WATExR
Climate seasonal prediction for adapting water resources to extreme events

European Research Area for Climate Services

JPI Climate

WP 3: Integrative tools
Deliverable Report 3

Release of end-user documentation and screencast tutorials on how to operate the QGIS plug-in

November 2020

Authors: Karsten Rinke, Muhammed Shikhani, Rafael Marcé and Dennis Trolle

Table of Contents

Table of Contents 2
1. Introduction 3
2. The QWET system 3
3. Freely available documentation of QWET application 4
3.1. Installations 4
3.2. Applying QWET 5
3.3. Test case “Lake Ravn” 7
4. Further activities 11
5. References 11

1. Introduction

The main target of the WateXr-workpackage 3 on “Integrative Tools” was the development of a QGIS environment that acts as a wrapper around a coupled catchment-lake model in order to provide an easy-to-use and freely available tool to the users. The QGIS environment is further an integrative tool for the operational application of the WateXr-models as this environment allows efficient control structures and automatized functionalities.

Given the fact that each stakeholder has its own IT infrastructures and management needs, the degree of implementation of this QGIS-platform is different from case to case within WateXr, but all WateXr partners have been applying the system in one or the other mode.

Originally, it was planned to provide the documentation for the QGIS-System on a GitHub site, but meanwhile, it turned out that a more visible way of presentation can be achieved by a separate domain (www.wet.au.dk). The system is very flexible and applied in many other activities; it has a growing user community (currently > 350 users) that moreover requires a more flexible and dynamic environment (see below).

QWET is developed and maintained by the Danish WateXr-partner lead by Dr. Dennis Trolle at Arhus University and is also applied in further ongoing research activities. This assures the maintenance and further development of the QGIS-based system beyond the timeframe of WateXr.

2. The QWET system

The QWET system consists of a model core and a wrapping GIS environment provided by a QGIS. The model core constitutes the underlying simulation engine of the system and is provided by the coupled physical-ecological lake model GOTM-WET and the catchment model SWAT. Here, SWAT provides the hydrological input data for the lake model, i.e., discharges and nutrient concentration in the lake inflows (SWAT is also open source, and a freely available QGIS plugin for application of SWAT itself can be downloaded from: https://swat.tamu.edu/). The basic workflow within this multi-model coupled system, at the core of QWET, was originally described by Nielsen et al. (2017) during the beginning of WateXr. QWET provides a graphical user interface for the application, evaluation, and experimentation of GOTM-WET that enable novice users a quick and easy start with state-of-the-art lake modelling. For a thorough description of QWET, refer to Nielsen et al (2021) that describe an updated version of the plugin, which is published in open-access and hence freely available from the publisher from the following URL https://www.sciencedirect.com/science/article/pii/S1364815220309439.

3. Freely available documentation of QWET application

3.1. Installations

QWET has been upgraded to Python 3 and is thus available for QGIS 3.x. To install QWET, users must first install the latest stable version of QGIS 3 (https://download.qgis.org) and proceed with the designated QWET plugin installer available at: www.wet.au.dk. The plugin installation is swift, followed by manual one-time activation via the “Manage and Install Plugins” window under the “Plugins” menu in QGIS. QWET may then be launched from its toolbar within QGIS (Figure 1). A video-documentation of the download and installation procedures is available at https://projects.au.dk/wet/resources/download-wet/ and https://projects.au.dk/wet/resources/installing-wet/.

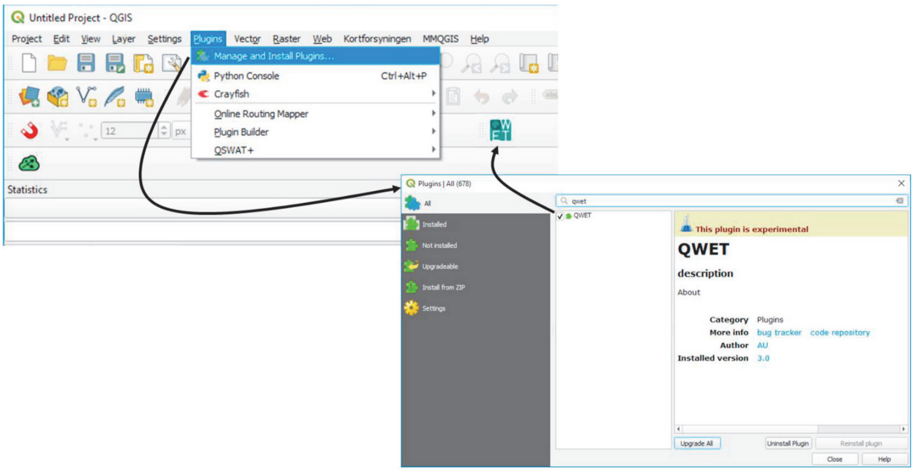

Figure 1: Menus and procedure for one-time activation of the QWET plugin within QGIS

3.2. Applying QWET

QWET builds on the principle of enabling users to set up a model for a given lake or reservoir based on only a few key details: surface area (m^2), maximum depth (m) and a number of vertical layers, water inflow (m^3/s) and associated nutrient concentrations (mg/l), provided as constants or time-series, respectively. Finally, information about the weather is required, optionally represented by a suite of pre-defined meteorological time series from the European Centre for Medium-Range Weather Forecasts (ECMWF, Dee et al., 2011) available in QWET. From here, users may choose to refine their configuration and setup by providing hypsographs (the relationship between depth (m) and the corresponding horizontal area (m^2)) to qualify the approximation of the physical domain or time series on inflow and associated nutrients from the watershed in order to better resolve actual transports into the modelled system. Users also have the option of linking to the watershed model SWAT (Soil & Water Assessment Tool) by Arnold et al. (1998), when needed. Nielsen et al. (2017) provide a detailed description of configuration options, supported by tutorials and test datasets, at: www.wet.au.dk, applicable for QWET.

When creating a new QWET project, users may now choose between three different templates, i.e. conceptual representations, for the ecosystem (Figure 2): Template 1, a simple nutrient–phytoplankton–zooplankton–detritus (NPZD) representation;

Template 2, a representation equivalent to FABM-PClake (Hu et al., 2016), including nutrients, three phytoplankton groups, zooplankton, zoobenthos, piscivorous, zooplanktivorous and benthivorous fish and macrophytes; and Template 3, an advanced version of Template 2 expanded with an additional zooplankton group. Several other conceptual representations may be of relevance to tailor case-specific needs, and QWET supports the inclusion of additional templates upon request.

Model parameters and model settings in both the physical and aquatic ecosystem domains are now accessible within QWET via a tree-structured GUI popup (Figure 3). Users are assisted by various predesigned categorisations (Figure 3) for quicker browsing and can change parameter values or initial values of state variables via, for instance, calibration schemes. Moreover, where needed, model settings can be customized by changing, e.g., the methods for determining phytoplankton and light inhibition or by activating ice simulation or nitrogen fixation for cyanobacteria.

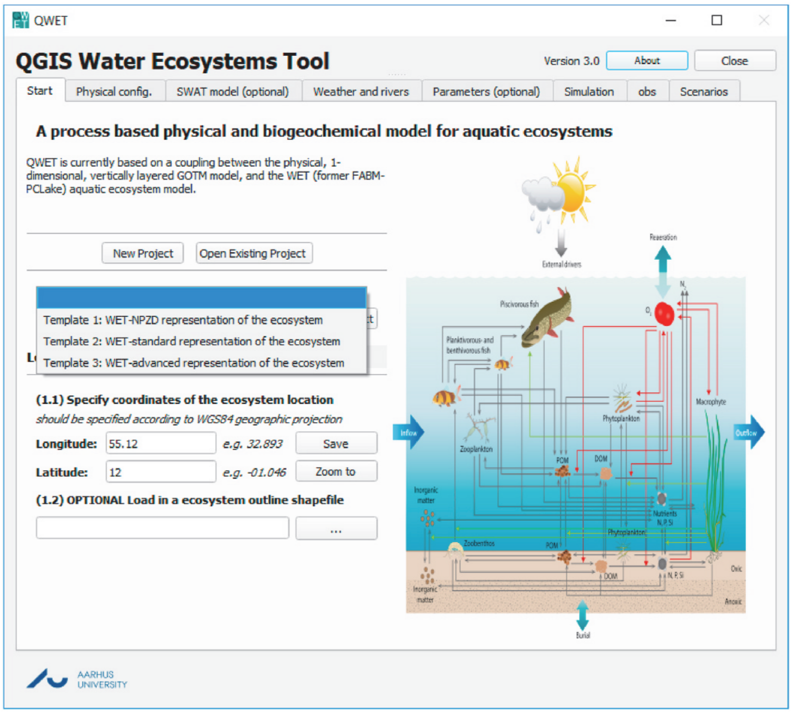

Figure 2: Selection of templates rendering the conceptual model representation in the aquatic ecosystem model.

A simplistic video tutorial for setting up QWET is available at the webpage under the following URL:

https://projects.au.dk/wet/resources/wet-tutorial-videos/#c64406

This tutorial provides all relevant information from opening QWET, input of settings and parameters, to running a simulation. Since QWET has a graphical user interface, a set of visualisations are easily available, as outlined in the video tutorial.

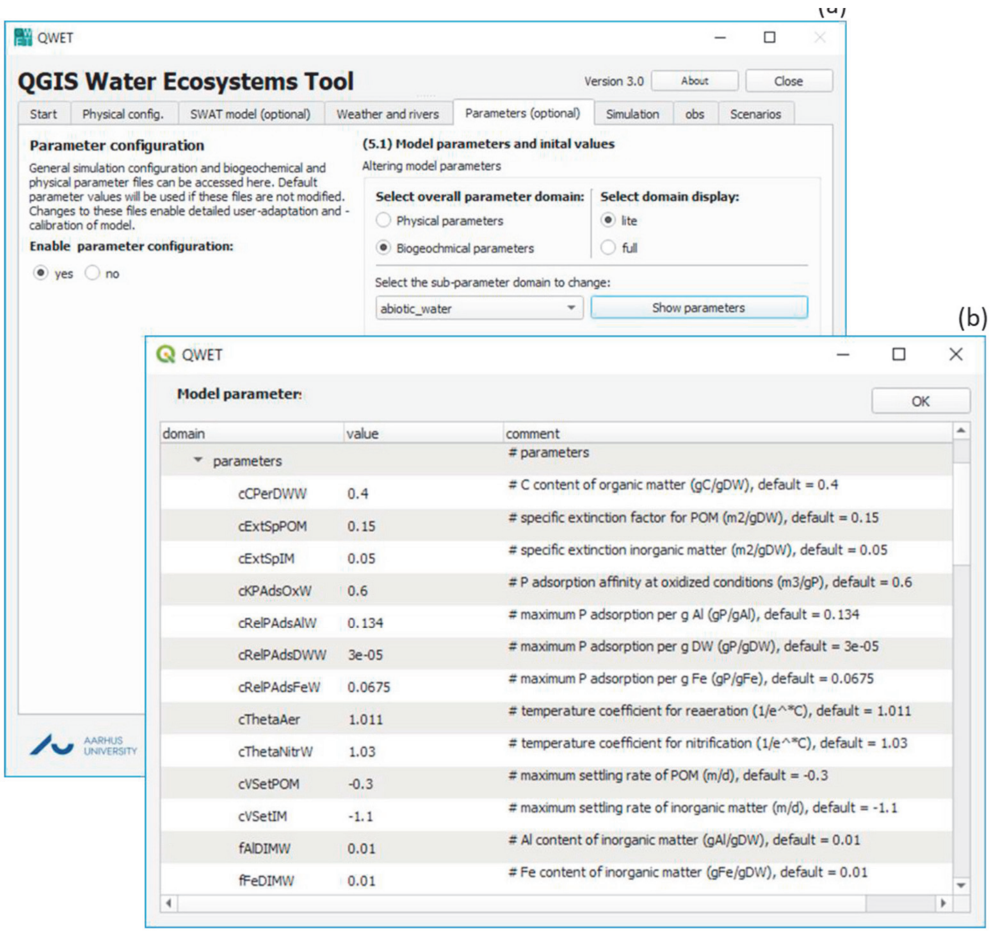

Figure 3: (a) "Parameters tab" in the main window of QWET. (b) GUI popup for parameter browsing and value modifications.

3.3. Test case "Lake Ravn"

As an example, the Danish Lake Ravn showcase a complex ecosystem model structure, i.e., we chose template 3 as conceptual representation in this QWET project (see above and compare Figure 2). The physical domain is represented by a lake-specific hypsograph, and time series of inflowing water and associated nutrients were obtained from the Danish National Monitoring Program of the Aquatic Environment

(NOVANA). Model calibration (from 1996 to 2000 with 6 prior years of warm-up) was conducted outside QWET via ParSAC (see: https://pypi.org/project/parsac/), a calibration tool that utilises a differential evolution algorithm to calibrate model parameters through optimisation against a maximum likelihood function (see Andersen et al., 2020, for other application cases).

A detailed video tutorial of setting up the simulation case for Lake Ravn is available at the webpage under the following URL:

https://projects.au.dk/wet/resources/wet-tutorial-videos/#c64406

We therefore do not describe all necessary procedures step by step in this document but refer to the extensive documentaries available at the QWET-webpage. Instead, we want to emphasize two features that are of particular interest for practitioners and therefore deserve special attention: (i) the comparison of simulation outputs and observations, and (ii) the use of QWET in scenario-based analysis relevant in lake and reservoir management.

Comparison of simulation outputs and observations: The *obs tab* allows QWET users to compare and evaluate model performance against observations. For that, navigation to an external model directory is possible if, e.g., calibration is conducted via auto-calibration routines outside the plugin. Time series of observation variables should be provided with each variable in its own text file. The format and tutorial videos of how to import observations into the plugin are provided at the following URL:

https://projects.au.dk/wet/resources/wet-tutorial-videos/#c48138

Fig. 4 exemplifies data on Lake Ravn displaying the modelled and observed water temperature ($_{o}$C). Users may switch between the variable displayed, the temporal period to be viewed, and the depth-related boundaries to query data for only parts of the water column (e.g., from the surface to 5 m depth) (see Figure 4a). Moreover, users may select between displaying the data as a combined line and scatterplot (Figure 4b), as a line plot (Figure 4c), or as profiles (not shown). Conveniently, the data, and thus the plot rendering, may be separated to permit distinction between calibration and validation (Figure 4c). Along with plot generation, QWET also produces various statistics (e.g., Nash-Sutcliffe efficiency, bias, root mean square error, and coefficient of determination; not shown here) to assist users in quantifying the model performance.

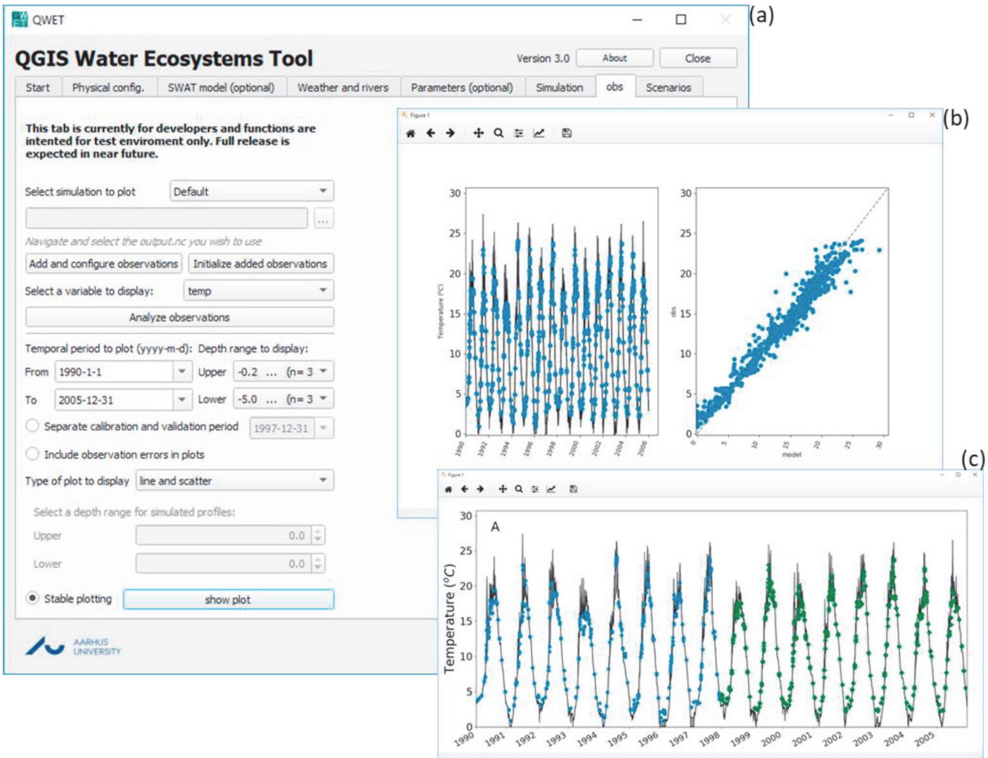

Figure 4: (a) The "obs tab" available in the main window of QWET – here users have several options for comparing model simulations against observations. (b) Examples of plotting options are shown for simulated and observed water temperature (°C) in Lake Ravn for a combined line and scatterplot. (c) Furthermore, a line plot can be made where data are separated into a calibration (blue dots) and a validation green dots) period.

Manipulations of simulations and scenario-based analysis: While the first workflows described in Nielsen et al. (2017) already included changing meteorological input variables in order to simulate climate change, the QWET platform has been expanded with the possibility of designing and applying manipulations to model state variables. With this feature, users can mimic and assess various management actions, such as the consequences of biomanipulation (Jeppesen et al., 2012) or the effects of oxygenation (Liboriussen et al., 2009). Manipulations can now be conducted using either a multiplier that manipulates a state variable during a specific time (e.g., removal of a certain percentage of fish) or a rate of change that either increases or decreases a state variable by a specified rate during a specified time interval. For the latter, a threshold value may also be assigned to control the onset of manipulation, e.g., application of oxygenation only when oxygen levels are below a given threshold. To demonstrate its potential usage, we simulated oxygenation in the hypolimnion of Lake Ravn (Figure 5) with an activation threshold of 6 mg/l operating from 2002 onwards. In response, the simulated hypolimnetic dissolved oxygen concentration rose (Figure 5c) compared with the pre-oxygenation period (Figure 5b). As such, QWET functions as a tool aiding in examining and quantifying oxygenation levels to counteract hypolimnetic oxygen depletion during summer in stratified eutrophic lakes prior to the actual implementation of restoration interventions.

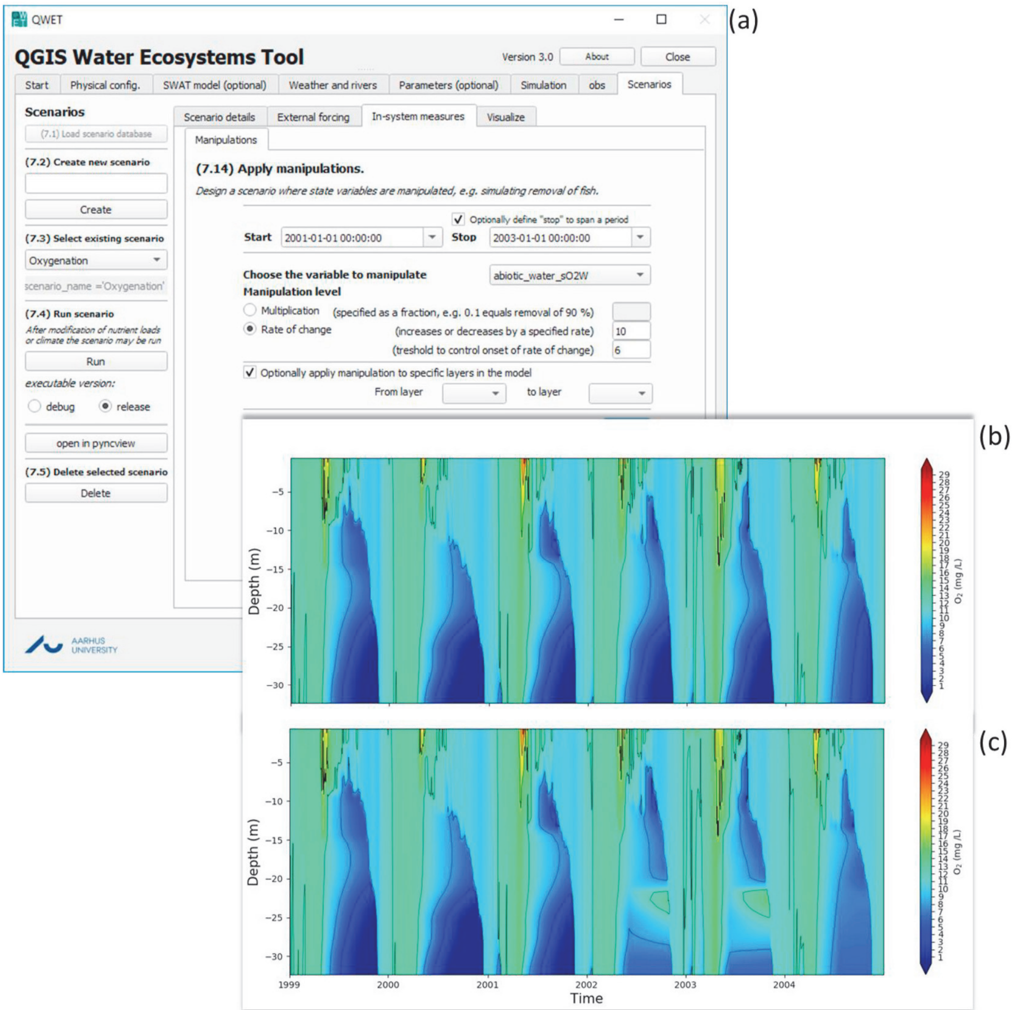

Figure 5: Manipulations are conducted under the QWET "Scenarios tab" (a). The figure illustrates the states before (b) and after (c) oxygenation of the bottom water layers in Lake Ravn. Manipulation is activated from year 2002 and onwards, and only when the

dissolved oxygen level is below a threshold value of 6.0 mg/L.

4. Further activities

- Given the fact that the group at Aarhus University is further developing the QWET system, and that > 350 users are using it, the webpage and its software will be further maintained and developed.
- The WateXr stakeholders, and also anyone outside WaterXr, are able to access and use the QWET system and may embed the system in their own operational workflows.
- Further publications are under preparation documenting the applicability of QWET.

5. References

Andersen, T.K., Nielsen, A., Jeppesen, E., Hu, F., Bolding, K., Liu, Z., Søndergaard, M., Johansson, L.S., Trolle, D., 2020. Predicting ecosystem state changes with an aquatic ecosystem model in shallow lakes: lake Hinge, Denmark as an example. Ecol. Appl. 2160 https://doi.org/10.1002/eap.2160.

Arnold, J.G., Srinivasan, R., Muttiah, R.S., Williams, J.R., 1998. Large area hydrologic modeling and assessment part I: model development. J. Am. Water Resour. Assoc. 34, 73–89.

Dee, D.P., Uppala, S.M., Simmons, A.J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M.A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A.C.M., Van De Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A.J., Haimberger, L., Healy, S.B., Hersbach, H., H´olm, E.V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., Mcnally, A.P., Monge-Sanz, B.M., Morcrette, J.J., Park, B. K., Peubey, C., De Rosnay, P., Tavolato, C., Th´epaut, J.N., Vitart, F., 2011. The ERAInterim reanalysis: configuration and performance of the data assimilation system. Q. J. R. Meteorol. Soc. 137, 553–597.

Hu, F., Bolding, K., Bruggeman, J., Jeppesen, E., Flindt, M.R., Van Gerven, L., Janse, J.H., Janssen, A.B.G., Kuiper, J.J., Mooij, W.M., Trolle, D., 2016. FABM-PCLake – linking aquatic ecology with hydrodynamics. Geosci. Model Dev. (GMD) 9, 2271–2278.

Jeppesen, E., Søndergaard, M., Lauridsen, T.L., Davidson, T.A., Liu, Z., Mazzeo, N., Trochine, C., ¨Ozkan, K., Jensen, H.S., Trolle, D., Starling, F., Lazzaro, X., Johansson, L.S., Bjerring, R., Liboriussen, L., Larsen, S.E., Landkildehus, F., Egemose, S., Meerhoff, M., 2012. Chapter 6 - biomanipulation as a restoration tool to combat eutrophication: recent advances and future challenges. In: WOODWARD, G., JACOB, U., O'GORMAN, E.J. (Eds.), Adv. Ecol. Res..

Liboriussen, L., Søndergaard, M., Jeppesen, E., Thorsgaard, I., Grünfeld, S., Jakobsen, T. S., Hansen, K., 2009. Effects of hypolimnetic oxygenation on water quality: results from five Danish lakes. Hydrobiologia 625, 157–172.

Nielsen, A., Bolding, K., Hu, F., Trolle, D., 2017. An open source QGIS-based workflow for model application and experimentation with aquatic ecosystems. Environ. Model. Software 95, 358–364.

Nielsen, A, Hu F.R.S., Schnedler-Meyer, N.A., Bolding, K., Andersen, T.K., Trolle, D. 2021. Introducing QWET – A QGIS-plugin for application, evaluation and experimentation with the WET model. Environmental Modelling & Software 135, 104886.