation Results of SALMO-HR

Overview of Research Models

CAEDYM: Computational Aquatic Ecosystem Dynamics Model

Overview of Research Models

Simulation Results of the model CAEDYM

Comparison of measured time series with 1D simulations of the Prospect Reservoir at 2 m (black symbols, thin line) and 17 m depth (white symbols, thick line)

The panels show temperature (A), dissolved oxygen (B), filterable reactive phosphorus (C), total phosphorus (D), nitrate (E), ammonium (F), total nitrogen (G), and chlorophyll a (H).


Romero et al. 2004 Ecological Modelling 174, 143-160
Overview of Research Models

**QUAL2E: River and Stream Water Quality Model**

![Diagram of QUAL2E model](image-url)
Overview of Research Models

River Water Quality Model No. 1 (RWQM1):

- Elemental mass fractions approach.
- Substances and organisms: DOMD, DOMI, NH$_4^+$, NH$_3$, NO$_2^-$, NO$_3^-$, HPO$_4^{2-}$, H$_2$PO$_4^-$, O$_2$, CO$_2$, HCO$_3^-$, CO$_3^{2-}$, H$^+$, OH$^-$, Ca$^{2+}$, HET, N1, N2, ALG, CON, POMD, POMI, PADS, INORG.
- Processes: Growth and respiration of HET, N1, N2, ALG, CON; death of ALG and CON; hydrolysis; chemical equilibria, sorption of phosphate.
ERIMO: Ecological River Model based on functional groups
Overview of Research Models

Streambugs: Community composition of macroinvertebrates

[Diagram showing various factors influencing the community composition of macroinvertebrates, such as temperature, habitat capacity, basal metabolic rate, and taxon biomass.]
Some case studies
New Challenge: Develop your own model

During the semester you have developed and implemented your own model (alone or in groups of two), interpreted simulation results and performed a simple sensitivity analysis.

We provided two topics to choose from:
Topic 1: Deep water extraction and P input reduction to decrease eutrophication.
Topic 2: Co-existence of two zooplankton groups under pesticide pollution.

In the oral exam we will ask you about your example (beside other topics).
Share experience with own model development

- What was your task?
- What were the difficulties?
- Most interesting experience, aha effects?
- Timing of deadlines ok? Code-check helpful?
Hints for the exam
Goals of the Course

- Being able to build models of aquatic ecosystems that consider the most important biological, biogeochemical, chemical and physical processes.

- Being able to explain the interactions between these processes and the behaviour of the system that results from these interacting processes.

- Being able to consider stochasticity and uncertainty.

- Being able to formulate, implement and apply simple ecological models.

- Emphasis is on integrating knowledge in the form of models, on their use for improving the understanding and management of aquatic ecosystems and on their limitations.
Goals of the Exercises

- Deepening and extending the knowledge gained in the course through implementation, simulation, sensitivity analysis, and discussion of the behaviour of a series of ecosystem models of increasing complexity introduced in the course.

- Learn to implement and use models using the publicly available statistics and graphics software R (http://www.r-project.org) and extensions in the form of packages.

- Learn to use R (this is also useful for statistical data analysis in future projects).

- Emphasis is on improving the understanding of the behaviour of the models and the underlying ecosystems through practical application and discussion and not on programming.
Hints for the exam

Core topics of this course / the exam are:

- **Formulation of models of aquatic ecosystems**
  Important processes in lakes and rivers, mass balances, stoichiometry, process rates (limitations/dependences, etc.), model structures.

- **Understanding the behaviour of such models**
  Steady-state and dynamic solutions, effects of limitation and inhibition, sensitivity to parameters, fluxes vs. concentrations.

- **Stochasticity and uncertainty**
  Causes, mathematical description and consequences of stochasticity and uncertainty.
Hints for the exam

- Be precise with the use of terms (state variable, process rate, rate constant, stoichiometric coefficients) and aware about units/dimensions.
- Be able to explain the process table notation and how to derive the differential equations from it for a simple box model.
- Be ready to explain how to derive the stoichiometric coefficients and how to formulate a process rate for a given biological process.
See hints for oral exam on the website. Do you have open questions?
Feedback

I liked!

I disliked!

My suggestions!
Feedback for improving the course?

• **Usefulness of content**
  Topics relevant for future career (in science, in practice)?

• **Appropriateness of course structure**
  Complementarity of lectures vs. exercises? What to improve?

• **Usefulness of course documentation**
  Manuscript, slides, exercises, R-scripts?

• **Appropriateness of presentation**
  Remote teaching: live zoom presentation vs. audio slides?
  Interactions during the exercises?

• **Personal responsibility of students**
  How do you value the task of developing your own model?

• **Other aspects**
  Any other suggestions for improving the course?
Finally...

Final questions?
Finally...

Prepare well!
Stay calm!
Good luck!

Thanks for your participation!