



Preface

Challenges for a new generation of marine ecosystem models: Overview of the Advances in Marine Ecosystem Modelling Research (AMEMR) Symposium, 23–26 June 2008, Plymouth UK

Since the early work of pioneers such as Gordon Riley and John Steele, modelling has remained an important tool for marine scientists, providing a means for the testing of understanding, synthesis and prediction. Giving the difficulties and expense of obtaining observations in the field, modelling provides the attractive capability to extrapolate and generate the bigger picture. However the emerging appreciation of the complexity of marine systems at many scales delivers huge challenges to model based science. Whilst evolving sophistication, coupled with rapidly increasing computational capacity, can make the predictions of models both attractive and persuasive, there remains the potential to seduce as well as elucidate. Further, modelling is a tricky business, and yet the underlying methodology is rarely afforded a deep appreciation. Who, for example, would consider the general modelling approach to be akin to that of the deductive method used by the fictional detective Sherlock Holmes (as proposed by [Anderson, 2010-this issue](#))?!

Model based predictions, for example those addressing climate change, are squarely in the public domain and many model applications are becoming specifically targeted towards management needs ([Wild-Allen et al., 2010-this issue](#); [Lenhart et al., 2010-this issue](#)). There is therefore a need for models to be carefully scrutinised, the onus being for simulation results that are rigorous, demonstratively evaluated and in themselves clearly understood. The very concept of a 'model' can mean many different things to different people, from precise replication to broad representation, from phenomenological models to process models, from simplistic to complex. Poor definition of a given model's *raison d'être* and lack of consideration of its limitations can frequently lead to misconceptions and erroneous interpretation. Much of the debate about the ideal level of complexity to be employed in models has for example been clouded by poor perception of the different needs of, say, earth system and ecosystem models ([Allen et al., 2010-this issue](#)) whose contrasting scales require different approaches. Further confusion arises from the necessary compromises that modellers make between approaches that are generally representative and rely on parameter tuning ([Ward et al., 2010-this issue](#)) and those that are mechanistically based and so rely on accurate and complete representations of key processes.

The AMEMR conferences (and associated workshops) were conceived to provide a forum for marine ecosystem modellers to discuss and share problems and solutions. The first of these conferences, held in 2005, highlighted a number of key challenges facing the modelling community ([Blackford et al., 2007](#)):

- How do we balance increasing model complexity, which is frequently needed to represent all relevant processes such as system

feedbacks, with the resulting increase in uncertainty associated with parameterisation?

- How can we enhance collaboration between modellers and experimentalists?
- How can we better evaluate, understand and reduce model errors?

The 2008 meeting, three years on, gave the community an opportunity to gauge progress and define new key challenges.

The conference was attended by around 160 scientists with significant representation from the Americas, Australasia, and Asia, as well as Europe and the UK. The entire meeting was held in plenary, a deliberate strategy to facilitate cross disciplinary communication and fertilisation. The conference comprised nine sessions over the four days covering climate related change, evaluation, operational models, complexity, processes, biodiversity, higher trophic levels, end to end ecosystems and environmental management.

The three year gap between meetings provided sufficient time for scientists to respond to challenges, as well as for the community as a whole to gauge progress. In particular, the marked increase in papers that seriously address the issue of model evaluation is encouraging ([Lynch et al., 2009](#) and papers within; [Los and Blaas, 2010-this issue](#)), as is the development in methods of treating complexity and model interpretation. What, then, are the key challenges facing those developing marine ecosystem models today?

The issue of model complexity remains perhaps the key challenge facing the modelling community, which was brought into focus by [Anderson \(2005\)](#). The debate continues, focussing on the continuum between Nutrient–Phytoplankton–Zooplankton (NPZ) and functional group models, the veracity of their process descriptions and the accuracy of parameterisations. Recent studies have suggested that the inclusion of additional articulation, such as variable stoichiometry or extra trophic links, in models may lead to greater generality and portability, although only if the underlying mechanisms are accurately represented ([Friedrichs et al., 2007](#) and [Ward et al., 2010-this issue](#)). The goal of producing an ecosystem model for climate studies that includes key system feedbacks, has a single parameter set, and which is both accurate and globally robust ([Fasham, 1993](#)), has not yet been realised. In part, difficulties in achieving this aim arise from the imperfect physical descriptions of regional and global systems that underpin the descriptions of biogeochemistry, and the sensitivity of biological parameterisations to small variations between physical models ([Sinha et al., in press](#); [Allen et al., 2010-this issue](#)). Physical processes impact upon many biological processes, including turbidity (see [Le Fouest et al., 2010-this issue](#)), phytoplankton competition ([Perruche et al., 2010-this issue](#)) and planktonic and larval distribution ([Savina et al.,](#)

2010-this issue), underscoring the importance of the appropriate treatment of physical properties.

So, if recreating contemporary observations in simulation models remains a challenge, where does this leave predicting the future? Future states will be affected by multiple interacting drivers including climate, weather, acidification, eutrophication and resource use, all of which are likely to alter over time (Blackford, 2010-this issue). Indeed some studies indicate that, for example, the impacts of ocean acidification could be sensitive to changes in climate and vice versa (e.g. Pörtner and Langenbuch, 2005). The challenges cannot be underestimated when it comes to assessing multiple driver impacts, and at the same time providing reasonable predictions of future weather patterns or human behavioural responses.

Marine ecosystems are not static and have the potential for acclimation, adaptation, feedbacks and species shifts, such as the shift seen from cold water to warm water calanoid species with their different phenologies in the North East Atlantic (Beaugrand et al 2002). Another example, central to quantifying the impact of ocean acidification is that not all calcifiers are the same nor may respond in the same way, a problem exacerbated by our lack of understanding of the associated physiology. Parameterisations may often be based on experiments carried out on a handful of species or laboratory cultures that do not adequately represent the diversity of species seen in the field, nor their plasticity to changing environment. How, therefore, should this diverse group of organisms be represented in models? Currently, many models do not allow for such plasticity within functional groups. Another common omission is that of trophic flexibility, which in itself affords a degree of plasticity to a model system but necessitates a food web rather than food chain approach.

These difficulties beg the question: are these traditional thermodynamic or Newtonian approaches, characterised by energy and mass conservation, fundamentally limited in scope, and are there alternative approaches that may move toward more realistic structures (food webs). A relatively new class of models has presented an appealing solution to defining model structure – let the structure itself be an emergent property of the simulation, e.g. ‘Darwinian’ approaches such as complex adaptive and stochastically defined emergent systems. These novel methods have the advantage of conceptual simplicity, and encourage the use of physiologically consistent relationships (Follows et al., 2007; Pahlow et al., 2008).

A holy grail for modellers is to develop a rigorous representation of the system end to end (i.e., from physics to fish), the challenges of which are discussed by two papers in this issue (Fulton, 2010-this issue) with an applied example described by Fennel (2010-this issue). One of the pressure points for end to end modelling is in correctly describing zooplankton because trophic level provides the link between two distinct communities of modellers – the lower trophic functional community, often addressing biogeochemical issues, and the higher trophic species community that addresses fish stocks. Issues relevant to representing zooplankton in models are discussed in three papers in the special issue, (Neuheimer et al., 2010-this issue; Uttieri et al., 2010-this issue).

In listing emerging challenges, it is necessary to take into consideration the increasing pressure on scientists to deliver products that speak more directly to research users – policy makers and environmental managers (e.g., Wild-Allen et al., 2010-this issue). One consequence is that the horizons of the modelling effort are expanding to include socio-economic interpretation (e.g. Merino et al., 2010-this issue). Quantification of uncertainty is strongly desired by policy makers, but this is rarely achieved in studies using deterministic models. It is envisioned that probabilistic approaches based on scenario ensembles are more likely to deliver reliable information to policy makers, but this puts pressure on computational resources and analysis techniques (Lenhart et al., 2010-this issue). Thus the development of efficient and clever analysis methodology, (multivariate, Bayesian, neural nets etc) is relevant to the final challenge listed above.

The AMEMR meetings have provided a valuable forum for the international modelling community. Consequently, it is our intention to organise a further open conference, to be held during the summer of 2011. It will be interesting to assess then to what extent the challenges identified here have directed progress in the intervening years.

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