Comparative Ecological Study of Two Dutch Lakes Using Computational Modelling

A Thesis Submitted for the Award of Doctor of Philosophy

Anita Talib B.Sc, B.Sc (Hons), M.Sc
Ecoinformatics and Watershed Ecology Laboratory
School of Earth and Environmental Sciences
The University of Adelaide, Australia

April 2006

Contents

Abstract

Long-term time-series data sets of the eutrophic Dutch lakes Veluwemeer and Wolderwijd were modelled by means of non-supervised and supervised artificial neural networks (ANN) and hybrid evolutionary algoritms (HEA). The lakes appear as hyper-eutrophic and have been managed both with bottom-up and top-down management approaches for the past three decades. Non-supervised or Kohonen ANN (KANN) was applied to both lake data sets for comparative clustering and ordination. Dividing the lake data into three distinctive management periods has facilitated an analysis of both the seasonal and long-term dynamics with regards to eutrophication control. Results of the study have demonstrated that KANN allow to elucidate complex ecological processes (1) within the phytoplankton functional groups and (2) between the specific genus, *Oscillatoria* and *Scenedesmus* and (3) as a result of the combination of external nutrient control and in-lake food web manipulation of the two lakes achieved to control eutrophication. It has been shown that external nutrient control combined with food web manipulation has turned both lakes from nitrogen to phosphorus limitation, from blue-green algae to diatom and green algae dominance and specifically from *Oscillatoria agardhii* to *Scenedesmus* dominance. The second part of this study focussed on the application of recurrent supervised ANN (RANN) and HEA to forecasting and knowledge discovery.

Eleven years of water quality time-series of the two Dutch lakes Veluwemeer and Wolderwijd were subject to predictive modelling by RANN and HEA. The modelling aimed at forecasting changes of the phytoplankton community in response to the control of external nutrient loadings and fish abundances as consecutively implemented to both lakes since 1979. The water quality time-series of both lakes were structured for the RANN and HEA modelling using single-lake and merged lake data sets in order to reflect following three different management periods by both training and validation datasets: no management (1976-1978), lake flushing and waste water treatment (1979 onwards) and lake flushing, waste water treatment and food web manipulation (1991-1993). This approach facilitated a comparative analysis for the two lakes and the three management periods. Firstly, RANN achieved reasonably accurate results for 5-days-ahead forecasting of abundances of blue-green algae *Oscillatoria* and green algae *Scenedesmus* in both lakes. Secondly HEA achieved similar good forecasting results but also provided model representations for both algae species in the form of rule sets. HEA has been designed to evolve both the structure of rule sets as well as the parameter values imbedded in the rule sets by means of a genetic algorithm.

The use of merged lake models for prediction using RANN and HEA is a novel approach. The rules sets for chlorophyll-a, *Oscillatoria*, *Scenedesmus* and phytoplankton functional group dynamics discovered are generic for both shallow lakes in relation to eutrophication.

With regards to the different approaches for eutrophication management the modelling results have shown that only the combination of external nutrient control with food web manipulation has changed the lakes from hypereutrophic to mesotrophic conditions reflected by the change from the dominance of blue-green algae *Oscillatoria* to the dominance of green algae *Scenedesmus*. Even though both modelling techniques have forecasted the succession of two functional algal groups represented by *Oscillatoria* and *Scenedesmus* only HEA provides rule sets for the explanation of these ecological changes. Modelling of the phytoplankton dynamics at the chorophyll-a level and phytoplankton function group levels revealed similar forecasting results, showing successional changes from hyper-eutrophic conditions (1978) dominated by blue-green algae followed by increasing diatoms and green algae abundance (1985 and 1993) that can be explained by sensitivity analyses and the HEA rule-sets discovered. The results revealed that phosphorus limitation by means of seasonal lake flushing and wastewater treatment in combination with increased zooplankton grazing by food-web manipulation diminished the abundance of the harmful blue-green algae groups, and *Oscillatoria* but enhanced the abundance of harmless green algae groups, *Scenedesmus* and diatoms. These findings are consistent with literature findings e.g. by Benndorf (1995) that the eutrophic lakes requires primarily efficient nutrient control that secondarily can be finetuned by food-web manipulation.

This led to the final part of the thesis, which involved modelling of phyto- and zooplankton dynamics as a result of biomanipulation in Lake Wolderwijd by applying the integrated modelling approach of KANN, RANN and HEA. The results have shown that the changes that occur at the phyto- and zooplankton functional groups or individual genera reflect the dynamics of the lakes on a short-term and long-term basis. The clear-water, grazing-induced hypothesis proved that the dynamics of the food web, although complex; are predictable and also explanatory, within the limits of the variables tested and the assumptions made.