Marine Ecosystems Research Programme

Science Summaries

Session 1: Linking data, models and ecosystem services

Integrating MERP data into Ecosystem Services

Melanie Austen, Plymouth Marine Laboratory

Linkages between the ecosystem and services can affect trade-offs in our effects on, or exploitation of different ecosystem services. By enabling simultaneous consideration of multiple ecosystem services MERP aims to support management of the environment and sustainable use of resources. The UK marine environment is relatively data rich, yet the links between ecosystem and ecosystem services were poorly described. For example, much of the evidence gathered to document and monitor change in marine ecosystems for other purposes (e.g. Marine Strategy Framework Directive monitoring for GES) can be linked to changes in services. A conceptual model has been developed that links ecosystem components and key processes to four services they provide and highlights the trade-offs between them. The model was subsequently further developed to include pressures and management mitigating measures. This was used to build the first structure for a Bayesian Belief Network (BBN) that could synthesise MERP model outputs and empirical data, together with additional data and expert judgement. The intention is that the models can be used to communicate wider natural capital and ecosystem service implications of management measures with managers and stakeholders and applied to available and new marine data to facilitate evidence-based marine management.

Bayesian Belief Networks and Ecosystem Services

Paul Blackwell, University of Sheffield

Understanding trade-offs to maximise the benefits from living marine natural capital

Mike Heath, University of Strathclyde

MERP Module 7 consortium (University of Strathclyde, Bangor University, CEH, Cefas, PML, SAMS) presented by Michael Heath (University of Strathclyde)

Module 7 of MERP is an additional component of the Programme which began in 2017 and continues until November 2018. The overall aim is to better understand the monetary and non-

monetary benefits from harvesting and recreational use of the marine environment. We are doing this by integrating social and economic processes into our existing ecology models to explore the trade-offs between management goals for the consumptive and non-consumptive exploitation of marine natural capital. This talk will introduce the work that has been accomplished so far and set the scene for some of the talks to follow.

Session 2: Modelling and the social dimension

Cultural values of marine ecosystem services

Gill Ainsworth, CEH

This study assesses non-monetary values of marine ecosystem services in the Celtic Seas. Using the Community Voice Method, we investigated cultural ecosystem service values through the lens of the UK NEAFO cultural services and IPBES valuation frameworks. We describe the cultural values, places, practices, identities, experiences and capabilities derived by people using inshore and offshore marine environments and stakeholder attitudes towards NEAF policy scenarios developed elsewhere in MERP. The findings focus on marine users' values regarding management of the marine environment. This research can significantly impact on spatial planning for marine protected areas in the Celtic Seas and elsewhere because it informs us about marine users' shared values, competing interests and the potential trade-offs they may be prepared to make regarding marine ecosystem services and their own activities.

Integrating ecological-economic model in contingent behaviour approach to assess changes in preferences and values of tourism, leisure and recreational experiences

Simone Martino, SAMS

Simone Martino (SAMS), Jasper Kenter (SAMS), Natalia Serpetti (SAMS), James Waggitt (Bangor University), Peter Evans (Sea Watch)

The presentation proposes a methodology to integrate ecological information from a food web model, biological distribution of marine wildlife and economic evidence of recreationists' preferences (watchers, divers and anglers) for some marine species (seabirds, seals, porpoises, and whales). The ecological model provides changes in biomass of wildlife species under the UK National Ecosystem Assessment (NEA) world views; the marine wildlife distribution (maps of density and encounter rate) is used to assess the probability of wildlife sighting; and the economic model describes to what extent recreationists preferences vary under hypothetical scenarios of wildlife protection. These three models are integrated to describe how recreationists' preferences (in the South-West of England and West of Scotland) and their monetary benefits change over different fishing management scenarios proposed under the UK NEA world views.

Humans are part of the ecosystem too. Linking models of marine ecology to economic drivers

Mike Heath University of Strathclyde

Michael Heath, Aidan Hunter, Douglas Speirs, Robert Wilson (University of Strathclyde)

Human pressures on the marine ecosystem are usually represented in models as fixed external drivers, with no feedback between the state of the ecosystem and the level and distribution of human activity. However, this become a major limitation when we want to model, for example, the effects of establishing a marine protected area (MPA) on the wider marine ecosystem. Where will fishers displaced from the MPA choose to go and fish? This talk describes how we have incorporated fishing as a dynamic component of our ecosystem models representing economic processes, and shows a working example.

Policy brief: End-to-end marine modelling needed for evidence-based policy making

Sheila Heymans, European Marine Board

A small writing group (Morten Skogen (IMR), Sheila Heymans (SAMS, EMB), Corinna Schrum (Helmholtz Institute, Germany), Cosimo Solidoro (National Institute of Oceanography and Experimental Geophysics, Italy) are currently writing a Policy Brief on 'Enhancing Europe's capability in end-to-end marine ecosystem modelling for societal benefit.' The policy brief was initialised at an expert workshop organised back-to-back with the AMEMR conference in Plymouth (July 2017). The workshop brought together international experts from 12 countries. An outcome of the workshop was that in Europe there remains a mismatch between scientific research and what policy makers need to know. This foresight activity will communicate community-driven European research needs and priorities to policy makers and wider stakeholders. The policy brief looks at the state of the art, with some case studies, emerging science, gaps and future research needs. The Working Group aims to have a full draft in early 2018 ready for external review.

Session 3: Managing multiple stressors

Managing indicators, an ensemble approach

Mike Spence Cefas

Bow Tie Analysis in Cumulative Effects Assessment

Adrian Judd, Cefas

Applying Bow Tie Analysis to a suite of environmental indicators allows for complex cumulative interactions, risks, impacts and management options to be identified and assessed in the context of their environmental, social and economic drivers (causes) and consequences. Building on the approach being developed for the OSPAR Intermediate Assessment 2017 and Quality Status Report 2023 the work in MERP has expanded the utility of the approach. In a workshop with stakeholders with interests in Cardigan Bay, Bow Tie Analysis was used as part of the interactive sessions to

identify the social, economic and environmental causal factors and consequences for the top seven issues of concern raised by the stakeholders in questionnaires (wildlife tourism; recreational boating / water sports; coastal developments (including sea defences); sea angling; scallop dredging; lack of joined up decision-making and enforcement; litter). This was the first time that Bow Tie Analysis had been used with stakeholders in this way and it proved to be a very efficient and responsive tool to draw together a complex mass of information and expert knowledge. Work is currently underway to use Bow Tie Analysis and the MERP Model Ensemble together. The information within individual or chained 'bow ties' are being used to set questions / scenarios for the models to process. Conversely, Bow Tie Analysis can be used to help interpret model outputs.

Cumulative Impacts and the Management of Marine Ecosystems

Tom Webb, University of Sheffield

The MERP Cumulative Effects project has been an exercise in synthesis and in 'triangulation' - employing different approaches to address similar questions, in the search for more robust and general answers. The overall aim is to show how extensive empirical data, statistical and mechanistic modelling, and expert judgement can be translated into principles for marine management in the face of complex interactions and cumulative effects. Our work has been centred around concepts of risk modelling, but within that we are combining data from multiple sources, including risk mapping for top predators, new ecosystem modelling work, macroecological analyses, and direct stakeholder input. In this talk I will provide a synthesis of what this work has achieved, and where we are heading over the remainder of the project.

Capturing thresholds of biodiversity change to support environmental management

Elena Couce, Cefas

Elena Couce (Cefas), Georg Engelhard (UEA), Michaela Schratzberger (Cefas)

Sedimentary habitats, which constitute the largest single ecosystem on Earth in spatial coverage, contribute to human well-being by providing essential services such as food production and nutrient cycling. Humans have been leaving marked environmental footprints in many benthic ecosystems around the world. A key challenge for decision-makers is to develop strategies to protect, conserve and manage benthic ecosystems and scientists are challenged to generate robust scientific evidence that underpins wise management. Disentangling natural and anthropogenic drivers of alterations in benthic community composition is key to informing adequate ecosystem management. However, natural and human stressors often interact in complex and non-linear ways and are difficult to separate, compounded by a scarcity of data on subtidal benthic communities. Here we present a big-data approach to tackling this problem, using the North Sea as a case-study. Over 500,000 OBIS entries, corresponding to locations of benthic species sampled in the period 1985-2015, were related to modelled sea bottom temperature, shear stress, and reconstructed beam and otter bottom trawling effort. Using a gradient forests approach, we explore the level at which each stressor causes significant shifts in community composition and develop scenarios under which shifting rather than static baselines are appropriate.

Session 4: Modelling the marine ecosystem

The effects of model resolution on the ecosystem of the Celtic Sea

Sarah Wakelin, NOC

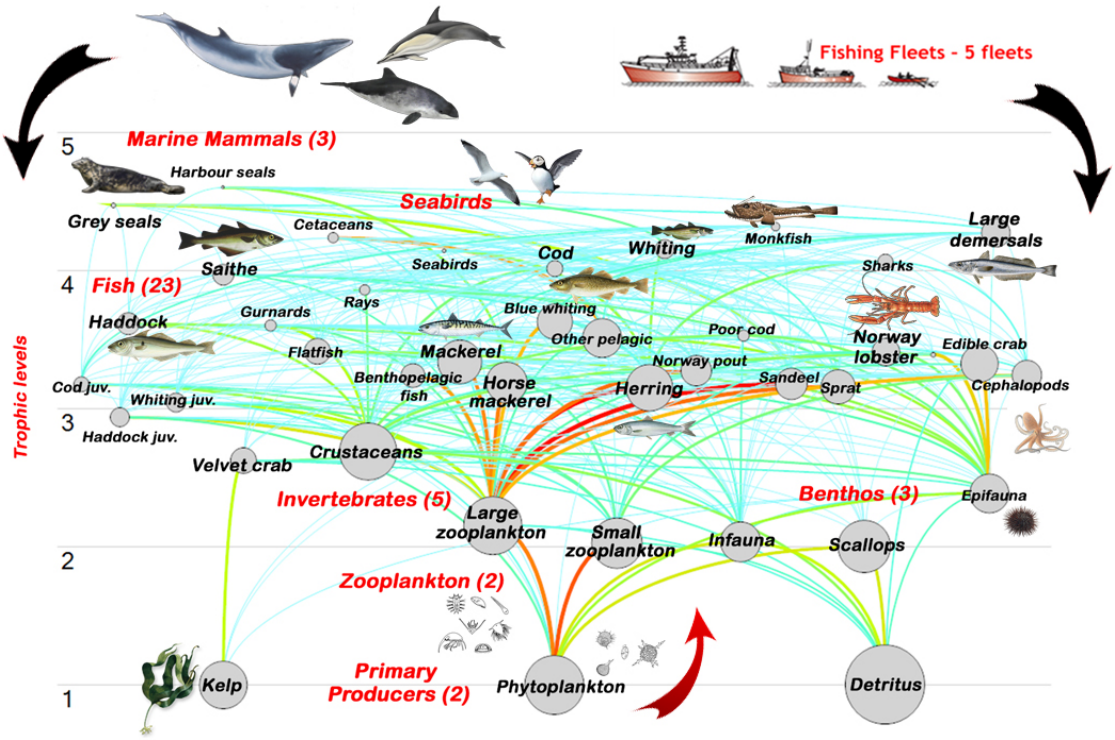
Three-dimensional coupled hydrodynamic-ecosystem models are computationally expensive especially for models with high (~km) spatial resolution. However, finer resolution models are able to resolve more physical processes (eg. internal tides). Three coupled models extending over the Celtic Sea and English Channel are used to investigate how increasing horizontal resolution (from 7km to 3km to 1.5km) changes the model physics and ecosystem. The 1.5km and 3km-resolution models show finer spatial variations in hydrodynamics, leading to differences between models in the location of mixing fronts and in the onset and duration of stratification. This influences the nutrient supply to surface waters and changes the model net primary production. The vertical distribution of phytoplankton communities is also affected, with potential implications for food webs.

Temporal / Spatial coupling of Ecospace: bottom-up and top-down controls - the West Coast of Scotland example

Natalia Serpetti, SAMS

Serpetti, N., Artioli, Y., Waggitt, J.J., Evans, P.G.H., Burrows, M.T. and Heymans, J.J.

Coupling modelling approaches has been identified as a promising method to improve model performances when simulating the temporal/spatial distribution of species. The multi-disciplinary interactions within different modelling approaches and fieldwork analysis allowed us to fill in knowledge gaps identified at the beginning of this large project. The Ecopath with Ecosim and Ecospace model of the West coast of Scotland has been modified integrating fieldwork results, and coupled with NEMO-ERSEM and modelled distributions of top-predators, to constrain bottom-up and top-down ecosystem controls. Resulting species temporal/spatial distributions were therefore driven by primary productivity, cetaceans and seabirds distributions as well as species habitat and temperature preferences, dispersal rates, predator/prey interactions and fishing activities. Results showed cumulative effects of these drivers which cascade through the entire food-web. The new model is currently used to understand trade-offs to maximise the marine natural capital benefits and to assess the cumulative impacts of stressors to advise marine ecosystems management.



Uncertainty in Marine Ecosystem Modelling

Hayley Bannister, University of Sheffield

Models often include many highly uncertain parameters, some of which may have a large impact on the model projections. Ignoring the sensitivity of the model projections to uncertain parameter values risks suboptimal, ineffective or potentially damaging management decisions if the model is used to support policy. Despite this, there are few examples of sensitivity analyses being applied to complex models. We aim to fill this research gap by applying a Derivative-based Global Sensitivity Analysis (DGSA) to a multispecies size spectrum North Sea fisheries model, known as *mizer.* The analysis consisted of over 300,000 model runs and the sensitivity of multiple model outputs, such as community biomass and the Large Fish Indicator (LFI), were considered. We use the results of the DGSA to discuss where further research should be focused to help reduce the uncertainty in the parameter estimates and thus enable us to produce more accurate model projections.

Session 5: Functional biodiversity

Trait Explorer: from sparse data to traits for all species

Jorn Bruggeman, PML

The Trait Explorer (TE - http://www.marine-ecosystems.org.uk/Trait_Explorer) is an online tool that estimates trait values of any marine species. It fills gaps in our existing knowledge through a form of "automated expert judgement" that combines the large trait datasets compiled within MERP with the latest taxonomic information. Currently, TE provides information about organism size, body composition, feeding mode, age at maturity and fecundity. Work is in progress to extend this to tolerance/sensitivity indices (AMBI) and variables needed to parameterize ecosystem models

(Dynamic Energy Budget models; Monod models for phytoplankton growth as function of light and nutrients). A key function of TE is to facilitate integration among modellers and empiricists: it currently supports several cross-module collaborations within MERP and features in a number of papers. It has also attracted interest outside the project from the academic community and commercial parties. We therefore anticipate the service to maintained and further developed after MERP.

Marine biodiversity: metrics, function and drivers

Miriam Grace, University of Sheffield

Miriam Grace (Sheffield), Murray Thompson (Cefas), Elena Couce (Cefas), Beth Churn (Sheffield), Laura Abels (Sheffield), Jorn Bruggeman (PML), Tom Webb (Sheffield), Michaela Schratzberger (Cefas)

Effective marine conservation depends on targeting resources to protect regions of importance for biodiversity. Species richness is a commonly used metric to identify such areas, but can lack key information on the variety of ecological functionality present in a community. We compare the location of hotspots of functional diversity in the UK to those based on taxonomic diversity metrics, using species occurrence data from the Ocean Biogeographic Information System, and a number of key lifestyle traits. We find that these metrics are strongly influenced by functional group. We further assess the role of environmental and anthropogenic variables. Using the Scottish MPA network as a case study, we link functional diversity to MPA designations, fishing pressure and management measures. Finally, we use our findings to evaluate the potential and limitations for the use of functional metrics in conservation.

Modelling benthic macrofauna: state, function and diversity

Gennadi Lessin, PML

Within sediments, transformation of material by benthic macrofauna depends on dominant feeding modes, diet compositions and habitats. Macrofaunal community composition is, in turn, shaped by food supply regime and physical forcing. To explore links between forcing, community structure, food webs and biogeochemistry, we apply models explicitly representing dynamics of benthic fauna. To infer feeding modes and dry weights of observed macrofauna, Trait Explorer is used. A simplified model version is implemented to study temporal response of major benthic macrofaunal groups to phytoplankton dynamics, while model with diversified structure of feeding types is parameterised to explore the impacts of biodiversity on benthic dynamics and benthic-pelagic exchange at Station L4 of the Western Channel Observatory. Large-scale 3D simulation with diversified macrofauna structure was performed for a period 2000-2015. The model, initialised with equal and uniform distributions of functional types, is used to investigate how hydrodynamics and food supply shape benthic community structure.

Session 6: Top-down and bottom up effects

The effects of variations in trawling and primary production on size-structured food webs in marine benthic ecosystems

Jan Hiddink, Bangor University

Howarth, L. (Bangor University) Blanchard, J.L. (University of Tasmania), Somerfield, P.J. (PML), Cendrier, M. (Bangor University), Maurin, C. (Bangor University), Waggitt, J.J. (Bangor University), Allender, S. (Bangor University), and Hiddink, J.G. (Bangor University)

Macro-ecological patterns in size spectra (SS) emerge from predatory and competitive interactions in ecosystems. Models predict that SS of predators have shallower slopes than detritivores and that their SS steepen in response to fishing. High primary production levels are predicted to increase the abundance of all sizes and groups. Here we test these model predictions by sampling SS of benthic communities in the Celtic Sea across gradients of trawling and primary production (PP). As predicted, the SS of predators exhibited lower intercepts and shallower slopes than detritivores, and both groups exhibited higher intercepts in areas of high PP. Differences between modelled and observed SS suggest that modelled growth compensation of large size classes under high levels of PP may not be as strong, reducing the degree to which high levels of PP would reduce the effects of fishing.

Scale dependency of top-down and bottom-up control

Angus Atkinson, PML

One of the elements behind the Marine Ecosystems Research Programme was our current uncertainty over the relative roles of top-down and bottom-up forcing on marine ecosystems, and the scale-dependency of these processes. This presentation will briefly provide some examples from MERP-supported empirical work that examines the temporal scales of these control processes, ranging from seasonal, through inter-annual to multi-decadal. I will compare and contrast two valuable pelagic systems both served well with time series data: first an inshore stratifying shelf sea (i.e. the Plymouth L4 time series) with a spring diatom bloom and second the krill-dominated food web in the Atlantic sector of the Southern Ocean. Their key zooplankton contrast greatly in their population fluctuations and these fluctuations provide clues to population regulation mechanisms (including density-dependent processes) and their response to climatic fluctuation and change.

Top-down and bottom-up effects in marine communities: quantification, modelling, prediction

Axel Rossberg, QMUL

Session 7: Food-webs

Blue carbon in deep coastal waters: the role and fate of seaweed detritus

Ana Queiros, PML

We recognised that while macroalgae are the most productive marine macrophytes globally, we simply did not have sufficient information about the 80% of their production exported from shore

habitats annually or how this may support ocean foodwebs. A substantial lack of field data thus prevented us from representing this potentially important bottom up forcing of UK foodwebs in available modelling tools, and the management of a potentially important service delivered by these species: climate mitigation. PML undertook a 13 month field and lab based programme to address these questions. Using eDNA and Bayesian Stable Isotope Mixed Modelling to trace macroalagal detritus in the coastal ocean, we found that detritus from most species in our study region enters coastal, deep benthic foodwebs, and that this is a vital resource to the benthic fauna especially when other key food resources are seasonally low. Through associated benthic-pelagic process measurements we also established how much of this carbon is annually retained in coastal deep sediments, contributing to organic carbon stores. The study is a significant step forward toward informing the representation of bottom up processes in ecosystem modelling frameworks, and suggests the potential need to manage connected macroalgae beds and coastal sediments.

The contribution of macroalgae to coastal food webs

Mike Burrows, SAMS

Estimates of the biomass of coastal seaweeds suggest a substantial contribution of energy to coastal foodwebs through their contribution to organic detritus. We have used a combination of models and novel estimates of production from field experiments (in collaboration with non-MERP colleagues) to calculate the likely total contribution from macroalgae as carbon, and inshore sampling cruises to collect material for assessment of seaweed biomarkers. Proportional macroalgal contributions are scale dependent but, for coastal areas within 5km of the shoreline, range from near zero on soft coasts in southeastern UK to over 50% of carbon production around Scotland. Bulk stable isotope analysis of over 2000 samples from four inshore cruises repeated in 2015 and 2016 show a large range of carbon isotope ratios among and within benthic species, with less negative values associated with macroalgal-derived material, with coastal benthic fishes having less negative delta 13C values than offshore pelagic species. The non-specificity of these biomarkers suggest further analysis using compound-specific SIA, and a subset of samples will be analysed in this way.

The research has contributed to recent ‘Blue carbon’ initiatives, MSFD reports on kelp habitats, and a recent assessment of the available resources for seaweed harvesting in Scotland.

Comparing and contrasting the food webs of NW European fishing regions using the StrathE2E model

Mike Heath, University of Strathclyde

Michael Heath, Aidan Hunter, Douglas Speirs, Robert Wilson (University of Strathclyde)

The main fishery regions around the UK (North Sea, West of Scotland, Irish Sea, Celtic Sea, and English Channel) are very different in terms of ecology, fishing fleet sectors, and economic productivity. Using remote sensing data, terrestrial hydrology data, and output from the shelf-wide ERSEM as a common platform of hydro-chemical driving conditions, we have configured a network of regional StrathE2E food web models to cover the entire shelf. This talk will briefly compare the food webs in each of the model regions and their sensitivity to fisheries.

Session 8: Higher trophic levels

Diet diversity in seabirds varying with ecological conditions

Ruedi Nager, Glasgow University

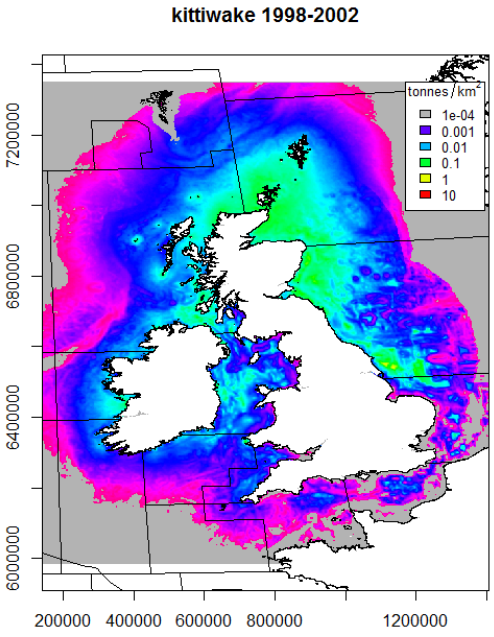
Ruedi Nager (Glasgow University), James Grecian (Glasgow University), Francis Daunt (CEH), Sarah Wanless (CEH), Agnes Olin (Glasgow University)

Ecologists have long used niche theory to describe the ecology of a species as a whole, for instance with respect to diet. In some species populations can specialise on very specific diets even if the species as a whole has a much wider diet niche. Diet specialisation differs between seabird species. Theory also predicts that diet specialisation may change when conditions become tough: foragers may become either more generalist or more specialised. Here I want to explore the spatial and temporal differentiation in seabird in relation to food supply and competition using a diet dataset compiled from the literature across several seabirds in the Northern Atlantic. We expect populations to be more specialised than the species as a whole and between-population differences to vary across species and to be driven by local circumstances.

Understanding seabird responses to pressures in the marine environment – combining environmental drivers, movement and demographics to map predator seascapes

Kate Searle, CEH

Mapping the distribution and energy consumption exerted by top predators in UK waters underpins and informs interactions between wildlife and human activities (fishing activities, SPA designations and offshore renewable energy development). We have developed predator seascape maps estimating the tonnes of energy removed per km^2 for breeding populations of four important UK seabird species (black-legged kittiwake, common guillemot, razorbill, and European shag) which together represent over 1/3 of the total UK breeding seabird biomass. We have developed predator seascape maps for time periods around the year 2000 and for the current day. The maps we have produced will enable more informed assessments of key habitat areas used by breeding seabirds in the UK, and when overlaid with other marine pressures can identify regions and areas with likely strong trade-offs between competing wildlife and human activities.



Advances in understanding top predator distributions in NW European seas

Peter Evans, Sea Watch Foundation

The last ten years has seen a marked increase in the number of research groups undertaking at sea surveys for top predators like seabirds and cetaceans. In order to address spatial and temporal gaps in coverage, 2.19 million km of cetacean surveys and 1.36 million km of seabird surveys were collated across NW European seas from Norway to Portugal. Hurdle models were applied to the data sets incorporating ecologically informed variables predicting presence and abundance. Density surfaces were produced for the 12 most common cetacean and 12 most common seabird species at a spatial resolution of 10 km and a monthly temporal resolution over 32 years across this region. These have provided the most detailed maps yet available for all the major seabird and cetacean species occurring in NW European seas, and form the basis for developing risk maps of the cumulative effects of different human pressures on individual species as well as upon general biodiversity. We now have a greater understanding of the factors influencing spatio-temporal changes in top predator distributions, and are better equipped to provide more robust input to wider ecosystem models.

Session 9: MERP and ERSEM

Modelling plankton, fish and biodiversity across the UK seas – what ERSEM development has brought us

Jorn Bruggeman, PML

The European Regional Seas Ecosystem Model (ERSEM) is a model of the biogeochemistry and lower trophic levels of marine food webs. It is specifically suited for spatially explicit applications in shelf seas. Within MERP, ERSEM is used to drive fish models and to explore the role of biodiversity in lower trophic levels. For this purpose, ERSEM has been rewritten from scratch as a modular model, allowing it to scale from a canonical 1-phytoplankton/1-zooplankton configuration to setups with 100s of types of phytoplankton, zooplankton and benthic fauna. These setups are used to explore the role of functional diversity in plankton and the benthos (see talks by Sailley and Lessin). In addition, we have developed a fish module that supports full two-way coupling with ERSEM, enabling us to track bottom-up (plankton to fish) and top-down (fish to plankton) control throughout the marine ecosystem in a spatially explicit model of UK seas.

Advances in biogeochemical models plankton diversity

Sevrine Sailley, PML

Diversity of zooplankton is key for representing processes and linking primary production to ecosystem services of interest to human activity. In this respect we targeted representation of zooplankton by looking at size of organism and trait with two target groups: copepods (a food source for fish) and jellyfish. The European Regional Seas Ecosystem Model (ERSEM) is now capable of modeling copepod and jellyfish, making it the first biogeochemical ecosystem model to do so. This result is a stepping-stone toward improved representation of diversity in this type of model with already improved capacity for use in ecosystem services application.

MERP Partners

1. Plymouth Marine Laboratory (PML)
2. Glasgow University (GU)
3. Sir Alister Hardy Foundation for Ocean Science (SAHFOS)
4. Bangor University (BU)
5. Sheffield University (SU)
6. University of Strathclyde (UoS)
7. Queen Mary, University of London (QMUL)
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10. Scottish Association for Marine Science (SAMS)
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12. National Oceanography Centre (NOC)