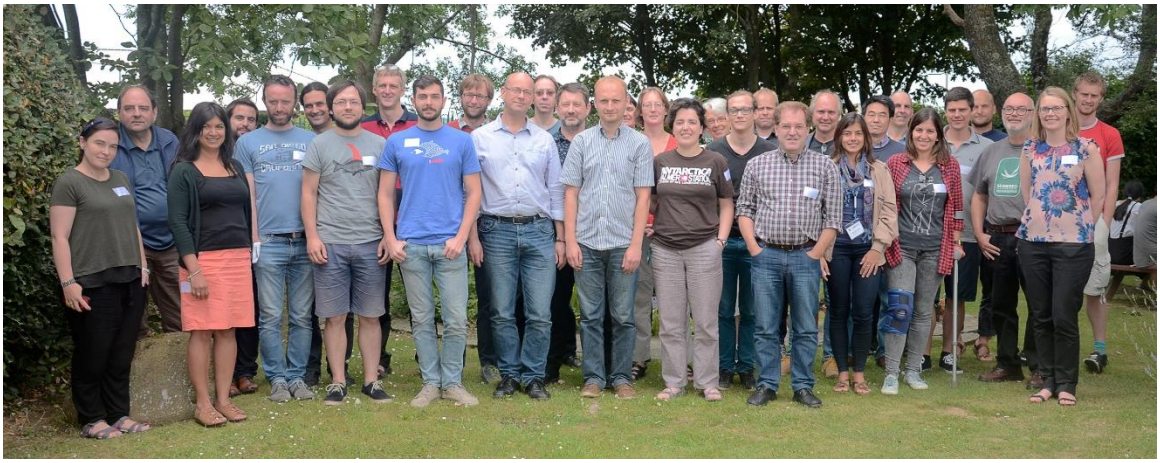
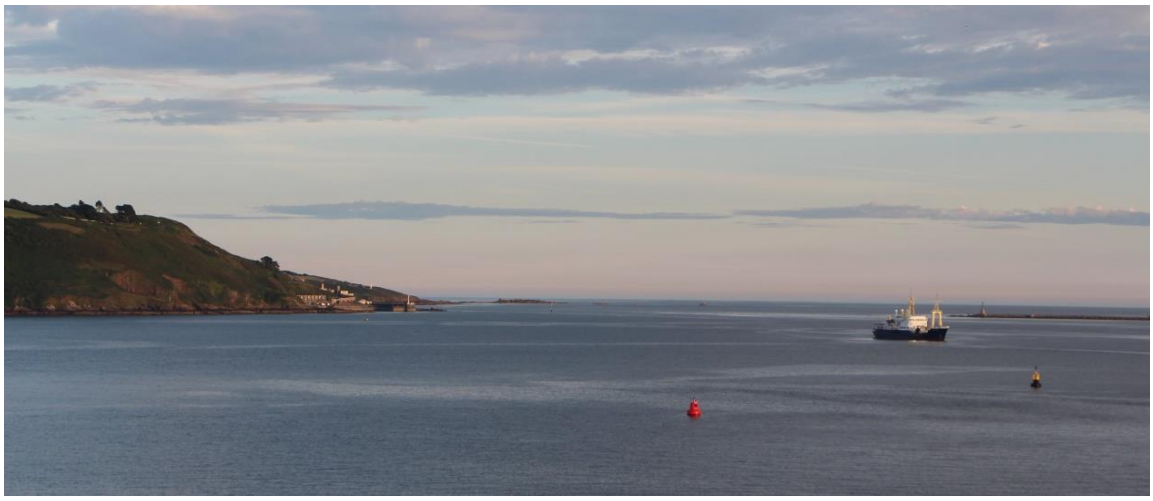
EMB expert workshop: End-to-end (E2E) marine ecosystem models: R&D needs for ecosystem-based management.

7 July, PML (Marine Matters Centre), Plymouth, UK

Workshop report and contribution to EMB WG Marine Ecosystem Modelling



Participants of the EMB expert workshop on marine ecosystem modelling, 7 July 2017, Plymouth, U.K. (Credit: PML)



Plymouth Sound, July 2017. (Credit: EMB)

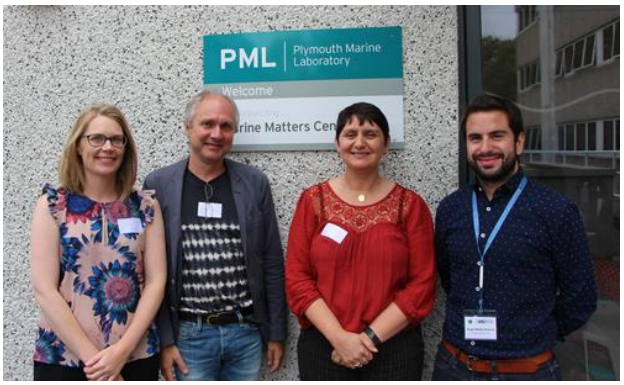
Contents

1. Introduction

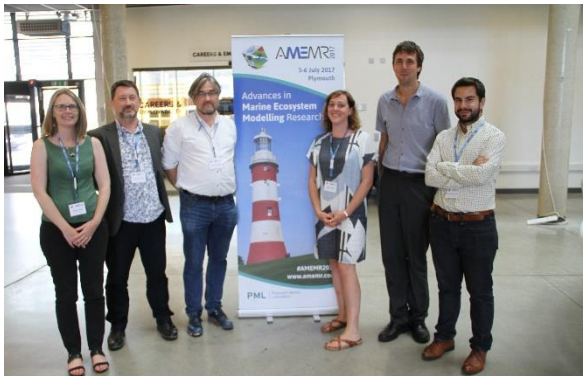
On 7 July 2017, the European Marine Board (EMB), in association with Plymouth Marine Laboratory (PML), organized an expert workshop 'Towards end-to-end (E2E) marine ecosystem models: R&D needs for ecosystem-based management'. This took place at the Marine Matters Centre, PML, Plymouth, U.K., back-to-back with the international AMEMR (Advances in Marine Ecosystem Modelling Research) 2017 conference. The main purpose of the workshop was to bring together experts in marine ecosystem modelling to assess how such models are currently used as support tools in environmental decision-making and policy-setting. The workshop was organized in the context of a EMB Working Group on Marine Ecosystem Modelling, co-Chaired by Morten Skogen (IMR, Norway) and Sheila Heymans (SAMS, U.K.). The workshop brought together 30 international experts from 12 countries (see Annex 1) in marine ecosystem modelling for interactive discussions, organized and facilitated by Kate Larkin and Ángel Muñiz Piniella of the EMB Secretariat, including preparatory material and a briefing paper.

A main driver for this activity is there remains a mismatch between scientific research and what policy makers need to know. EMB noted that whilst there are examples of National efforts[1] to assess capability and future development needs, it was timely to conduct such foresight activities at European level and communicate community-driven European research needs and priorities to policy makers and wider stakeholders. Through interactive discussions, experts identified research and development needs for developing next generation end-to-end (E2E) marine ecosystem models to meet existing and emerging policy drivers. They were also tasked with identifying cross-cutting areas and key enablers, including infrastructure and a skilled workforce, that will increase the uptake and impact of E2E marine ecosystem models by policy makers as more effective decision support tools for ecosystem-based management.

This workshop report summarizes key outputs from the discussions and WG developments since the workshop. Community-driven recommendations and key messages from the workshop are being taken forward by the EMB Working Group on Marine Ecosystem Modelling into a EMB Policy Brief, for publication in Autumn 2018.



EMB Working Group co-Chairs Sheila Heymans (SAMS, UK; centre, right) and Morten Skogen (IMR, Norway; centre, left) with EMB Secretariat staff Kate Larkin (far left) and Ángel Muñiz Piniella (far right) (Credit: PML)



AMEMR2017 conference organizers and EMB Secretariat staff (from left to right) Kate Larkin (EMB), Jeremy Blackford (PML), Icarus Allen (PML), Jessica Heard (PML), Jorn Bruggeman (PML), Ángel Muñiz Piniella (EMB) (Credit: PML)

[1] 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

2. Workshop Design and Methodology

The workshop was specifically designed back-to-back with the AMEMR 2017 conference to enable a wider representation of experts to attend and contribute their inputs. AMEMR2017 showcased the latest state-of-the-art in marine ecosystem modelling. Organizing a workshop back-to-back also enabled the meeting discussions to focus directly on the policy context, drivers and future Research and Development needs.

The workshop agenda was designed by the EMB Secretariat and WG co-Chairs to consist mainly of interactive group discussions to seek expert opinion and develop key recommendations. The full agenda is presented in Annex 2 and included introductory plenary presentations by the EMB Secretariat and the WG co-Chairs (presentations available on request):

1. Kate Larkin (EMB Secretariat): Overview and policy drivers
2. EMB WG co-Chair Sheila Heymans (SAMS, UK): End-to-end marine ecosystem modelling: where are we now and where are we heading?
3. EMB WG co-Chair Morten Skogen (IMR, Norway): State-of-the-art in end-to-end marine ecosystem modelling

Participants were then randomly mixed for group discussions on three specific topics (see section 2.2).

3. Discussion Sessions and key outputs

This section presents a summary of expert discussions for each session (raw data for each group is available on request to the EMB Secretariat).

3.1 E2E marine ecosystem models as tools for ecosystem-based management (EBM)

Session 1
Overview: *Existing and emerging policy needs for ecosystem-based management and current capabilities of E2E marine ecosystem modelling as decision support tools for addressing these requirements.*
Output: *List of current and future policy needs for ecosystem-based management, current capabilities in E2E marine ecosystem modelling for addressing needs, major gaps/limitations.*

Group discussions highlighted a number of key policy drivers for marine ecosystem modelling, including, but not limited to:

- food security
- marine spatial planning
- coastal zone management
- good environmental status
  e.g. marine strategy framework directive, including biodiversity and pollutants
  e.g. water framework directive – land-sea interface with nutrient loadings
- fisheries (common fisheries policy),
- climate change and variability (and ocean-climate interactions)
- blue economy (e.g. renewable energy, tourism)

This discussion session noted that with numerous relevant policies and that a change towards more of an integrated approach with multi-sectoral and trans-disciplinary approaches was required that links the natural environment and human interactions. This social science component was essential for an end-to-end ecosystem approach.

It was noted that capability in marine ecosystem modelling is very variable depending on the policy driver or sector. Whilst capability in climate change variability was high, capability in climate change adaptation was low and also low in other areas such as population growth/change behavior, multi-scale modelling and new pollutants.

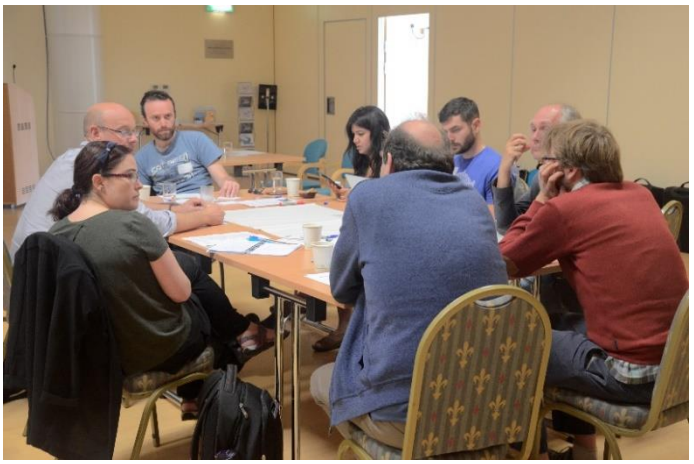
Currently, it was noted that models are built by researchers, largely for research purposes. Models should be developed to address multiple scales depending on the policy driver and that this may need a flexible and adaptable approach, e.g. due to the lack of continuity or changes to policy. This requires a dialogue between policy makers and scientists and wider stakeholders to ensure appropriate models are being developed. It also may need a change in policy structure so policies interface more and 'speak to each other'.

Participants identified cross-cutting gaps in existing capability which included:

- 2-way coupling of models and feedbacks that have the ability to assess cause and effect, i.e. you change one parameter in a fish model it has an impact on the zooplankton model etc.
- Better access to data and filling knowledge gaps in marine ecosystems
- High Performance Computing (in terms of access and training in data processing and visualization)
- Including the human dimension (behavior, interactions)
- More focus on processes, not just observations
- Boundaries, interfaces models, disciplines
- Long-term funding
- Validation of data and each model component
- Restrictions of research project time/funding for model integration
- Ways of publishing models
- common language for models
- No current base line of what's in the landscape e.g. for nitrification at the land-sea interface.
- Break down of multi-sectorial component

A specific focus of discussions across some breakout groups was on fisheries. Here, drivers, capabilities and gaps are summarized below:

Policy/Management Drivers	Existing capabilities in E2E marine ecosystem models	Gaps in existing capability
Fisheries: Common Fisheries Policy, Marine Strategy Framework Directive, Regional monitoring programmes (ecosystem based approach and stock assessment)	> Population dynamics > Maximum Sustainable Yield estimation > Environmental constraints > Fleet behavior > Human/socio-economics >Sub-regional approach was in some cases well developed (e.g. Iberian sardine) It was noted that there is no one size fits all but that currently single box models for fish stocks are used for policy as they are simple. However, such models are often restricted to one species and to commercial stocks although they do not assess an integrated, holistic approach.	1) Dynamic linking of higher and lower trophic levels 2) Better estimates of "actual catch" (technology and data) 3) Communication (style + content) 4) Link to, and integration with, social sciences: Feedback (human + environment) e.g. Understanding catch information produced. 5) Engagement with stakeholders 6) Easy manual to show managers it is all linked. May demand change in policy structure to prevent single interest management



Workshop participants in breakout group discussions (Credit: PML and EMB)

3.2. Horizon scanning: R&D needs for next generation E2E marine ecosystem models

Session 2:
Overview: *Recommendations on R&D needs for developing next generation E2E marine ecosystem models as more effective decision support tools for ecosystem-based management.* ***Output:*** *List of R&D needs and future directions for next generation E2E marine ecosystem modelling for ecosystem-based management including advancement towards a) fully functional E2E models b) true forecasting ability c) new applications?*

Research and Development Needs

The need for detailed process understanding of marine ecosystems in combination with observations was discussed by participants and led to some key knowledge gaps in specific environmental components of the marine ecosystem[2].

In addition, other gaps and needs were identified as current barriers requiring further research and development. In the framework of these discussions, emerging and evolving areas of marine science and wider technological advances were also discussed in terms of future capabilities in observations that may be available to marine ecosystem modelling.

Natural Science knowledge gaps and components:

- Land-sea interface
- Benthic component missing
- Processes and fluxes e.g. benthic-pelagic coupling, sediment-water interface, and the impact of physics. Sediment models need to interact with the overlying water column, including the memory effect of sediments and physics mediates the benthic-pelagic through vective waves or light diffusion.
- Zooplankton: Whether you have a top-down or bottom-up model, zooplankton is vital component where we lack data and understanding, e.g. life cycles. There are not enough data, and not the right data, to validate the models
- Heavy metal presence
- Multi-stressor approach to understanding stresses on marine environments (e.g. pollutants)

It was also recognized that the Human dimension and social science/economic component was often crucial to link with to assess changes in our behavior, interactions and stressors.

Other gaps and needs:

- Transdisciplinary experts and decision makers involved in model developing
- Two-way communication with observation

[2] *For more information see keynote presentation at the AMEMR2017 conference by Thomas Kiørboe (Centre for Ocean Life, DTU Aqua, Denmark) on "The Mechanistic Underpinning of Plankton Models: From complex details to simplified generalizations" which noted how a mechanistic understanding of the marine ecosystem allows simplification in a meaningful way (referred to as the "Picasso principle").* https://www.ememr.com/uploads/7/6/4/3/76438943/kiørboe_ememr_presentation.pdf

- More data more efficiently taken
- Platform for models/ international network (accessible and stable i.e. long-term funded)
- Ecosystem forecasts (like weather forecasts)
- Fundamental understanding of the marine ecosystem
- Repository of data sets (dynamic, including models)
- Validation: Of data, models and training of people once validation is done to build on expertise.
- More links and coupling to Earth models
- Emulators: On-demand building of emulators (with access to large model library and outputs)
- Optimization of model performance
- To have a glue to stick all the sub-models together
- Defining and obtaining data that are representative in time and space
- Lack of recognition for sharing models
- Benchmarking, baselines and hindcasts are needed
- Better adaptation of current codes/languages to new computing architecture
- Understanding of sensitivity of outputs will drive understanding of processes
- Model storage: The Cloud may not be a solution as it may be too slow for running some models, and local storage and/or real-time access during a run may be required, or rearrangement of model information.

Evolving areas likely to influence, impact future marine ecosystem modelling:

- Genomics: technology capability for autonomous data collection and analysis improving
- Visualization – games and apps (and wider information technology developments
- Big Data: how to synthesize data and analyze outputs in a useful manner
- Artificial Intelligence e.g. machine learning

The emergence of big data e.g. for biological datasets including DNA and genomics, was proposed to be driving new capability in dynamic linking of low and higher trophic levels. However this would require new approaches to synthesizing data to ensure useful and reliable information for take-up into models.

In addition, producing future end-to-end models with forecasting ability was discussed. It was noted that the time-scale of the model forecast would be important to clarify. Weekly or daily forecasts may not be useful for the policy scale/strategic management whereas seasonal forecasts may on the one hand enable more robust model integration with the ability to forecast bloom times, economy, etc. but may not be good/fast enough for long term forecasting as some parameters e.g. physics are very uncertain on longer time scales (month, season year).

3.3. Increasing the uptake and impact of E2E marine ecosystem modelling in ecosystem-based management

Session 3:
Overview: *Discuss and identify key enablers for improving a) capability b) uptake and impact of E2E marine ecosystem modelling in ecosystem-based management, including gaps in current capability and how to fill these.*
Output: *A list of key enablers for improving a) capability b) uptake and impact of E2E marine ecosystem modelling in ecosystem-based management*

Cross-cutting enablers that would enhance current capability included:

- Plug and play system
    - Common computer language or framework or logic (only interface needed)
    - Training issues related to this
    - Consider different assumptions for different models
- Long-term Platform, hosted by EC, also for repository of data (example of Helmholtz)
- Tailoring the model design depending on the policy question e.g. taking different boxes to build a model to answer a particular question
- Genomics becoming more important, but never replacing observations
- Visualization for engaging wider society – games and apps
- Move towards longer-term funding for modelling approaches e.g. taking the example of Argo floats which has formed a European Research Infrastructure Consortium (ERIC)
- Metadata template on how to understand a shared model
- Online tools to see results of models
- Assess the required frequency and distribution of observations (in some cases more intense observations are required)
- Ways of making models more simple, not more complicated
- Bring in early career scientists with good ideas into the co-design stage
- Ecosystems services: Ensure a combination of natural science and monetary valuation in defining ecosystems and their services/value.
- Long-term funding for research and short-term funding for training
- Model storage: A more standardized approach is required, including metadata templates, recording of core concepts and processes and the production of a knowledge platform for marine ecosystem models. This could include the production and management of a 'Model Bank' in the same way there is a 'Gene bank' where researchers would be obliged to store information on models, parameterization etc in a central portal for cross-referencing, standardization, interoperability etc so that people are aware of latest developments and build on existing capability rather than starting from scratch.
- Develop a new framework to publish models (as done now for datasets): DOI-type model configuration, code standard. Informatics DOI for software into published journals.

A number of enablers related to training:

- There is no end-to-end (E2E) marine ecosystem model degree – you need to build up transdisciplinarity:
  Transdisciplinary/intersectoral collaboration and skill development is required for marine scientists, social scientists, policy makers, computer scientists
- It was recognized that not everything lends itself well to computer modelling and experts need to work across disciplines to understand mechanisms of ecosystems and ecology/physiology as well as environmental variables
- Model 'Interface' experts with strategic vision to integrate/link up models: 'Sticking' models together acting as the interface. This requires experts e.g. in physiology/ecology, functional group
- Integration and communication: Whilst is may not be realistic to expect everyone to have an interdisciplinary degree, there is a need for more multidisciplinary people and projects, and structured information for emerging experts to give them overview of the field, widen their skills, entry points, and to avoid re-inventing the wheel.
- Training and information platforms (which require additional funding):
  - Knowledge training platform (linked to knowledge platform of models)
  - Transdisciplinary workshops with modellers and empiricists
  - Summer schools with end users, agreement between universities
  - Increased mobility of experts across countries, disciplines and into other work environments e.g. science-policy placements linking scientists and decision-makers
  - Brokerage events across stakeholder communities

To improve the uptake and communication between stakeholders, participant recommendations included:

- Engage citizens in citizen science projects/initiatives e.g. citizen open coding
- Long-term funding for research and short-term funding for training
- Improved communication skills (gamification of science often mentioned) targeted more specifically (but not only) policy makers (enhanced knowledge and involvement in policy)
- Building in broader peer-review processes e.g. wider stakeholders beyond the scientific community
- Getting scientists to interact with wider stakeholders e.g. environmental officers
- Incentives to get multi-stakeholder approach from the beginning

The workshop also raised the question "What role do researchers/marine ecosystem modelers have in implementing these enablers?" and the potential need for 'knowledge brokers' to work between the science and policy interface to ensure research/models get used and understood correctly.

3.4 Key messages and next steps

Throughout all discussions, participants highlighted that whilst there is a good European capability developing in marine ecosystem modelling, there needs to be far more transdisciplinarity with communication between and involvement of different groups from stakeholders, modelers, observers (experiment), mathematician and computer experts, social scientists, decision makers. Both scientists and policy makers need to understand what is required and the limitations. A number of clear knowledge gaps in basic understanding of the marine system (and/or data gaps) were identified for

marine ecosystem models. The participants identified an increasing need for a holistic end-to-end ecosystem approach, moving beyond single-species analyses. However, it was noted this required a multi-scale approach that affected model runs (higher trophic levels requiring longer model runs) and this would need to be addressed to achieve a fully end-to-end model.

Participants also noted the need to build on existing capability in terms of making model outputs, parameters and metadata openly available and accessible (e.g. through an online knowledge portal) to allow experts to access information and build on existing expertise and capability rather than starting from scratch, in combination with active training components. Despite advancements in big data, machine learning and data storage, the workshop recognized that the cloud may not be a viable solution for running end-to-end models was noted of importance to the developing European Open Science Cloud (and pilot blue cloud initiative[3]).

4. EMB Policy Brief

Following the expert workshop in 2017, the EMB Working Group co-Chairs, Morton Skogen and Sheila Heymans and two additional experts nominated by EMB Member Organizations, Corinna Schrum (HZG, Germany) and Cosimo Solidoro (OGS, Italy) have been working with the EMB Secretariat to develop a Policy Brief on '*Enhancing Europe's capability in end-to-end marine ecosystem modelling for societal benefit*' for delivery in Autumn 2018. The table of contents for this are given below:

1. **Introduction**
2. **State-of-the-Art of marine ecosystem modelling, including case studies of applications for EBM** (including International case studies)
3. **Emerging Areas**
   - Marine biodiversity and ecosystem function in marine ecosystem modelling
   - Marine ecosystem forecasting tools in European seas
   - Machine learning and neural networks
4. **Research and Development (R&D) needs**
   - What are the challenges of end-to-end modelling?
   - key R&D and capacity/cross-cutting gaps and needs (including workshop outcomes)
5. **Recommendations**

International case studies will be included on marine ecosystem models and their use for Ecosystem-Based Management (EBM). Horizon scanning recommendations on future marine ecosystem modelling gaps, needs and required capabilities are contributing to a EMB Policy Brief to be communicated to wider stakeholders, including research funders, marine managers and policy makers to shape future research agendas at European (e.g. Framework 9) and National agendas for developing next generation holistic marine ecosystem models as effective decision support tools in marine environmental management and to inform the implementation of existing marine policy, such as the Marine Strategy Framework Directive (MSFD), the Common Fisheries Policy, marine spatial planning and Regional Sea Monitoring programmes.

[3] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/bg-07-2019-2020.html

5. Related European initiatives

The EMB Secretariat identified a number of related ongoing European activities to interact with during the WG development. These include:

4.1 MEME

An informal network of Experts for ReDeveloping Models of the European Marine Environment (MEME), is jointly organized by DG Environment and DG JRC (IES –Water Resources Unit)[4]. On 5 December 2017, Kate Larkin (EMB Acting Head of Secretariat August-December 2017) and Charlotte Simon (EMB Junior Science Officer) presented the EMB marine ecosystem modelling Working Group to the European Commission (DG Environment and JRC representatives) at a meeting in Brussels. Following this, EMB Executive Director Sheila Heymans attended a MEME expert meeting on 20-21 March 2018 and presented the latest updates on EMB's activities where longer-term plans for a marine modelling framework were also discussed.

4.2 BLUE2

The BLUE2(B) study links ecosystem models to policy drivers and uses computer models to simulate the physical, chemical and biological aspects of the freshwater and marine environment. It is developing a framework which includes the methodology for formulate policy scenarios accompanied by purpose-built software to translate these scenarios into input data that can be used by the models. To achieve this objective, four types of models are incorporated into a single modelling framework/toolbox:

- hydrological models that provide information on river flow and nutrient discharge in terms,
- hydrodynamic models (that simulate marine water transport),
- lower-trophic-level biogeochemical models (including phytoplankton and zooplankton),
- higher-trophic-level food-web models (from phytoplankton to marine mammals/seabirds).

The models will be aligned for comparison with policies, i.e. hydrological models with the Water Framework Directive (WFD), and higher-trophic-level food-web models with Biodiversity policies.

4.3 Copernicus Marine Environment Monitoring Service

Since May 2015, the Copernicus Marine Environment Monitoring Service (CMEMS) is working on an operational mode. As part of the Copernicus evolution, the European Framework Programme 8, Horizon2020 has included recent calls related to ocean model development[5] which notes that "*a high priority is the evolution of Copernicus Marine Service global and regional systems to better describe ocean phenomenon with high dynamics at fine spatial scales to provide enhanced boundary conditions to coastal models (both physics, biogeochemistry or marine ecosystems) thus strengthening the links with downstream coastal monitoring activities from the public or private sectors*". There have also been training workshops to discuss operational applications[6]. These initiatives remain mainly focused on developing capabilities for physical and biogeochemical ocean dynamics rather than full marine

[4] within the framework of the Administrative Arrangement NoENV.C.2/2015/070201/705766 (Deliverable 2.2) and the Marine Strategy Framework Directive (MFSD).

[5] e.g. LC-SPACE-03-EO-2018: Copernicus evolution - Preparing for the next generation of Copernicus Marine Service ocean models http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/lc-space-03-eo-2018.html

[6] https://www.eumetsat.int/website/home/TechnicalBulletins/Training/DAT_3634865.html

ecosystems, however the outputs from these models to link to the higher trophic level models in one way coupling, so it is still very important for the model ensemble approach.

4.4 European Ocean Observing System (EOOS)

Outputs from this EMB activity are also contributing to the wider development of a more coordinated and comprehensive European Ocean Observing System. The EMB WG on marine ecosystem modelling is timely to feed into developments of EOOS, specifically a EOOS Strategy and Implementation Plan 2018-2022 being developed in 2018 (see public Consultation online). In addition, the marine ecosystem modelling community are encouraged to engage in EOOS stakeholder meetings. At the first EOOS Forum on 8 March 2018, stakeholder input included the recognition that EOOS should be multidisciplinary, multi-sectoral, multi-national and multi-platform (including strong links to modelling and satellites). Modelling was also seen as a key "platform" and capability for a societally-relevant European Ocean Observing System, including to improve predictive capabilities in coastal seas and for maritime safety and to provide a more holistic view. It was also noted that underpinning European capability is the need for skilled people with the right competencies for data management and for linking data to models. On 21-23 November 2018, an EOOS Conference, is being funded by DG MARE, co-organized by EMODnet, EMB and EuroGOOS Secretariats, in association with the EOOS Steering Group and Advisory Committee of wider stakeholders. Registration is now open and it is free to attend. A call for abstracts and exhibition space is also open until 2 July 2018.

6. Acknowledgements

The European Marine Board wishes to extend sincere thanks to the Plymouth Marine Laboratory, particularly AMEMR 2017 organizers Jeremy Blackford, Icarus Allen, Jessica Heard and Leon Thompson (photography). Thanks are also extended to the WG co-Chairs Sheila Heymans and Morten Skogen along with all experts who participated in the EMB workshop on 7 July 2017. The report was prepared by EMB Secretariat staff Charlotte Simon (trainee, July-December 2017), Ángel Muñiz Piniella and Kate Larkin.

7. Annexes

Annex 1: Participant list

Annex 2: Workshop Agenda

Plymouth lighthouse, July 2017 (Credit: EMB)

Annex 1: List of Participants

Name	Family Name	Institute	Country
Guttorm	Alendal	University of Bergen	Norway
Yuri	Artioli	Plymouth Marine Laboratory (PML)	UK
Jerry	Blackford	Plymouth Marine Laboratory (PML)	UK
Paul	Blackwell	University of Sheffield	UK
Momme	Butenschon	Plymouth Marine Laboratory (PML)	UK
Baixin	Chen	Heriot-Watt University	UK
Scott	Condie	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Australia
Morten D	Skogen	Institute of Marine Research (IMR)	Norway
Kevin	Flynn	Swansea University	UK
Fabian	Große	Dalhousie University	Canada
Sheila	Heymans	Scottish Association for Marine Science (SAMS)	UK
Jason	Holt	National Oceanography Centre	UK
Suzana	Leles	Swansea University	UK
Hermann	Lenhart	University Hamburg	Germany
Gennadi	Lessin	Plymouth Marine Laboratory (PML)	UK
Chris	Lindemann	University of Bergen	Norway
Martin	Marzloff	French Research Institute for the Sustainable Exploitation of the Sea (IFREMER)	France
A. Miguel	Santos	Portuguese Institute of the Sea and the Atmosphere (IPMA) / Centre for Marine Sciences, Faro (CCMAR)	Portugal
Aditee	Mitra	Swansea University	UK
Marta	Pascual	Basque Centre for Climate Change (BC3)	Spain
Arnaud	Pourchez	Takuvik Joint International Laboratory	Canada
Paul	Somerfield	Plymouth Marine Laboratory (PML)	UK
Michael	Spence	Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	UK
Ricardo	Torres	Plymouth Marine Laboratory (PML)	UK
Sonja	van Leeuwen	NIOZ Royal Netherlands Institute for Sea Research (Coastal Systems) and Utrecht University	Netherlands
Audric	Vigier	French Research Institute for the Sustainable Exploitation of the Sea (IFREMER)	France
Kelly	Ortega	Rhodes University	South Africa
Susan	Kay	Plymouth Marine Laboratory/Met Office	UK
Sevrine	Sailley	Plymouth Marine Laboratory (PML)	UK
Maria	Grigoratou	Bristol University	UK
Ángel	Muñiz Piniella	European Marine Board (EMB)	European
Kate	Larkin	European Marine Board (EMB)	European

This list includes those who both registered and attended the workshop on 7 July 2017.

Annex 2: Meeting agenda

Towards end-to-end (E2E) marine ecosystem models: R&D needs for ecosystem-based management

EMB expert workshop, 7 July 2017,
Marine Matters Centre, PML, Plymouth, UK

08:40 Coffee + Registration.

09:00 Introduction: The European Marine Board, motivation for workshop, expected outcomes and impact *(Kate Larkin, EMB Secretariat)*

09:10 E2E marine ecosystem modelling: Where are we now and where are we heading? (*Chair Morten Skogen and co-Chair Sheila Heymans*)

09:30 Session 1: E2E marine ecosystem models as tools for ecosystem-based management (EBM)

Overview: *This session will identify existing and emerging policy needs for ecosystem-based management and current capabilities of E2E marine ecosystem modelling as decision support tools for addressing these requirements.*

Structured discussion in groups (40 mins; assign a rapporteur for each table)

1)What are the existing and emerging policy drivers/needs for ecosystem-based management?
2)For each policy question/application identified in Q1, assess the current capabilities in E2E marine ecosystem modelling to address these needs. Where does Europe have a leading capability? What are the gaps and limitations to achieving comprehensive, fully functional E2E marine ecosystem models?

Output: *List of current and future policy needs for ecosystem-based management, current capabilities in E2E marine ecosystem modelling for addressing these needs, major gaps and limitations (1 summary sheet / group)*

10:10 **Plenary discussion on Session 1** *(Chaired by Sheila Heymans)*
Key points from Group rapporteurs/participants on key policy drivers and current capabilities

10:40 Comfort break (Refreshments will be available throughout the meeting)

10:50 **Session 2: Horizon scanning: R&D needs for next generation E2E marine ecosystem models**

Overview: *This session will produce recommendations on Research and Development (R&D) needs for developing next generation E2E marine ecosystem models as more effective decision support tools for ecosystem-based management. R&D needs should*

take into account policy drivers from Session 1, new marine research frontiers e.g. –omics, emerging capabilities, e.g. in advanced computing (cluster/cloud computing) and the need for a transdisciplinary approach.

Structured discussion in groups: (60 mins; assign a rapporteur for each table)

1) *What R&D is required to make E2E marine ecosystem models more realistic and relevant for ecosystem-based management? How will new research frontiers drive better validation and new developments?*
2) *What steps are needed to get from bespoke models to a fully functional E2E marine ecosystem model? Are there alternatives to this approach?*
3) *How can we achieve E2E marine ecosystem models with true forecasting ability?*

Where possible R&D needs should indicate if they are a) short-term (i.e. achievable by 2025) and b) longer-term requirements (i.e. 2035).

Output: *List of R&D needs and future directions for next generation E2E marine ecosystem modelling for ecosystem-based management including advancement towards a) fully functional E2E models b) true forecasting ability c) new applications? (1 summary sheet / group)*

11:50 Plenary discussion on Session 2 *(Chaired by Morten Skogen)*

Key points from Group rapporteurs/participants on R&D needs

12:30 Key messages from Sessions 1 + 2 *(Morten Skogen and Sheila Heymans)*

12:40 Lunch (provided at the venue)

13:15 Session 3: Increasing the uptake and impact of E2E marine ecosystem modelling in ecosystem-based management

Overview: *This session looks at cross-cutting areas and key enablers that will a) underpin next generation E2E marine ecosystem modelling b) increase the uptake and impact of E2E marine ecosystem models by policy makers for ecosystem-based management*

Structured discussion in groups: (30 mins; assign a rapporteur for each table)

1) *What are the key enablers for next generation E2E marine ecosystem modelling? e.g. infrastructure, hardware, trans-disciplinarity?*
2) *What skills sets will next generation E2E marine ecosystem modellers require? What is missing from current training programmes?*
3) *How can we increase the uptake and impact of E2E marine ecosystem models by policy makers for ecosystem-based management?*

13:45 Plenary discussion on Session 3 *(Chaired by Sheila Heymans)*

14:15 Closing discussion and next steps

14:30 Workshop ends