Predictive modelling of eutrophication and algal bloom formation in tropical lakes

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CONTENTS

Abstract

My original contribution to knowledge is the successful application of two modelling paradigms 1) SALMO-PLUS process based model and 2) HEA data driven model to tropical lakes of different morphometry and trophic status. The application of SALMO-PLUS to tropical lakes involves utilising the SALMO-OO model structure for optimisation. This was followed by multi objective parameter optimisation on selected parameters to seek the optimum parameter values that can model the algal dynamics and state variables fluctuations in the tropical lakes to an acceptable magnitude and peaks.

SALMO-PLUS is another version SALMO-OO with capability to run optimisation by means of particle swarm optimisation (PSO) method. SALMO-OO has been used as a research tool over a number of lakes with different trophic states and mixing conditions to simulate algal succession and respond to ecosystem dynamic. SALMO-OO is driven by process-based differential equations and works by utilizing a library of three phytoplankton growth and three grazing process models.

Evolutionary algorithms (EA) are bio-inspired adaptive methods which mimic processes of biological evolution, natural selection and genetic variation such as cross-over and mutation to develop solutions to complex computational problems (Recknagel *et al*, 2006). HEA is designed for rule discovery in water quality time-series (Cao *et al*., 2006b) and is capable of forecasting potential algal population dynamics and outbreaks in water bodies.

The SALMO-PLUS model was applied for simulating the state variables of selected lakes (Lake Kenyir, Lake Penang, Saidenbach Reservoir, Roodeplaat Dam and South Para Reservoir). Measured data from the year 2005 and 1992 were used for Lake Penang and Lake Kenyir respectively. The HEA was applied for predicting the Chl-a and algal biovolume abundance on tropical lakes (Lake Putrajaya, Lake Penang and Lake Kenyir) in Malaysia. This study discusses the application of SALMO-PLUS and HEA towards tropical lakes eutrophication management. The results of application of SALMO-PLUS on tropical lakes are presented, simulating response of the phytoplankton community to fluctuation in nutrient loading, light availability and hydrological aspect in the water bodies. Results of applying HEA on tropical lakes are also interpreted in the context of empirical and causal knowledge on Chl-a and algal biovolumes dynamics under tropical lake water quality conditions by means of rule-based model.

Results for both Lake Kenyir and Penang showed that SALMO-PLUS were able to predict annual average trends not only for chlorophyll-a but also other state variables and algal functional groups. Simulated state variables namely Chl-a, N and P showed good agreement with field observations data for both lakes. Despite the fact that this is the first time SALMO-PLUS been used for tropical lakes and the limited data availability from this region, the simulated values of biological and nutrient state variables match reasonably with measured data. Outcomes from SALMO-PLUS simulation show consistent compliance with algal community assembly obtained from other researchers.

The HEA achieved reasonable accuracy in predicting timing and magnitudes of algal blooms up to 7-days-ahead. The HEA proved to be most efficient in modelling and predicting seasonal dynamics of chlorophyll-a and algal biovolumes. A sensitivity analysis conducted for Lake Penang revealed that algal abundance is not only driven by physical and chemicals characteristics of the water body but also by impact of inorganic substances in the water that contributes to high level of chemical oxygen demand in the water as well.

In addition, this study has successfully implemented a new process model from Law *et al.* (2009) consisting algal growth, algal grazing, zooplankton growth and zooplankton mortality functions into the SALMO-OO simulation library. Combination of this new process models were tested on dataset from Lake Kenyir, Lake Penang, Saidenbach Reservoir and Roodeplaat Dam within the simulation library to discover the optimal model structures for respective water bodies. Even though the new process model was not selected in complete totality as the optimal model structure for any of the test lakes, the addition has added another alternative for water body simulation in SALMO-OO process library.

Based on these forecasting results, both SALMO-PLUS and HEA have showed potential for utilisation in early warning and strategic control of algal blooms in tropical freshwater lakes. The generic nature of HEA forecast model was also observed when tested for forecasting algal biovolume for merged data of similar lake ecosystem category. Results from merged Lake Kenyir and Lake Penang data showed reasonable accuracy in predicting the timing and magnitudes of algal blooms up to 7-days-ahead. Addition of the new process model from Law *et al.* (2009) into the SALMO-PLUS simulation library has also expanded the alternative for lake category simulation to give a more comprehensive decision support tool for lake and reservoir management. This study has also affirmed the generality and flexibility of SALMO-PLUS for usage in tropical lakes modelling. SALMO-PLUS was observed to be capable of simulating simultaneous seasonal fluctuations in algal growth and nutrients (phosphate and nitrate) making it valuable for forecasting the impacts of various simulated scenarios for various lake management regimes.

Declaration

I declare that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Libraries, being made available in all forms of media, now or hereafter known.

Mohd Yusoff Ishak

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