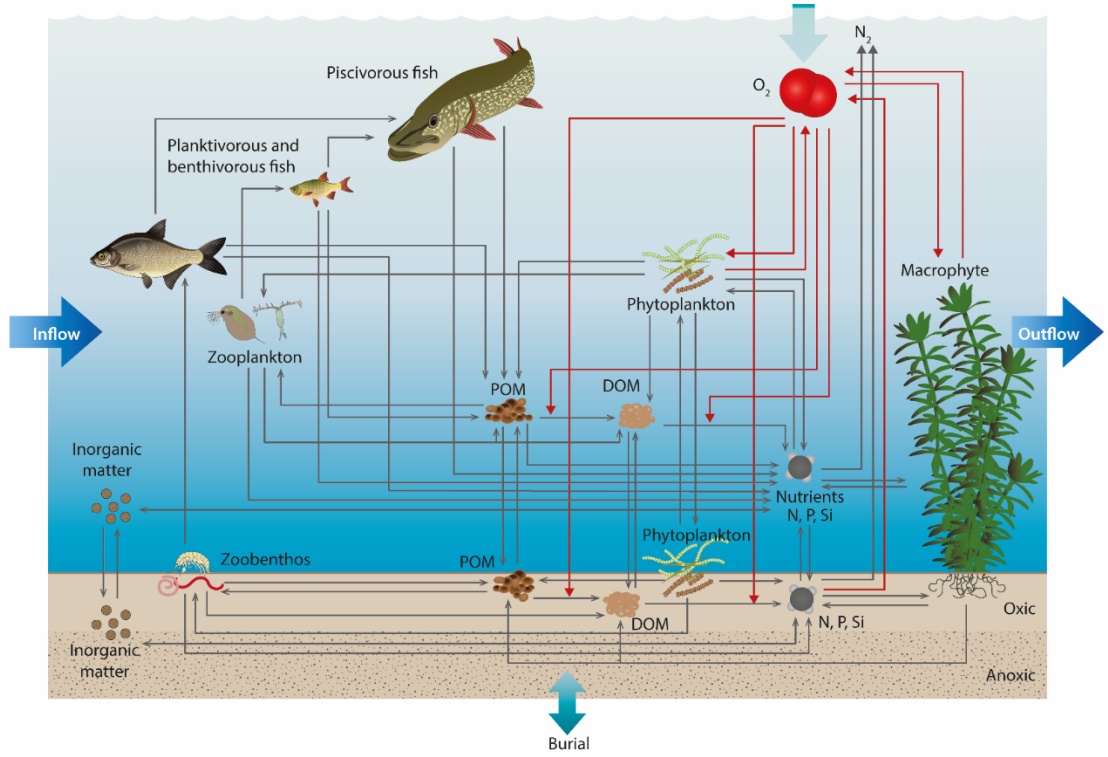
Program for 3-day workshop on:

Modelling lake ecosystems with WET and PCLake

Purpose of the workshop

This workshop trains participants in the theory and practical application of the state-of-the-art lake ecosystem model Water Ecosystems Tool (WET). The workshop covers the theory behind as well as model development of the lake models PCLake and WET. Through combined lectures and hands-on exercises on participants own computers, participants will learn how to

- Set-up a WET lake model via the QGIS interface QWET
- Manual calibration and scenario executions with WET models
- Auto-calibration and sensitivity analysis of WET models with parsac
- Compile GOTM-FABM-WET executable from source code
- Contribute to the development of WET modules



The software used has been developed for Windows computers, and participants therefore need a Windows computer to be able to follow the hands-on exercise.

Workshop instructors

Your workshop instructors will be Postdoctoral researcher Dr Tobias K Andersen (tkan@aqua.dtu.dk) and Senior researcher Dr Xiangzhen Kong (xzkong@niglas.ac.cn). They both have great experience with model development and application for lakes and

reservoirs all over the world.

Dates
14th to 16th October 2024

Workshop location
UCAS Nanjing campus, 江苏省南京市江宁区天泉路 188 号 中国科学院大学南京学院
Classroom to be announced.

The workshop is free and open for students and researchers with basic knowledge of aquatic ecosystems and interest in ecological modelling of waterbodies.

Workshop materials
To participate in the hands-on part of the workshop of day 1, you will need to have a working version of QGIS and the graphical user interface QWET. You will also need to have downloaded data on the Shahe Reservoir. If you are a Mac user, we highly recommend you apply a windows-partition on your system, as the QWET installer is only available in windows format.

On day 1, we provide video tutorials on setting up, calibrating and running scenarios of GOTM-WET models with QWET. We therefore recommend bringing a headset, so you can work on the exercises while viewing the video tutorials by yourself.

QGIS
To run QWET you need to install QGIS3 64 bit version 3.16 or newer (available here: www.qgis.org). We recommend you install QGIS3 64 bit version 3.34 (QWET is currently tested up to version 3.36).

QWET
QWET is an open source QGIS plugin for application and user adaptation of the Water Ecosystems Tool (WET). The QWET installer is available on the workshop Github page under *Materials*. You will need to have installed QGIS before installing QWET. To activate QWET in QGIS,

GOTM-WET executables
GOTM-WET executables are available to users with QWET download and installation. For users not interested in using QWET, GOTM-WET v2.1 executable for 64-bit Windows can be downloaded on the WET Zenodo repository.

Case study data for Shahe Reservoir
For our case study, we will work with the Chinese Shahe reservoir. You can access Shahe data folder in *Materials* folder on the WET workshop page (under *Shahe_data*). The folder includes files to configure a GOTM-WET model to Shahe Reservoir with QWET with lake specific hypsography and inflow and weather forcing as well as in-lake observations and

files with calibrated parameters.

We also recommend also installing PyNCView for the first day.

PyNCView
To visualize model output with contour plots, we recommend using the software PyNCView. You can download an installer (for Windows) at this page (pyncview-0.99.9.msi): https://github.com/BoldingBruggeman/pyncview/releases (under Assets). You can also download PyNCView in Python via "pip install pyncview".

For day 2, you will need to have installed a working environment of Python and the Python package parsac. We will provide more details for day 2 installations on the first day.

parsac
parsac is a Python-based tool for sensitivity analysis and auto-calibration in parallel developed by Bolding&Bruggeman. It is designed for analysis of models that take significant time to run.
parsac can be installed in a working Python environment. We recommend using Python3 via Anaconda distribution. To install the latest released version of parsac, type in your Anaconda prompt window "pip install parsac –user". Remove "—user" to install in the system's shared Python directory (not recommended). Some systems have multiple versions of pip, e.g., pip for Python 2, pip3 for Python 3. Make sure you use the command that corresponds to the Python version you want to install into.

For day 2 and 3, you need to install Python 3.12 to use parsac.
We recommend using Python3 via Anaconda distribution:

1. Click here Anaconda distribution
2. Optional if you will register for Anaconda (else click "skip registration")
3. Download and install Anaconda with Python 3.12

Once Anaconda is installed, open a Anaconda prompt window and type "pip install parsac –user". Python will now download and install parsac (you need internet connection for this).

Remove "—user" to install in the system's shared Python directory (not recommended). Some systems have multiple versions of pip, e.g., pip for Python 2, pip3 for Python 3. Make sure you use the command that corresponds to the Python version you want to install into.

parsac dependencies
parsac supports parallel simulations through Parallel Python. This package supports Python 2 out of the box (pip install pp --user), but its Python 3 version is currently in beta. To install pp in Python 3, either download the zip file with the Python 3 port of Parallel Python or use the pp version provided on the USB stick today ("pp-1.6.4.4.zip"):

1. Extract contents of pp-1.6.4.4.zip,
2. Open a command prompt there and navigate the the folder with extracted pp-

1.6.4.4 directory,
3. Execute command run “python setup.py install”.

parsac uses SALib for sensitivity analysis. Typically, this can be installed with pip install SALib --user. If you are using the Anaconda Python distribution, you can instead do “conda install SALib” (you may need to add “-c conda-forge”).

For more details on parsac and its installation, we recommend checking out its Github page: https://github.com/BoldingBruggeman/parsac.

If you have problems installing the required software or downloading the case study, you are welcome to contact us via the Github Issues board.

More resources

Water Ecosystems Tool (WET)

WET is a further development of FABM-PCLake by Hu et al., at Aarhus University, Denmark. Key features originate from the PCLake aquatic ecosystem model by Janse and van Liere (1995), but key features and inspiration from CAEDYM and Ecopath/Ecosim has also been implemented. WET can describe interactions between multiple trophic levels and abiotic nutrient dynamics in both the water column and the sediment. The model accounts for the dynamics of dry weight, nitrogen, phosphorous, silica and oxygen, and features bottom-shear-dependent resuspension, as well as two different light-limitation functions for phytoplankton. WET is also implemented within the FABM framework, allowing the model to be coupled to various physical driver models, e.g. GOTM (1D, Burchard et al., 1999) or GETM (3D, e.g. Stips et al., 2004), without changing any of the model code. For introduction to WET, we refer you to the scientific articles:

Schnedler-Meyer, N. A., Andersen, T. K., Hu, F. R. S., Bolding, K., Nielsen, A., & Trolle, D. (2022) *Water Ecosystems Tool (WET) 1.0 – a new generation of flexible aquatic ecosystem model*. Geoscientific Model Development

Schnedler-Meyer, N. A., & Andersen, T. K. (2024) *Dining in danger: Resolving adaptive fish behavior increases realism of modeled ecosystem dynamics*. Ecology and Evolution

General Ocean Turbulence Model (GOTM)

Most commonly WET is coupled to the lake branch of 1D hydrodynamic model GOTM (source code available at https://gitlab.com/wateritech-public/waterecosystemstool/gotm). For details on lake branch GOTM, see the models Gitlab page. For more information on GOTM in general, check out https://gotm.net/portfolio/.

For a brief description of GOTM and how it compares to other 1D hydrodynamic models, we recommend

Feldbauer, J., Mesman, J.P., Andersen, T.K., Ladwig, R. (under review) *Learning from a large-scale calibration effort of multiple lake models*. Preprint egusphere-2024-2447

Framework of Aquatic Biogeochemical Models (FABM)
The Framework for Aquatic Biogeochemical Models (FABM, developed by Bolding & Bruggeman) allows coupling a biogeochemical model to a wide variety of hydrodynamic models in 0D, 1D, 2D or 3D, without changing any model code, and encourages and supports modularization of ecosystem models. For more details, we refer you to FABMS wiki page https://github.com/fabm-model/fabm/wiki.

Model study on the Shahe Reservoir
You can find more information on the model study of Shahe Reservoir, which this workshop is based around, in the paper

Cui, Y., Zhu, G., Li, H., Luo, L., Cheng, X., Jin, Y., & Trolle, D. (2016). Modeling the response of phytoplankton to reduced external nutrient load in a subtropical Chinese reservoir using DYRESM-CAEDYM. *Lake and Reservoir Management*, *32*(2), 146–157.

Tentative agenda for the workshop

Datetime	Content
Day 1	
9:00-9:15	Introduction to the workshop and instructors
9:15-10:00	**Lecture 1:** Theory and use of PCLake
10:00-10:30	Break
10:30-12:00	**Lecture 2:** Theory on lake ecosystem modelling with focus on WET
12:00-13:30	Break
13:30-17:30	**Hands-on exercise 1:** Basic set-up of WET with QGIS and the Shahe example
	Prepare for day 2: Install Python, parsac, pp and SALib
17:30-19:00	Break
19:00-21:00	**Free work session**
Day 2	
9:00-9:15	**Catch-up on the previous day**
9:15-10:15	**Lecture 3:** Calibrating lake ecosystems: Recommendations for WET users
10:15-10:30	Break
10:30-11:00	**Tutorial 1:** Introduction to parsac and auto-calibration
11:00-12:00	**Hands-on exercise 2:** Auto-calibration of your WET model
12:00-13:30	Break

13:30-14:00	Continue and finish exercise 2
14:00-14:45	**Tutorial 2:** Introduction to parsac and sensitivity analysis (SA)
14:45-15:00	Break
15:00-16:00	**Hands-on exercise:** Perform a SA of your WET model
16:00-16:45	**Lecture 4:** Why all modelers should do sensitivity analysis
16:45-17:00	Break
17:00-17:30	Continue and finish exercise 3
17:30-19:00	Break
19:00-21:00	**Free work session**
Day 3	
9:00-9:15	**Catch-up on the previous day**
9:15-10:00	**Lecture 5:** WET modularization and the link to FABM
10:00-10.15	Break
10:15-11:15	**Tutorial:** WET code compilation and development
11:15-11:30	**Lecture 6: Outlook and future of WET**
11:30-12:00	Closing remarks of the workshop
13:30-17:30	A tour of the new campus of NIGLAS and UCAS-Nanjing
17:30	Leave