Roadmap for development of UK Ecosystem Modelling

Output from Joint MSCC/MASTS Workshop on Ecosystem Modelling, May 2014

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The MSCC Science Alignment Working Group sponsored an initiative to assess UK ecosystem modelling capability and develop a roadmap for the future. This aimed to maximise the uptake of ecosystem models in policy and regulation. This paper is the outcome from a joint MSCC/MASTS workshop on ecosystem modelling that brought together advisors, assessors, biologists, socio-economists, modellers, policy makers, and funders. Here, we describe the future vision and current state, and then outline the roadmap for development of UK ecosystem modelling needed to achieve the future vision.

Future Vision for UK Ecosystem Modelling

Implementing ecosystem-based management requires sufficient understanding to support the assessment of impacts on whole ecosystems over long periods of time. The funding needed for data collection is considerable but limited, so it is important to examine new cost-effective ways of obtaining and processing data. Ecosystem models are central to delivering current and future policy requirements including: predicting the effects of competing management options, assessing potential impacts across the whole ecosystem, testing the sensitivity of socio-ecological indicators, optimising monitoring programmes, understanding the application of theoretical concepts like Maximum Sustainable Yield (MSY), developing ecosystem service flows, and providing an assessment of the risk associated with management measures.

To realise the potential of UK ecosystem modelling, we have the following vision:

"To deliver world-class ecosystem modelling that supports our understanding, use, and management of the marine environment through impact on policy and regulatory decision making."

To achieve this vision, the UK ecosystem modelling community needs to adopt **5 core principles**:

1. ***Maximise policy and regulatory impact*** – ensure policy makers know where and how ecosystem models can be used, and maximise the impact of existing models on policy and regulatory decisions.
2. ***Build multidisciplinary communities*** – build multidisciplinary communities of policy makers, observationalists, modellers, data scientists, and socio-economists. These will speak a common language, have regular contact, share new policy requirements, and co-deliver ecosystem modelling.
3. ***Deliver novel policy-relevant science through ecosystem modelling*** – maintain the UK at the forefront of ecosystem model development, horizon scan new science to maximise pull through of new techniques, and put in place programmes to fill existing knowledge gaps that could be addressed using models.
4. ***Ensure quality and availability of model-derived products*** – define and employ rigorous quality standards to satisfy legal challenge in policy and regulatory decisions, and ensure that model-derived products are available and robust.
5. ***Produce people with the right skills*** – assess existing UK ecosystem-modelling capacity and develop training programmes for new personnel with the right skills to ensure that the utility of ecosystem modelling is optimised in future.

Current State of UK Ecosystem Modelling

The UK is a leader in marine ecosystem modelling, and has developed many classes of marine ecosystem models from those representing low trophic levels to size-based approaches to models of the whole food web (Hyder et al. 2014a). The UK has a key role in the development and application of ecosystem models, but also draws on experience from the international scientific community. There are a limited number of model types, and various models within each type that can be applied to ecosystem problems, so the challenge is the application of these methods to address specific management questions. Parameterisation and validation of large complex ecosystem models often relies on limited data sets, so there is a challenge to make best use of existing data. To encompass a wide range of both physical and biological processes, models often need to be coupled, which is usually a technical challenge and may affect the mechanics of the individual components. The UK is a leading proponent of the application of ecosystem models, the coupling of models, and development of ensemble approaches. Specific examples of the application of ecosystem models in support of policy include forecasting water quality, eutrophication in the North Sea, and Maximum Sustainable Yield (MSY) and the Large Fish Indicator (LFI).

While the UK has leading capability in ecosystem modelling, this capability is widely dispersed across the community in different member organisations using different types of ecosystem models for different purposes. Often groups are quite isolated from the policy makers that need model-derived products and this is one of the barriers to maximising the utility of UK ecosystem models in policy. Firstly, it is important to produce the right information from models to inform policy and this can only work where there is good dialogue between policy makers and modellers. Policy makers need to have confidence in model-derived products and be provided with information about the uncertainty around predictions, especially where policy and regulatory decisions could be subject to legal challenge. Modellers need to improve the visibility of models and access to model-derived products, so that they become more widely used, and the methods are transparent. Finally, there is need for targeted development of ecosystem models to address specific issues including scales of applicability, validation, uncertainty, and data assimilation.

For a full description of the current state of UK ecosystem modelling and the key challenges associated with development and utility of ecosystem modelling see Hyder et al. (2014a).

Roadmap for development of UK Ecosystem Modelling

A joint MSCC/MASTS ecosystem modelling workshop was held in May 2014 that brought together 55 people from 23 organisations across England, Wales, Scotland and Northern Ireland to set the agenda for the future of UK marine ecosystem modelling. The workshop brought together advisors, assessors, biologists, socio-economists, modellers, policy makers, and funders, to build a shared understanding and improve communication. This roadmap reflects the outputs from the workshop and generated a set of actions that will take the UK towards the delivery of its vision for ecosystem modelling. This has been developed in the context of the 5 core principles described above. Actions have been identified for the next 12 months to address each issue including key contact and delivery date. A delivery plan for future years will be built on the basis of these outputs.

Maximise policy and regulatory impact

The potential for quick wins to increase the use of model-derived products in the policy and regulatory environment were developed as part of the MSCC/MASTS ecosystem modelling workshop (Table 1). While there is good potential for progress, there were also concerns about the translation of policy needs to tractable modelling questions (Hyder et al. 2014b). Some work is required on each of these quick win topic areas to better identify how work that is already being done can deliver these aims (e.g. NERC MERP and SSBGC programmes) and to put mechanisms in place to do so. This work should focus on attributing drivers of change, integration of models and monitoring to maximise the efficiency and utility of existing programmes, assessing MSFD indicators and interactions between MSFD descriptors, and cost-benefit of the implementation of legislation (Table 1).

ACTION 1: assess delivery of quick wins from existing research programmes and indentify mechanisms for delivery of the quick wins. Leads: Steve Mackinson, Kieran Hyder, & Stuart Rogers by Oct 2014.

The two page model summaries produced for the workshop were difficult to understand and not useful for either modellers or policy makers. A simple description is required for policy makers of the existing and potential impacts of each of the ecosystem models on policy and science to maximise the utility and uptake of ecosystem models for policy-making.

ACTION 2: develop and deliver more useful ecosystem model summaries for policy and decision makers. Leads: Kieran Hyder & Caron Montgomery by Oct 2014.

Build multidisciplinary communities

It was clear at the workshop that there is need for more dialogue between the community of policy makers, observationalists, modellers, data scientists, and socio-economists. There is no common language making it very difficult to maximise the utility of the ecosystem models for policy making and there is need to engage policy makers in discussions with modellers. Horizon scanning the policy landscape is also needed to identify new areas where ecosystem models can be used and have techniques available within the timescales required for policy. Inclusion of the observationalists in this community will ensure that we maximise the utility of data collected to enact the principles of "collect once, use many times" and exploit emerging data sources (e.g. gliders, ships of opportunity).

ACTION 3: create a regular forum to increase the dialogue between the communities that collect data, develop models, and those that use model-derived products. This will also provide a mechanism for identifying new policy challenges where ecosystem models can be used. Leads: Kieran Hyder & David Paterson by Dec 2014.

Deliver novel policy-relevant science in ecosystem modelling

There are knowledge gaps in our existing ecosystem modelling capability that are needed to deliver useful input for existing policy and regulation. Ecosystem models are not routinely used to assess the impact of non-native species, disease transmission, ocean acidification, the land-sea transition zone, networks of MPAs, cumulative effects, socio-ecological systems, human behaviour, and pollution and spills (Table 1). Development of models in these areas could increase the impact of UK ecosystem modelling. It may be possible to address all these new areas, but the need for development must be addressed in the context of other existing models (e.g. Marxan for MPAs, OSCAR for spills), international ecosystem modelling capability (e.g. France), and other modelling strategies (e.g. the NERC strategy for ocean modelling – Holt et al. 2013).

ACTION 4: identify mechanisms for the development of ecosystem modelling and work with NERC and the EU to set up programmes to address these areas. Leads: Icarus Allen, Axel Rossberg, & Jason Holt by Dec 2014.

Horizon scanning of new scientific methods is required to maximise the utility of ecosystem models in the next few decades. It is also useful to consider the development of modular code and model coupling as ways of developing quick wins across disciplines (e.g. scales, uncertainty and ensembles). Many of these are already being addressed in current programmes including EU FP7 (e.g. Operational Ecology - model coupling), NERC (e.g. shelf-seas biogeochemistry programme – uncertainty, marine ecosystem research programme - socio-ecological systems), and working groups (ensembles - ICES Working Group on Multispecies Assessment Methods).

ACTION 5: identify methods for multi-model ensembles for ecosystem modelling and incorporating ecosystem models into a socio-ecological framework for adaptive management that can be used for policy development. Leads: Julia Blanchard, Momme Butenschon, & Mel Austen by Dec 2014.

Ensure quality and availability of model-derived products

At present there is little consistency in quality assurance of model products with different systems being used across the academic and government communities. A common quality assurance standard is required for all models that are used in a policy context could be subject to legal challenge, so model-derived products need to be robust, transparent, efficient, and tested against the best data available. There are quality standards that have been developed and implemented for government and government suppliers called Analytical Quality Assurance (AQuA). This or an equivalent level of quality assurance needs to be available for all models that impact on the policy and regulatory environment.

ACTION 6: produce simple documentation outlining the principles of AQuA and the expectation of quality assurance for all model products used by the government. Leads: Rosa Barciela & John Bacon by Nov 2014.

Model-derived products are not always freely available for use by the modelling community, although some are provided routinely through initiatives like Copernicus (http://www.copernicus.eu/). It is important that model products are made available to the scientific community in order to maximise the impact of ecosystem models on policy.

ACTION 7: identify systems available for delivery of model products and produce simple guidance for their use. Leads: Rosa Barciela & John Bacon by Dec 2014.

Produce people with the right skills

The workshop participants identified specific areas where development of a skills base is required before we can maximise the utility of ecosystem models. The key areas identified were bio-economic modelling, socio-economics, and systems thinking. It is necessary for us to work together as a community with NERC and MASTS to develop training programmes in these areas.

ACTION 8: list existing UK capability in bio-economic modelling, socio-economics, and systems thinking and potential mechanisms to develop training programmes. Leads: Mike Heath (bio-economic modelling), Mel Austen (socio-economics), & Sheila Heymans (systems thinking) by Dec 2014.

ACTION 9: develop training programmes if required in bio-economic modelling, socio-economics, and systems thinking. Leads: Mike Heath (bio-economic modelling), Mel Austen (socio-economics), & Sheila Heymans (systems thinking) by Mar 2015.

References

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Table 1: Potential for use of ecosystem model-derived products in addressing policy needs in terms of quick wins, multi-model *ensembles (in italics)*, and gaps that cannot currently be addressed.

Theme	Quick Wins	Gaps
Environmental change and climate adaptation	• *Regional scale climate impacts and their value* • *Attributing change in ecosystems to environmental drivers and the systems response* • *Impacts of changes in shelf-seas biogeochemistry on ecosystem state, function and services*	• Introductions and impacts of non-native species • Animal and human disease • Local effects of pressures • Impacts of ocean acidification • Impacts on the land-sea transition zone • Impacts of geo-engineering • Impacts of offshore structures
Natural variability and monitoring	• *Distinguishing between the sensitivity and utility of different indicators.* • *Quantifying uncertainty* • Integration of models with monitoring to increase efficiency • Identifying current system state	• Improve the ability of models to capture inter-annual variability and long term trends.
Management measures, goods and services	• *Efficient programme of measures for achieving GES* • Impacts of landing obligations on MSY through food webs interactions • *Management strategies for achieving MSY in a mixed fishery* • *Effects of fishery management on food webs* • *Cost-benefit of implementation of legislation (e.g. MSFD, CFP, WFD)* • *Marginal costs / values of changes in ecosystem services* • *Links between ecosystem function and services*	• Assessing networks of MPAs in terms of connectivity, achieving management objectives and socio-economics. • Cumulative effects • Risk of decline of endangered species from CFP reform • Coupling between ecosystem services and benefits in socio-ecological systems
Good Environmental Status, state and pressure	• *Sensitivity of indicators to management measures and identification of better indicators* • *Effects of pollution on the marine environment* • *Interdependencies between MSFD descriptors*	• Impacts of population dispersants • Interdependencies between different descriptors within MSFD • Model interoperability – modular approaches