# Investigating the role of model structure on the performance of estuarine biogeochemical models

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I am working on a CSIRO Complex Systems Science (CSS) postdoctoral project investigating estuarine biogeochemical models, with an emphasis on exploring model structure and its impact on model performance. The work is part of a larger CSIRO CSS project entitled "The effects of model structure and dimensionality on the emergent properties of ecosystem model", led by David McDonald at CSIRO Marine Research.

Most of Australia's population lives on estuaries. Estuaries are the recipients of upstream land use, they in turn impact neighbouring reef systems, we build our cities next to them, they are rich sites of biodiversity and they are important breeding grounds for a variety of coastal fauna. The estuarine biogeochemical models developed within CSIRO Marine Research consist of a set of non-linear coupled differential equations representing the fate of nutrients entering a water body. The models account for water-column and sediment nutrient transformations, primary production and water column transport processes. The biogeochemical models have also been coupled to three-dimensional fluid mechanics models, allowing further exploration of important interactions between transport and chemical reactions. These models are needed to untangle and understand the underlying processes controlling water quality in estuaries. They have been used primarily as a research tool, but are increasingly being called upon to guide decision-making in human-impacted estuaries. A particular concern is that in specific situations these models have predicted dramatic flips between alternative states, with pronounced hysteresis effects: once an estuary has switched into an undesirable algal-dominated state, the change can't be reversed simply by undoing the actions that caused its deterioration in the first place.

My interest in these models is that there are some quite fundamental questions that need to be addressed, particularly with regard to model structure. These include:

1. The models extrapolate beyond existing conditions and make predictions about potentially dramatic flips to alternative system states. We are concerned that the results are sensitive to the underlying model structure and

in particular to the network of interactions among model components and the prescribed functional response of system components. How can this structural sensitivity be investigated and quantified?

2. Can we find lower dimensional representations of higher dimensional models? Due to the non-linear nature of these systems, a fully spatially resolved model produces markedly different results to its equivalent 'single box' model working only with basin-wide averages of all quantities. The computational requirements of the full model prevent a thorough exploration of the solution space, so simple models which capture the important spatial and temporal dynamics emerging from the full system are needed.

3. I'd like to explore questions of system resilience to disturbance (eg. meteorological variability, climate variation and land use change). Can model structure (eg. the network topology of interacting components) offer any insight into system response to disturbances?

4. How does the estuarine model interact with other models of different structure, timescales and spatial scales, such as catchment models and socio-economic models? Estuarine biogeochemical models will need to be integrated into these broader modelling frameworks in the future.

I hope to collaborate with other CSS researchers within the organisation in order to seek diverse ways of tackling my research questions. I attended the Santa Fe Institute Complex Systems Summer School in Santa Fe this year, and received introductory training in a number of CSS areas, including nonlinear dynamics, information theory, genetic algorithms and multi-agent systems. I will be drawing on these experiences and the wider CSS literature to guide my research over the next three years.