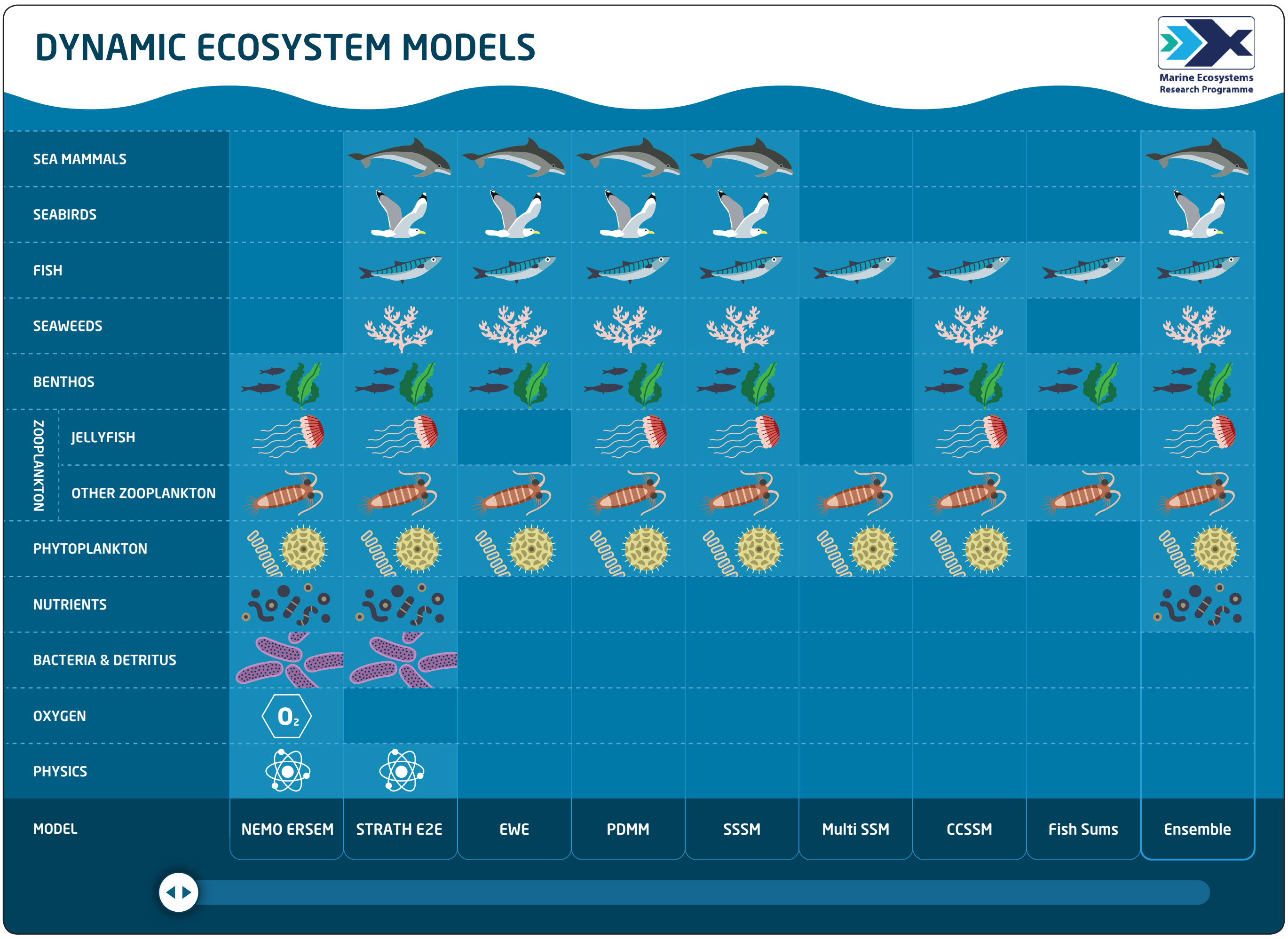
3 MARINE ECOSYSTEMS RESEARCH PROGRAMME – MODELLING

Marine Ecosystems Research Programme



MERP is advancing our understanding of the processes that drive the dynamics of marine ecosystems, and in particular marine food webs. This improved knowledge is integrated into existing ecosystem models, which are mathematical representations of an ecological system, to predict impacts of environmental change on the structure and function of marine food webs and the services they provide. The effectiveness of various indicators that are being developed to measure environmental status have also been explored. A range of existing marine ecosystem models and the modellers that have been developing them were brought together in MERP to determine which of the modelling approaches is best suited for particular groups of organisms, scales, geographical areas and required outputs. Developing and testing the models to more realistically represent the complexity of marine ecosystems, and making linkages between the models that enable them to 'feed' from each other or work together were key aims of MERP.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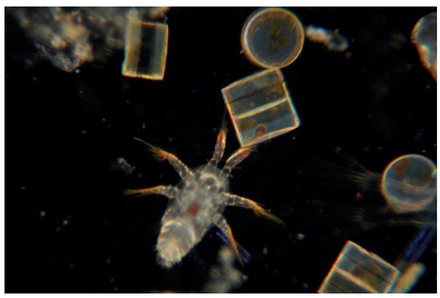
This infographic provides an overview of the MERP models and the food-web categories that are their inputs and outputs. Further information is included in the following pages, while a fully interactive version of this infographic can be interrogated on the MERP website. You are encouraged to get in touch with the contacts for each model if they can be of assistance with a policy or management issue where the models may be of some help.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European Regional Seas Ecosystem Model (ERSEM)

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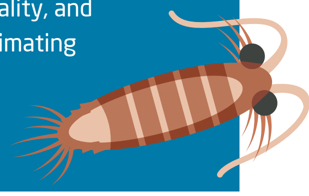
www.pml.ac.uk/Modelling_at_PML/Models/ERSEM

ERSEM is a planktonic ecosystem model which can be routinely coupled to a number of different hydrodynamic models such as the Nucleus for European Modelling of the Ocean (NEMO). It describes the biogeochemical cycling of carbon and the nutrients nitrogen, phosphorous, silicon, oxygen and iron. In ERSEM the ecosystem is subdivided into three functional types: producers (phytoplankton), decomposers (bacteria) and consumers (zooplankton), and then further subdivided by trait (size, silica uptake) to create a food-web. Physiological and population processes are included in the descriptions of functional group dynamics. Four phytoplankton, three zooplankton and one bacteria are represented, along with the cycling of carbon, nitrogen, phosphorous, silicon, and oxygen through pelagic and benthic systems. There are a number of existing ERSEM modelling initiatives in existence for UK shelf seas. These are geared towards three issues of interest to policy makers and managers: Understanding Natural Resources, Resilience to Environmental Hazards, and Environmental Change.

The ERSEM framework has been developed into a modular model that adjusts its detail and complexity in response to scientific questions and computational constraints; it now embraces diverse zooplankton groups and better represents food-webs. Uniquely ERSEM specifically represents jellyfish which are now recognised as increasing and impacting on the marine ecosystem in ways different from other non-gelatinous organisms. Sharing ERSEM outputs with other work across MERP and beyond will enhance guidance to policymakers and marine environmental managers. The model is being used by the UK Met Office to predict water quality, and is also of use in estimating UK shelf seas' carbon budget.



Strathclyde end-to-end ecosystem model (Strath E2E)

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E2E is geared towards marine ecosystem based management. It comprises an ecology model and a fishing fleet model that can be coupled to it. Now there is also an economics and fishers' behaviour model which creates the feedback between the state of the ecology and the properties of the fishing fleet. E2E works on two vertical layers in the water column and two horizontal components: inshore and offshore waters; it uses three inshore and three offshore habitats based on sediment properties. Geographically, model applications exist for North Sea, West of Scotland, Celtic Sea and English Channel.

E2E includes horizontal transport, vertical mixing, and sediment resuspension by waves and currents as 'physical' in-puts. Suspended and sediment detritus and bacteria are combined as detritus in E2E, sediment detritus is fixed in each seabed habitat from observational data. Also included are the ecologically important corpses and discards. Included in the E2E model are phytoplankton, omnivorous and carnivorous zooplankton, larvae of benthos and fish. Fish are represented by three types, including the external input from fish that migrate in at a set time of year, feeding, growing, being eaten or dying. Seabirds and sea mammals are included and there is an aim to separate them before the end of MERP. There is also intent to include seaweeds as part of MERP.

E2E is ready for use for carnivorous and omnivorous zooplankton and fish, while there is growing confidence in out-puts for nutrients, phytoplankton, benthos and seabirds and mammals. The outputs from E2E can be processed into other variables such as landings and discards for a particular fleet. Results of a model run can be converted into a range of graphs, spreadsheets, maps etc. E2E is more suited to annual projections at the current time.

Ecopath with Ecosim (EwE)

Contact: Natalia Serpetti,
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EwE is a whole ecosystem model that quantifies food-web and fishery interactions and can include fisheries impact and conservation and is also used to quantify changes in ecosystem indicators, including GES. The model is calibrated by comparing total model predictions with data of historical changes in populations and fisheries.

Inputs from other models and data sources, and outputs from EwE include sea mammals, seabirds, fish, seaweeds, benthos and zoo- and phytoplankton. The model is ready to be used with high confidence for phyto- and zooplankton and fish; there is growing confidence in its ability to produce meaningful results for seaweeds, seabirds and sea mammals.

The EwE framework is used worldwide, in MERP it is being used as a West coast of Scotland model, an area covering 110,000Km^2, and a Celtic Sea model. The joint research centre of the EU lists EwE as an important tool in its modelling suite.

Population-Dynamical Matching Model (PDMM)

Contact: a.rossberg@qmul.ac.uk

The **PDMM** is unique in its ability to resolve biodiversity to the level of interacting species across the entire food chain; each species is represented by its dynamic population biomass, and a set of fixed traits that determine food-web structure and physiological parameters. The model shifts the focus from the fate of particular species to that of biodiversity at community level. The model does not attempt a 1-to-1 representation of all species but aims to reproduce the high-level patterns and characteristic responses to pressures of species and the entire food web. The model does not distinguish between benthic and pelagic parts of the marine community.

Existing uses include:

- quantification of biodiversity ecosystem functioning (BEM) relations for exploited fish communities.
- Evaluation and comparison of 11 high-level management strategies to achieve multispecies MSY.
- Modelling and predicting recovery of fish-community size structure to changes in fishing pressure (Celtic Sea).
- Identification of processes driving and constraining the dynamics of the Large Fish Indicator.
- Modelling and predicting recovery trajectories of Large Fish Indicator, Large Species Indicator, Mean Maximum, Length, Mean Size at Maturation, and total fish biomass in response to changes in fishing pressure.
- Determination of time scales at which changes in fish community size structure affect fish species richness. PDMM has potential to assess impacts of biogeochemistry changes on marine biodiversity and fish production. It may quantify adaptability of marine food webs to climate change and species composition, as well as risk assessment of impacts of invasive species. It can be used to test novel food-web indicators.

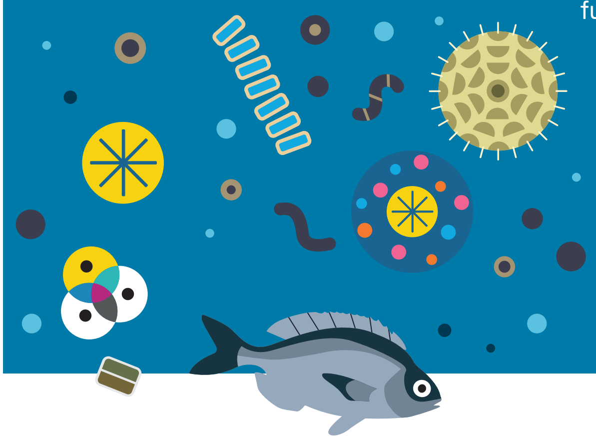
Species Size-Spectrum Model (SSSM)

Contact: Axel Rossberg, a.rossberg@qmul.ac.uk

The **SSSM** is simple and transparent, describing marine food webs using a size-based approach called size-spectra, in terms of the distribution of the biomass of the entire marine food web over species in different size-classes. This allows for simplified modelling of food-web dynamics and so is ideally suited for quick explorations of semi-quantitative "if/when" questions, as frequently occur in management contexts. An example might be responses of fish community-size structure to changes in fishing mortality at different size ranges such as forage fish, main commercial fish, top predators etc. The model can be related to several high level MSFD indicators and can assist in managing marine ecosystems at the indicator level. For example it could be used to inform policy makers about ecosystem responses to anthropogenic pressures (eutrophication, pollution, acidification, fishing etc.

Multispecies Size Spectrum Ecological Modelling in R (MIZER)

Contact: Paul Blackwell, p.blackwell@sheffield.ac.uk
https://cran.r-project.org/web/packages/mizer/vignettes/mizer_vignette.pdf



MIZER has been developed to represent the size and abundance of all organisms from phytoplankton and zooplankton, to large fish predators in a size-structured food web. Organisms are represented by species specific traits and body size, or body size alone. The model assumes that all species feed according to size and it requires future development to include other taxonomic groups ie seabirds and mammals.

It has been used to describe the effects of fishing on interacting species and the size spectrum and provides a means of scaling from individual processes to size distribution of species and community structure, or the sum of the size distribution of all species. MIZER can be used to estimate standard fisheries and conservation reference points for these species as well as a range of indicators for evaluating fishing effects; for example it was used to assess the response of the North Sea community to fishing pressure and whether meeting management targets will meet MSFD targets for biodiversity and food web functioning. MIZER can be used at any scale and outputs can be delivered as spreadsheets, maps, graphics, csv files and .Rdata files.

Coupled Community Size-Spectrum Model (CCSM)

Contact: Michael Spence, m.a.spence@sheffield.ac.uk

The CCSSM models the structure and dynamics of two interacting size structured communities. The 'pelagic' community consists of predators feeding on other predators and on 'benthic' prey that share and compete for detritus. Species are not represented explicitly and the model provides predictions of the abundance of organisms in each size-structured food chain at size, based on growth and mortality that arise from the organisms encountering and eating available and suitable food.

Predictions of size-spectrum slopes were validated in the North Sea by comparing model predictions with empirical data on the size structure of pelagic predator and benthic detrivore communities. Fish production estimates from an application of 78 EEZs showed reasonable correspondence with national catch statistics. Also modelled and empirical growth rates for species from the North Sea and elsewhere fell within reasonable bounds.

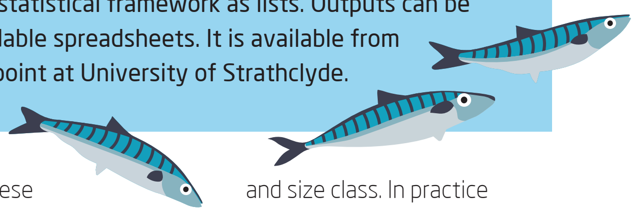
The model has been used for:

- Assessment of fishing impacts on community size structure and abundance in the North Sea.
- Exploration of the effects of coupling between pelagic and benthic food webs in response to fishing.
- Prediction of the effects of climate change on fish production at regional and global scale.
- Investigating the consequences of coral reef habitat complexity loss on fisheries.

Fish Strathclyde University Marine Scotland (FISHSums)

Contact: Dr Douglas C. Speirs, d.c.speirs@strath.ac.uk
https://www.strath.ac.uk/science/mathematicsstatistics/smart/marineresourcemodelling/researchtools/fishsums/

FishSUMS is a partial ecosystem model which simulates in detail a cadre of 10-15 species, each of whose populations is represented by a series of discrete length classes representing the full life-history from egg to adult. Species (currently fish) are selected from those that are commercially or ecologically important in a given ecosystem or as important as prey or predator. The length-based structure of the cadre makes FishSUMS different from other multi-species food web models based on age classes. It assumes that all species feed according to size and requires further development to include other groups such as benthos, seabirds and sea mammals. Outputs include a time series of total stock biomass (TSB), recruits and fisheries landings and discards, recruits and fisheries landings and discards, diet composition, and the population length distributions, for each of the cadre of focal species. FishSums is designed to simulate cascade dynamics – the propagation through the focal species food web of changes in harvesting rates, or climate driven changes in recruitment performance. The model is parameterised for the North Sea, it is being developed for use in the west of Scotland. It is parameterised as an R-package being stored in the R statistical framework as lists. Outputs can be as s readable spreadsheets. It is available from a share point at University of Strathclyde.



Multi-model ENSEMBLE

Contact: Paul Blackwell, p.blackwell@sheffield.ac.uk

The multi-model ensemble can produce outputs at a variety of scales and geographical extent depending upon the data available from the constituent models.

The Ensemble takes inputs from these models across the entire range of 'trophic' levels as represented in its constituent models (and indirectly from ERSEM). Which models and groups are included will vary between applications. The Ensemble can also take empirical data. Outputs also vary between applications, but in principle correspond to the highest resolutions in the constituent models e.g. by species and size class. In practice more certainty can typically be attached to more aggregated outputs, since those are covered in a greater range of models. Outputs may also be summaries of the behaviour/dynamics of outputs e.g. recovery times of indicators. So far the Ensemble has been used for phytoplankton, zooplankton, and fish and is being developed for Sea-birds and sea mammals.

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www.marine-ecosystems.org.uk

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Department for Environment Food & Rural Affairs