9th IWA Symposium on Systems Analysis and Integrated Assessment
14-17 June 2015, Gold Coast, Australia

Modelling aquatic ecosystem health: The changing role of prediction

Hipsey, M.R.*
*Aquatic Ecodynamics, School of Earth and Environment, The University of Western Australia

Keywords: hydrodynamic-biogeochemical model; water quality; ecosystem service

Summary of key findings

This presentation reflects on recent advances and current challenges related to the prediction of water quality and biogeochemical function of natural water bodies. The analysis identifies significant recent improvements in our ability to predict biogeochemical processes in aquatic systems, such as oxygen dynamics and nutrient cycling, however, there are still limitations on our ability to accurately simulate algal blooms and toxin production, pathogen dynamics, and the overall "health" of an aquatic system. Advances in sensors and data-assimilation approaches have the potential to significantly improve our prediction ability. In order to more sustainably manage natural waters, it is argued that the application of models must advance to be able to assess the relevant ecosystem services systems are providing, thereby allowing a more holistic view of system function.

Background and relevance

Natural waters including lakes, reservoirs, rivers and estuaries support multiple ecosystem services vital to society and form a critical part of the integrated water management cycle. Yet in both developed and emerging economies they remain subject to deterioration despite our best management efforts. A particular concern within Australia is understanding how changes to hydrological regimes, due to both water diversions or climate variability, may amplify the effects of existing stresses such as eutrophication and algal blooms, acid sulfate soils, hypoxia and anoxia, and loss of biotic habitat such as fish nurseries. A range of model types have become widespread to simulate aspects of aquatic system dynamics and identify impacts to ecosystem condition and risks to public health, but how good are our existing platforms to assess a broad range of attributes relevant to integrated water management within river basins? In particular, developing reliable models able to connect hydrological change and management actions to water quality attributes as well as overall ecosystem "health" remains challenging (Gal et al., 2014). By reflecting on various examples, this analysis assesses where models of the natural environment perform well and identifies where further research is required to allow them to better inform management and decision-making.

Results

Several case-studies of modelling inland water systems taken from across the nation are described, where coupled hydrodynamic-biogeochemical models have been applied and adapted to assess the above management challenges. These include urban river-estuarine systems such as the Swan-Canning Estuary (Hipsey et al., 2013), the Yarra river (Bruce et al., 2014) and the lower Murray River (Hipsey et al., 2014), and various reservoirs. Analysis of the these diverse examples identifies that a reasonably high level of prediction accuracy can be attained for attributes such as temperature, salinity, oxygen and nutrients, and sometimes chlorophyll. However it also highlights limits to our prediction ability, including:

- There remains uncertainty as to the level of model complexity that is required to satisfactorily predict key attributes relevant to assessing overall aquatic system health or public health risk.
- For many of the areas outlined above it is critical to model the interaction of waterbodies with the terrestrial margin, by integrating with models of riparian ecohydrology.
- Connectivity between systems in complex aquatic landscapes are still poorly captured by our model tools, yet essential to build a system-scale picture of catchment sustainability.

- More effort is required to validate models against system-scale emergent properties and signatures, to ensure models are fit to assess the long-term impacts of multiple stressors.

Discussion

Limitations that are identified above clearly highlight the need for more rigorous process and system-scale validation of model predictions to improve their utility, a framework for which is proposed in Figure 1. Opportunities for improved uncertainty assessment through model validation against advanced data streams from sensor networks are emerging and are rapidly changing the level to which we can assess model suitability. However, there still remains limited experience in using sensor data for improving models of natural waters, and new methods are required to support efficient data assimilation frameworks.

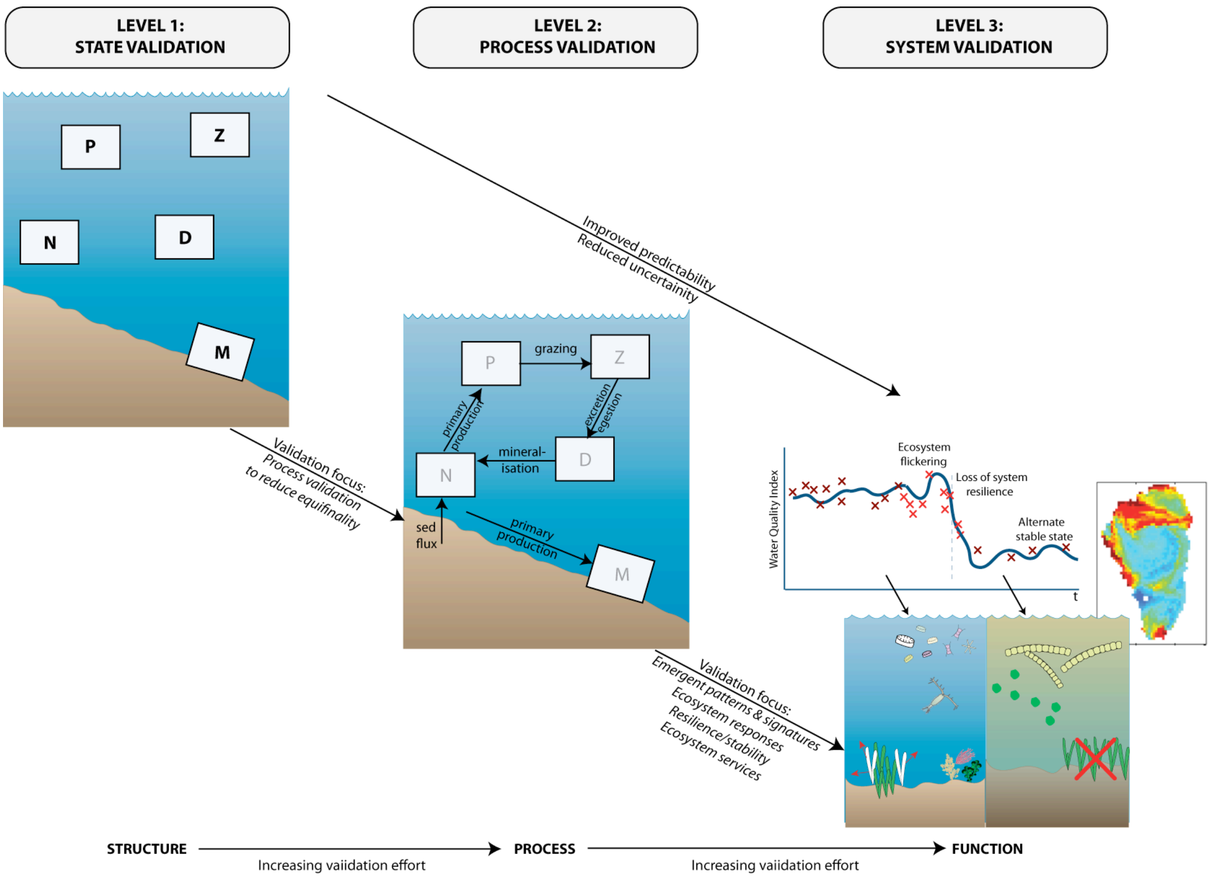

Figure 1 Overview of an improved framework for assessment of process-based models that are used to simulate natural water bodies, such as lakes, rivers and estuaries.

Finally, it is argued that new approaches to compute ecosystem services are required that are compatible with model outputs in order for models to provide more relevant outputs to decision-makers about management benefits and priorities. This requires the development of suitable proxy indicators of ecosystem services that natural waters provide, for example, pollution attenuation, water supply, habitat provision, and recreational use (e.g., Figure 2). It is anticipated that extending models to have this ability is essential for us to holistically assess the resilience of natural systems in response to degradation pressures and allow the optimisation of management activities.

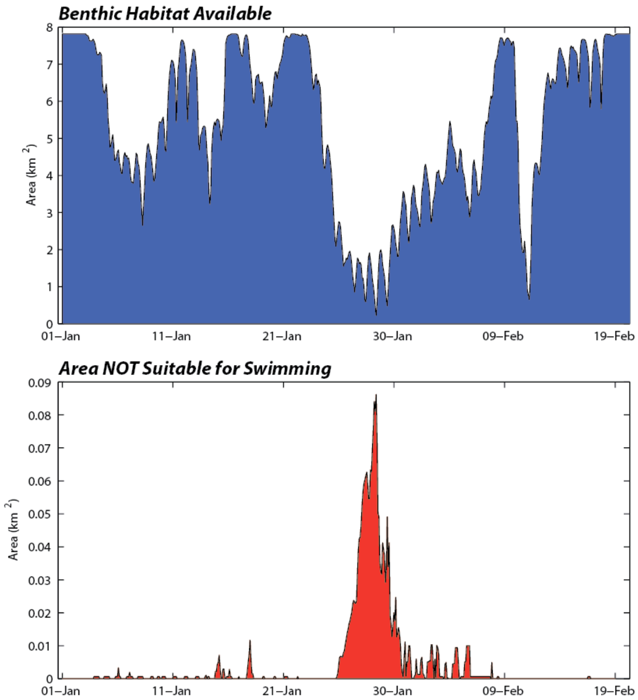

Figure 2 Example of system-scale ecosystem service proxies for the Upper Swan estuary, computed by integrating 3D output from the model of Hipsey et al., (2013), over a region of interest. The benthic habitat available data (top) is based on area below the critical oxygen threshold for biota, whereas the area not suitable for recreational use (bottom) is based on the likelihood of high cyanobacteria growth rates.

References

Bruce, L.C., Cook, P.L.M., Teakle, I. and Hipsey, M.R. (2014) Hydrodynamic controls on oxygen dynamics in a riverine salt-wedge estuary, the Yarra River estuary, Australia, *Hydrology and Earth System Sciences*, 18, 1397–1411

Gal, G., Hipsey, M.R., Rinke, K. and Robson, B. (2014) Novel approaches to address challenges in modelling aquatic ecosystems, *Environmental Modelling & Software*, 61, 246–248

Hipsey, M.R., Bruce, L.C. and Kilminster, K. (2013) A 3D hydrodynamic-biogeochemical model for assessing artificial oxygenation in a riverine salt-wedge estuary. In: Piantadosi, J., Anderssen, R.S. and Boland J. (eds) *MODSIM2013, 20th International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, December 2013, 1770–1776, ISBN: 978-0-9872143-3-1

Hipsey, M.R., Salmon, S.U. and Mosley, L.M. (2014) A three-dimensional hydro-geochemical model to assess lake acidification risk, *Environmental Modelling & Software*, 61, 433–457