Briefing Paper

In recent years, there has been a shift towards holistic, ecosystem-based management (EBM) of marine resources. In Europe, EBM is at the core of the Marine Strategy Framework Directive (MSFD)[1], legislation adopted in 2008 as the environmental pillar to the Integrated Maritime Policy. Internationally, commitments to keep the global warming below 2°C in the framework of the Paris Agreement (COP21) and to protect and sustainably use seas and oceans through the United Nations Sustainable Development Goals 2030 (particularly SDG14) will require integrated marine science and management approaches to monitor progress towards achieving and maintaining targets and goals. Such integrated and holistic management requires analytical tools that can synthesize knowledge across the full array of ecosystem components and interactions, including human activity, rather than considering single issues, species, or ecosystem services in isolation. But is marine science making the quantum leap towards holistic approaches and integrated research? And is this being done on a scale which will help us to better understand, protect, manage and sustainably exploit the seas and oceans which surround us?

Ecosystem modelling is highlighted as a key methodology needed to assess biodiversity and ecosystem services (IPBES)[2]. In particular, end-to-end (E2E) marine ecosystem models offer huge potential as a key analytical tool for evidence-based policy making. In recent years there have been increasing attempts to develop end-to-end models able to integrate physical, biogeochemical and ecological processes – across the full foodweb - into a single comprehensive modelling framework. Recent European projects such as MEECE[3] and OPEC[4] have brought the European community together to further advance the capabilities and relevance of marine ecosystem modelling and marine ecosystem forecasting tools. However, despite clear capability and progress in E2E modelling in Europe and indeed world-wide, there remains a dis-connect between scientific research and what policy makers need to know. *"Though end-to-end ecosystem models have clear utility for marine management, these new purposes, behaviours, and aspects of uncertainty inherent in end-to-end models are unfamiliar to most decision makers."* (Kaplan and Marshall, 2016[5]). Often, policy makers are unaware of the full potential of models for aiding ecosystem management, stemming from a lack of knowledge about the diversity of models (e.g. from linear regressions to 3-Dimensional end-to-end models) and their associated capabilities, limitations and uncertainties. On the other hand, researchers have often designed the models to answer specific scientific questions without knowledge of how the models may be used for policy-related work. How can we make E2E marine ecosystem models more relevant for evidence-based policy making? And how can we better communicate their potential to decision makers? This gap has already been identified by some countries at a national level. For example, in 2014, the UK held a Marine Science Co-ordination Committee workshop run by MASTS and the UK Marine Science Coordination Committee to increase the impact of ecosystem modelling (see workshop report and Hyder and Rossberg *et al.,* 2015[6]). A

[1] http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
[2] http://www.ipbes.net/sites/default/files/downloads/pdf/2016.methodological_assessment_report_scenarios_models.pdf
[3] http://www.meece.eu/
[4] http://marine-opec.eu/
[5] https://academic.oup.com/icesjms/article/73/7/1715/2458746/A-guinea-pig-s-tale-learning-to-review-end-to-end
[6] http://www.masts.ac.uk/research/marine-ecosystem-modelling/ and Hyder, K.*et al*. (2015). Making modelling count - increasing the contribution of shelf-seas community and ecosystem models to policy development and management. Marine Policy 61: 291-302

National Roadmap was produced, together with 5 core principles ranging from training next generation ecosystem modellers to maximizing policy and regulatory impact. **It is now timely to assess research gaps and needs in end-to-end marine ecosystem modelling for ecosystem-based management at a European level.**

Marine ecosystem modelling is a computer intensive science. What possibilities and opportunities will advanced computing unlock in a new era of cluster and cloud computing? Will this make it easier to achieve comprehensive functional models? Or will it fundamentally change the way research is done? In addition, how will new datasets, knowledge and understanding of the marine environment shape the future development and applications of E2E marine ecosystem models? For instance, only 1%–10% of marine microorganisms have currently been described and we are embarking on an era of discovery in the marine microbiome. We are also entering an –omics era where complex biological data such as DNA is not only possible, but is being automated by *in situ* samplers. What crucial data is still to make substantial advances in model validation and process understanding? And how can we ensure a continued dialogue with policy makers to communicate the potential of E2E marine ecosystem models as a key analytical tool in ecosystem-based management which will ensure continued investment in key areas of research and development and capacity building?

About the workshop

The European Marine Board workshop 'Shaping Future Research Agendas' will take place on 7 July 09:00-14:30 at the Plymouth Marine Laboratory (Marine Matters Centre), Plymouth, UK. The workshop is a key contribution to an EMB activity on end-to-end marine ecosystem modelling, Chaired by Morten Skogen (IMR, Norway) and Sheila Heymans (SAMS, UK), facilitated by the European Marine Board Secretariat. The workshop format will consist of interactive group discussions and plenary discussions to seek expert opinion and develop key recommendations. See the full agenda for sessions and discussion topics.

Main aim and outcomes: The workshop will gather leading experts in marine ecosystem modelling to produce community-driven recommendations for R&D gaps and needs for developing realistic end-to-end marine ecosystem models as a tool for ecosystem based management, in the context of key policy drivers. Discussions will focus on, but will not be restricted to, European waters and capabilities. The workshop will produce community-driven recommendations and key messages on R&D needs and priorities for end-to-end marine ecosystem modelling. These will be developed into a EMB Policy Brief and communicated to wider stakeholders, including research funders, marine managers and policy makers. The assessment will also contribute to the development of a more coordinated and comprehensive European Ocean Observing System (EOOS). www.eoos-ocean.eu

Registration: The workshop is run in association with AMEMR and is open to all AMEMR participants free of charge, including a light lunch. Registration is open until 3 July 17:00 BST. Register online at: http://www.amemr.com/shaping-future-research-agendas.html
For further information, please contact Kate Larkin: klarkin@marineboard.eu

The European Marine Board (EMB) is a leading European think tank in marine science policy. The EMB was established in 1995 to facilitate enhanced cooperation between European marine science organizations towards the development of a common vision on the strategic research priorities for marine science in Europe. Members are either major national marine or oceanographic institutes, research funding agencies, or national consortia of universities with a strong marine research focus. In 2017, the Marine Board represents 33 Member Organizations from 19 countries. http://marineboard.eu/