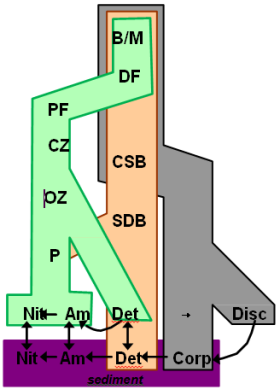
Marine Ecosystems Research Programme

Strathclyde end-to-end ecosystem model

(StrathE2E)



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1. What is the scope of the model?

Twenty-two state variables are included in the model, representing the nitrogen mass (moles N. m-2 sea surface) of classes of detritus, dissolved inorganic nutrient, plankton, benthos, fish, birds and mammals. Dynamics of these variables are simulated in continuous time and output at daily intervals by integrating a set of linked ordinary differential equations (ODEs) describing the key physical, geochemical and biological processes which occur in the sea and seabed sediments. These include the feeding of living components, and the production, consumption and mineralisation of detritus including fishery discards. Uptake of food is defined by Michaelis-Menten functions for each resource-consumer interaction defined by a preference matrix. Time-dependent external drivers and boundary conditions for the model are harvesting rates of fish and benthos, temperature, sea surface irradiance, suspended sediment, inflow rates of water and nutrient across the external ocean boundaries and from rivers, vertical mixing rates, and atmospheric deposition of nutrients.

2. What is the model doing?

The model represents the time-dependent dynamics of the ecosystem components in a spatial region which is assumed to be horizontally homogeneous, but vertically layered. The geographic setting is defined by fixed properties (layer thicknesses and sediment porosity) and the time dependent drivers and boundary conditions. Biological properties are defined by parameters of the various uptake, excretion, mortality and biogeochemical processes. Typically, the model outputs data at daily time intervals and also delivers annual averaged concentrations and annually integrated rates. A version of the model configured for the North Sea with limited scope for varying the inputs, can be run online at http://www.mathstat.strath.ac.uk/outreach/e2e/

For the published North Sea version of the model (Heath 2012), ocean driving and boundary were derived from runs of the NORWECOM model and from archived observations. As part of the EU-BASIN project, sets of driving and boundary data have been assembled for a range of European shelf sea regions from outputs of the UK ERSEM model. Running the model for these regions and comparing with data is work in progress.

3. How has the model been validated?

Simulated annealing was used (Heath 2012) to fit parameters of the StrathE2E model of the North Sea so as to minimise the discrepancy between the stationary annual cycle of the model and data on monthly and annual averaged abundances of state variables, production rates and feeding fluxes in the North Sea ecosystem, averaged over the period 1970-1999. During fitting, the model was driven by 1970-1999 average annual cycles of environmental conditions and harvesting rates of demersal and pelagic fish and benthic invertebrates. Details of the minimised discrepancy between outputs from the baseline model and each element the observed data are given in Fig. 1.

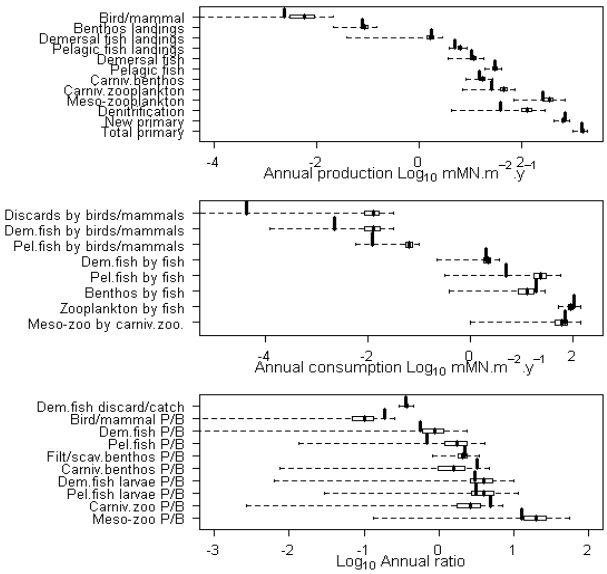

Figure 1 - Residual discrepancies between the best-fit model and observed data. The three panels show different categories of observed data from the North Sea – annual production, annual consumption, and annual ratios. Within each panel, each row is a discrete metric averaged over 1970-1999 where possible. Box and whiskers show the range, quartiles and median over the period, or a nominal estimate of variation where no firm data exist. The vertical tick-mark above each box and whisker indicates the corresponding value from the best-fit model as a result of parameter optimisation by simulated annealing.

4. How has the model been used?

- Simulation of fishery yields and MSY in relation to the combination of pelagic and demersal harvesting rates (Heath 2012).
- Simulation of trophic cascades and the sensitivity to top-down and bottom-up drivers (fishing and river nutrient inputs (Heath et al. 2014a)
- Sensitivity of fishery yields to environmental drivers and biological parameters (Morris et al. 2014)
- Cascading trophic effects of scenarios for implementing a discard ban (Heath et al. 2014b)

5. How could the model be used in the future?

- Sensitivity of fisheries to ocean acidification effects (work in progress)
- Hindcasting ecosystem harvest rates since the 1960's and dis-aggregating the effects of environment and fishing (work in progress)
- Comparing fishery yields and MSY in different shelf sea regions (work in progress)
- Projecting the cumulative effects of harvesting and environmental change (temperature, ocean transport) in the future
- Ecological effects of alternative discard ban measures
- Coupling of the E2E ecological model to economic and social models based on game theory and/or agent based methods (work in progress)

References

Heath, M.R. (2012). Ecosystem limits to food web fluxes and fisheries yields in the North Sea simulated with an end-to-end food web model. Progress in Oceanography (Special issue: End-to-end modelling: Towards Comparative Analysis of Marine Ecosystem Organisation) 102, 42-66.

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