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Making modelling count - increasing the contribution of shelf-seas community and ecosystem models to policy development and management

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ABSTRACT

Marine legislation is becoming more complex and marine ecosystem-based management is specified in national and regional legislative frameworks. Shelf-seas community and ecosystem models (hereafter termed ecosystem models) are central to the delivery of ecosystem-based management, but there is limited uptake and use of model products by decision makers in Europe and the UK in comparison with other countries. In this study, the challenges to the uptake and use of ecosystem models in support of marine environmental management are assessed using the UK capability as an example. The UK has a broad capability in marine ecosystem modelling, with at least 14 different models that support management, but few examples exist of ecosystem modelling that underpin policy or management decisions. To improve understanding of policy and management issues that can be addressed using ecosystem models, a workshop was convened that brought together advisors, assessors, biologists, social scientists, economists, modellers, statisticians, policy makers, and funders. Some policy requirements were identified that can be addressed without further model development including: attribution of environmental change to underlying drivers, integration of models and observations to develop more efficient monitoring programmes, assessment of indicator performance for different management goals, and the costs and benefit of legislation. Multi-model ensembles are being developed in cases where many models

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exist, but model structures are very diverse making a standardised approach of combining outputs a significant challenge, and there is a need for new methodologies for describing, analysing, and visualising uncertainties. A stronger link to social and economic systems is needed to increase the range of policy-related questions that can be addressed. It is also important to improve communication between policy and modelling communities so that there is a shared understanding of the strengths and limitations of ecosystem models.

1. Introduction

Marine legislation is becoming more complex as a consequence of increasing and more diverse use of the sea [1]. Commitments to marine ecosystem-based management that influence the UK are specified in national and regional legislative frameworks including the Marine Strategy Framework Directive (MSFD) [2], Common Fisheries Policy (CFP) [3], and the Water Framework Directive (WFD) [4]. However, the funding to provide the empirical evidence base that underpins monitoring, assessment, and management in support of these policies is decreasing in relative terms, requiring increasingly cost-effective decision tools for operational management and scenario planning. The key requirements for decision-makers are to understand links between human and environmental pressures and the state of the environment, to determine suitable management measures to meet objectives, to track progress in relation to those objectives, and to assess the performance of management options based on their environmental, social and economic consequences [5–7]. Shelf-seas community and ecosystem models (hereafter termed ecosystem models) can help to meet these requirements. Specific examples of contributions could include testing the sensitivity of indicators, increasing the cost-effectiveness of monitoring programmes, and supporting practical application of theoretical concepts like maximum sustainable yield (MSY).

Ecosystem models often differ fundamentally from models of physical systems because ecosystem dynamics are rarely directly governed by physical laws alone, but result from complex biological feedbacks requiring some form of approximation. Thus, it is usually important to embrace model diversity to account for uncertainty about the most appropriate model structure [8]. Consequently, multi-model ensemble approaches similar to that used by the Intergovernmental Panel on Climate Change (IPCC) for climate projections [9] can be used to convey uncertainty that results from differences in structure; an approach that is starting to be applied to advice on the management of fisheries [8,10].

Ecosystem models could make a much greater contribution to the evidence base that underpins policy development and decision-making, because they allow a priori testing of policies and management scenarios and quantification of the risk and uncertainty. In most cases, it is impossible to assess the performance of policies and potential management measures without models. For models to fulfil a greater role in policy development and decision-making, and for the associated advice to be treated as credible, salient and legitimate, the modelling approaches used need to be more transparent, verifiable, and repeatable than they are at present.

Ecosystem models are increasingly used in support of marine environmental assessment, management, and policy development in other parts of the world including the USA and Australia (e.g. [11,12]), but are not routinely used in the UK and Europe. In this paper, the prospects for increasing the contribution of community and ecosystem models to the evidence base that underpins assessment, management and policy support is assessed. Focussing on the UK shelf-seas community and ecosystem modelling capability, the range of models available are reviewed, actions expected to increase the uptake and use of these models in environmental management are identified, and priorities for model development, application and presentation are highlighted.

2. UK ecosystem modelling capability and its impact on policy

Many different global marine ecosystem models have been developed [13] and extensive intercomparisons have been made [14], but here the focus is on regional models (e.g. shelf-wide, regional sea) as these have the most direct relevance for application to UK marine environmental policy and management including regulation. UK institutes and universities already use many classes of models that represent different components of the ecosystem (Fig. 1). These range from models of biogeochemistry and low trophic levels (e.g. [15]) to size-based approaches (e.g. [16–19]) and models of the whole food web (e.g. [20,21]). Some ecosystem models have been coupled to physical models and aim to represent the entire system from physics to fishers [22]. Models vary in structure and parameterisation since they have been developed to address different questions by researchers with different philosophies and approaches. For example, ERSEM was originally developed as an end-to-end ecosystem model to study nutrient cycling and planktonic ecosystem dynamics [15], the Population-Dynamical Matching Model (PDMM) (e.g. [23,24]) was constructed to develop theoretical understanding of food-web patterns and biodiversity [25,26], and Ecopath with Ecosim (EwE) to assess the impacts of fisheries on food webs and consequences for fisheries (e.g. [27]).

At least fourteen different marine ecosystem models are being used in the UK (Table 1 and model summaries provided at http://www.masts.ac.uk/research/marine-ecosystem-modelling/). Few of these models have directly influenced or routinely supported management and policy development, but many are likely to have influenced societal and scientific perceptions about the state of the marine environment. This has had an indirect influence on the emphasis given to ecosystem considerations in contemporary policy (e.g. [28–31]). As policy-making is normative and reflects societal values, alongside the evidence base [32], it is often difficult to ascribe direct links between models and decisions. However, there are some good examples including predicting harmful algal blooms, eutrophication, and comparisons between targets for environmental legislation as explained below.

Operational forecasting and monitoring of water quality enables timely interventions by both stakeholders and the agencies responsible for public health. The AlgaRisk monitoring tool is a prototype that provided warnings of algal blooms to support the statutory obligations of the Environment Agency [33,34]. This tool combines data from an operational physical–biological coastal model with satellite observations, and the results are available through an internet portal where users can visualise both model output and observations (http://www.neodaas.ac.uk/multiview/pa/). A demonstration AlgaRisk service was implemented in 2008 to support the European Union Bathing Waters Directive.