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A System for the Spatially Explicit Modelling of Communities of Class-Structured Benthic Organisms

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The aim is to develop a model to predict the response of benthic community structure To the environment and human impacts; at high resolution and over large spatial scales.

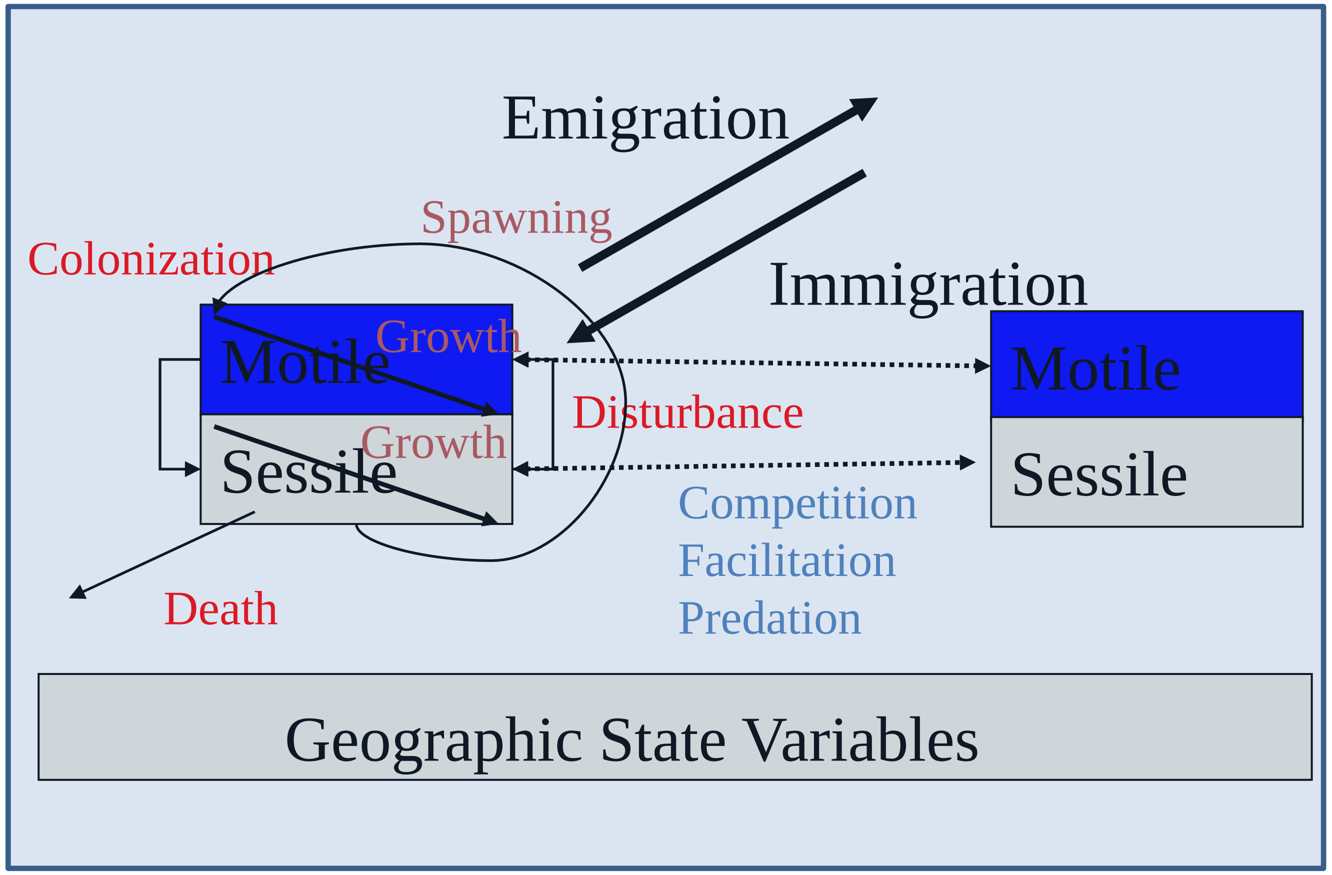
It should allow data input and visualisation through a GUI and have GIS Capabilities.

A Conceptual Outline of the Benthic Model

The model is grid based, made up of a number of functional groups. Each functional group is made up a number of size based classes which can vary in their fraction of calcified structure (shell). Each functional group is either motile, sessile or has both motile and sessile phases.

The processes that are modelled include spawning, mortality, growth (as a rate of transition from one size / calcification class to another), the rate of transfer between motile and sessile phases and vice versa as a result of disturbance.

Migration can occur as a diffusion process, or via a single pool across the whole area. The interactions between functional groups are predation, which is size and calcification class dependent, and competition and facilitation



State Variables and Middleware

For each process the value of any of the parameters can be determined by a state variable (e.g. temperature, prey biomass, fishing pressure).

State variable types:

constant (fixed parameters) - 1 value

geographic - 1 value per cell from GIS.

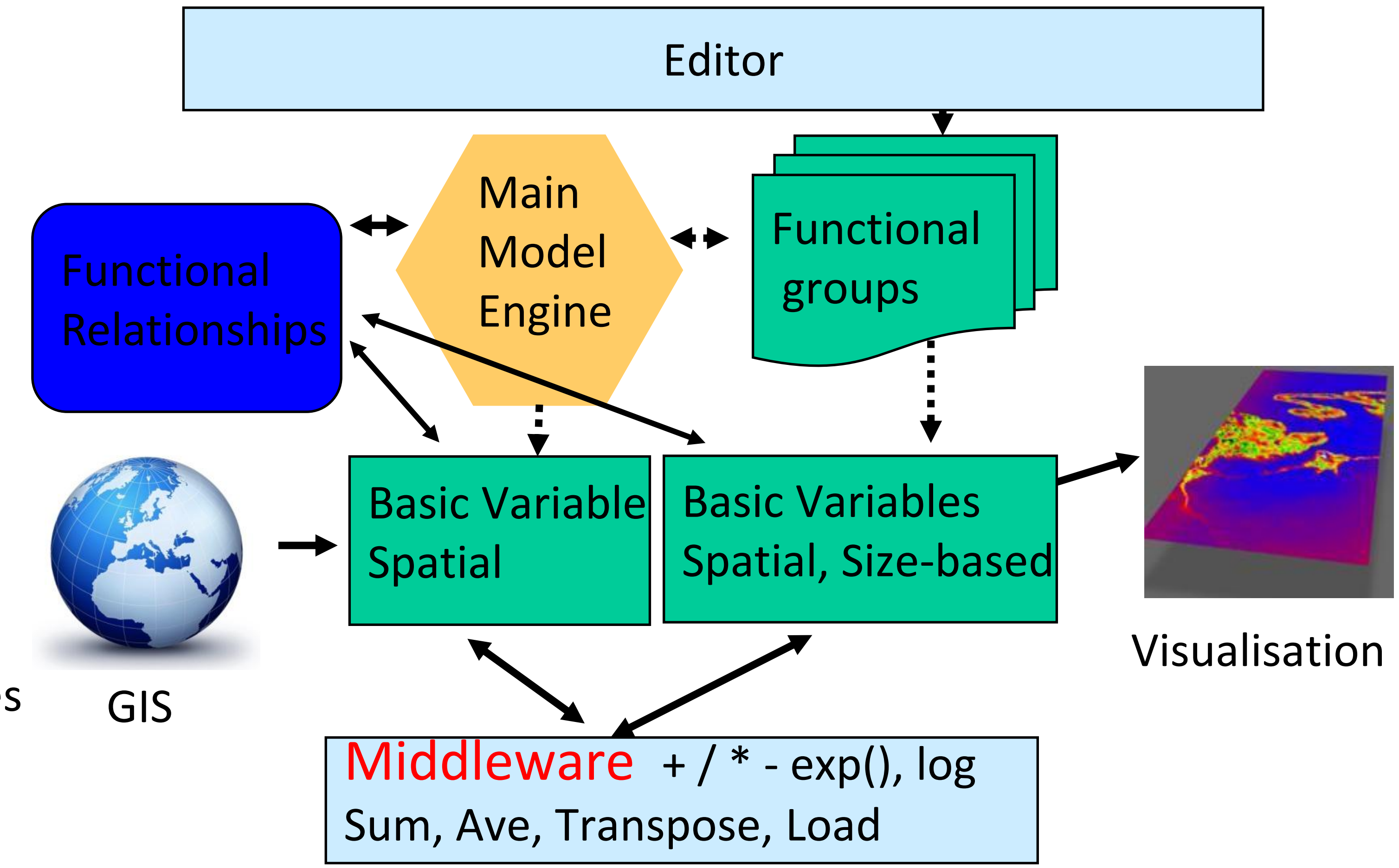
class specific - 1 value per or size class

Size and class specific – Cells x Size Classes values.

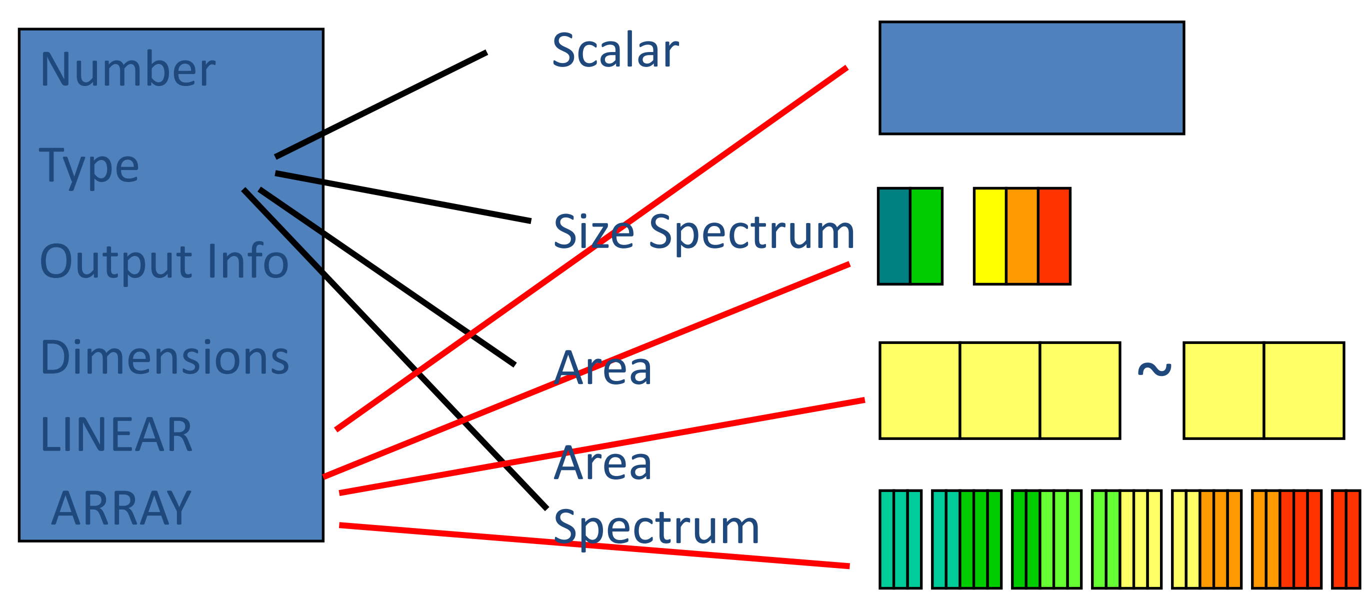
Functions are added to the model to describe relationship between state variables and to create new values.

A library of middleware is provided for efficient vector processing of large array of values, efficiently aligned in memory.

Line graphs, bar charts and maps can be produced from any state variable.



The Basic Variable



Specifying the Model

The front end allows model parameters to be edited, GIS layers to be added, and relations between functional groups to be specified.

The population trajectory, which describes size and calcification classes for the functional groups is derived from the growth function.

$$G_p = Wg(1-c)^{2/3} - Wl(1-c) - Wic$$

G_p is total growth, c proportion of shell. W is biomass, g is growth constant , l is maintenance cost of body, i is maintenance cost of shell.

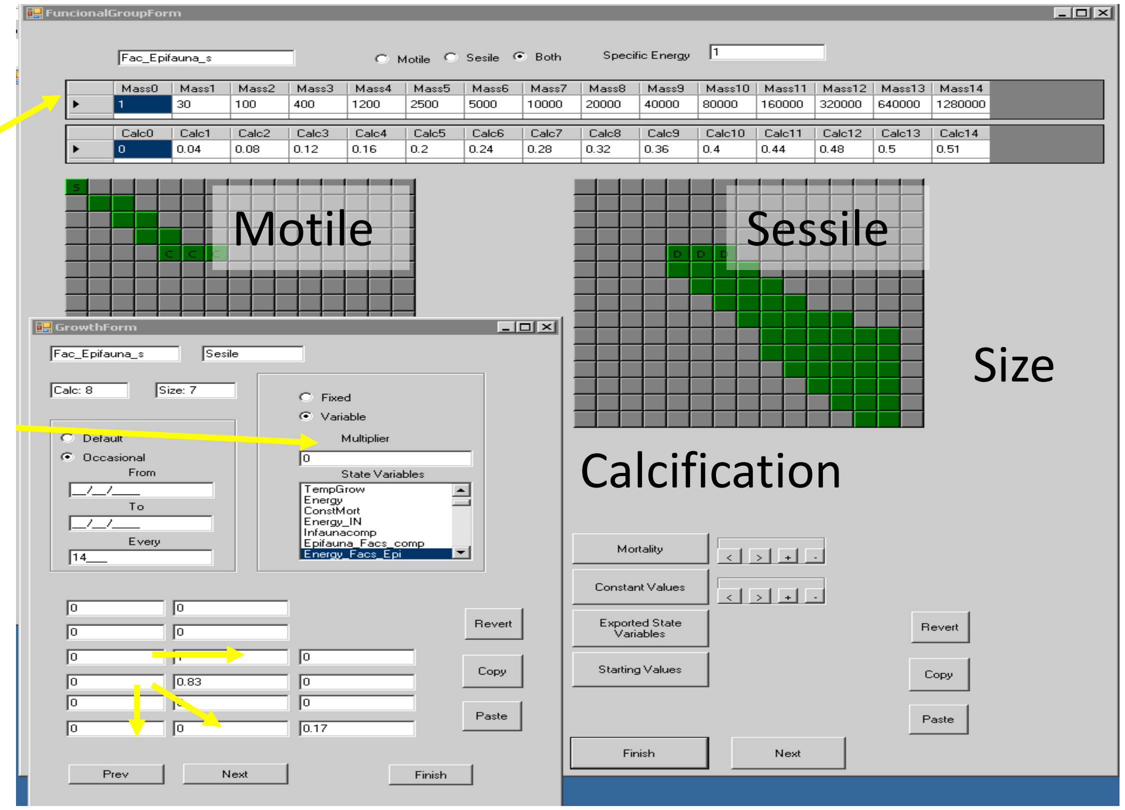
Growth is modelled in terms of rate of transition between classes and may depend of a state variable.

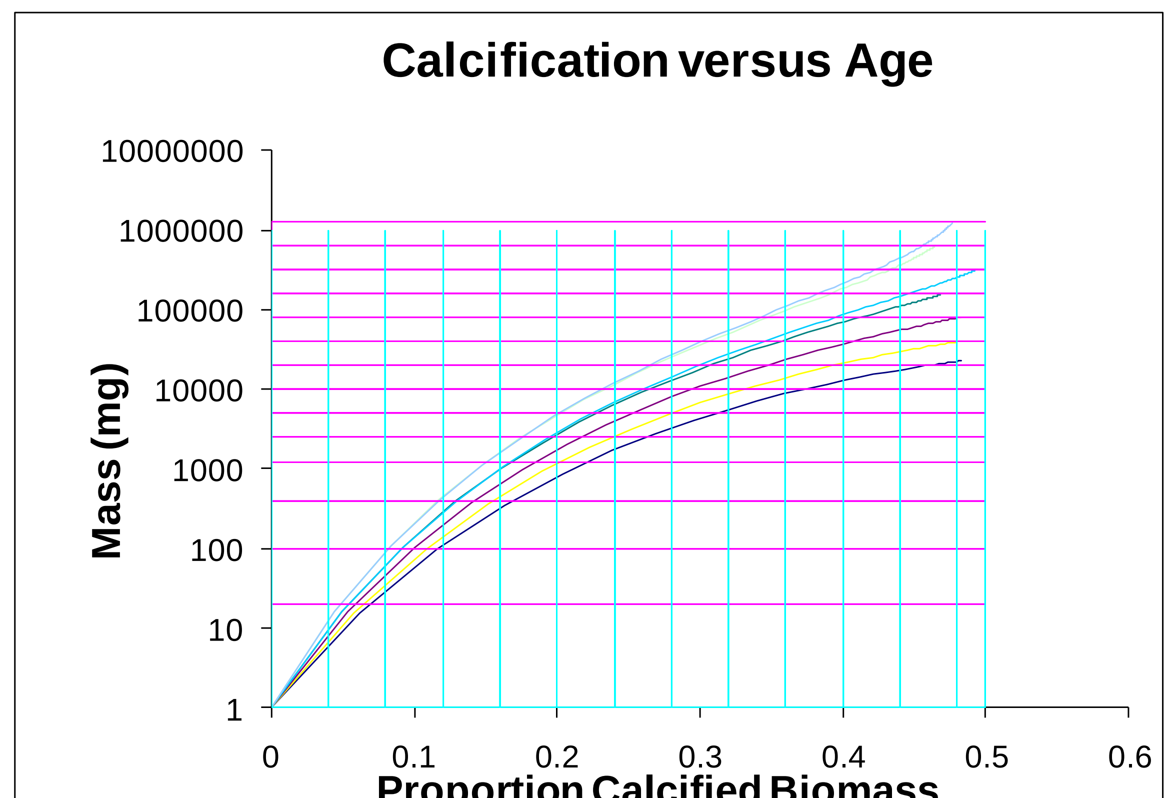
Other processes such as spawning, colonization, can also be specified via the front end, using user functions.

Size & Calc. Classes

Dependent State Variable

Growth Rate





Geographic Layers

The ability to add data layers from a GIS makes this a powerful tool for modelling where there is existing GIS information on the physical environment and human impacts.

Benthic Variables used are:

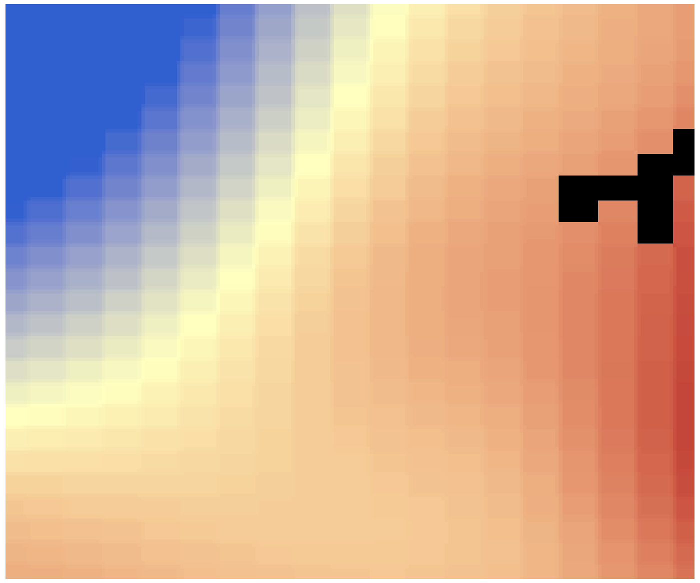
Temperature – used in growth and mortality calculations.

Seabed Type – affects colonization and mortality due to trawling.

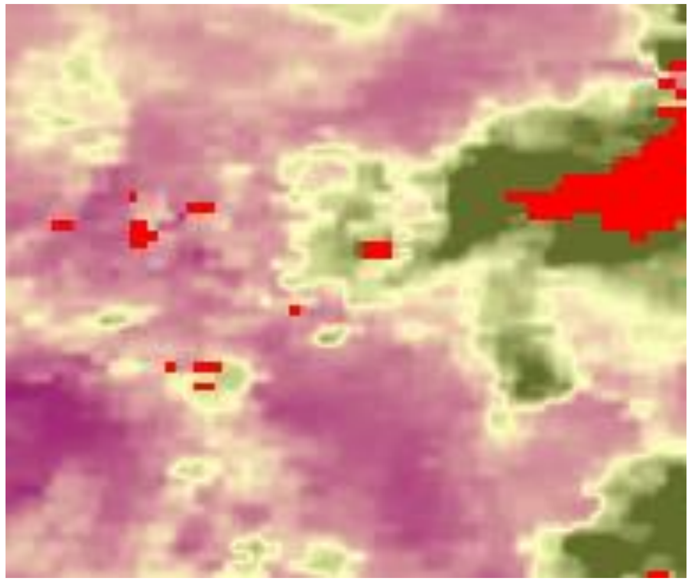
Trawling frequency – from vessel monitoring system (VMS) , describes human impact.

Chlorophyll – from remote sensing, used in growth calculations.

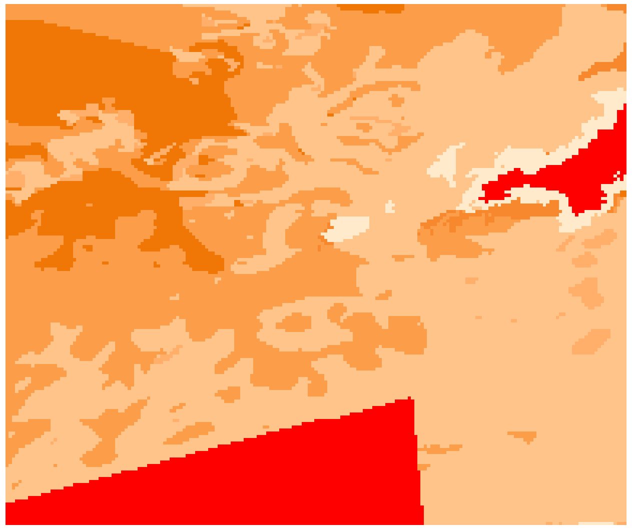
A spatial resolution of 160 by 196 cells is used for the first iteration in the Celtic Sea benthic model.



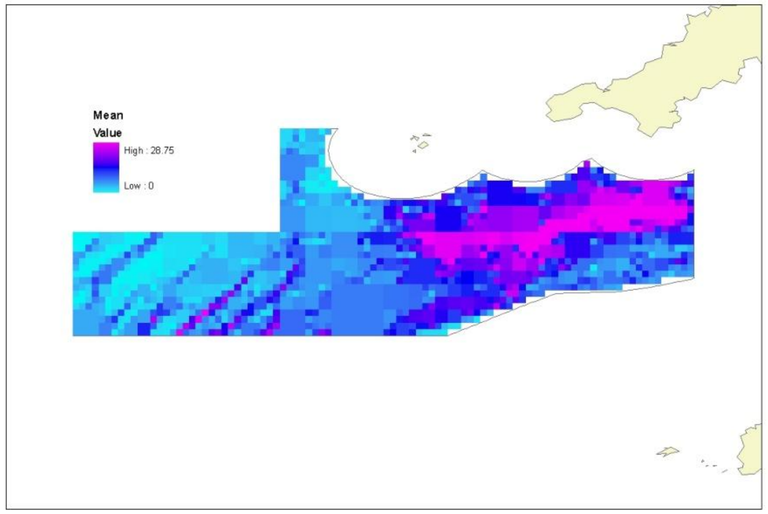
Seabed Temperature (red is warmest)



Chlorophyll (green is highest concentration)



Seabed type (darker orange is finer sediment)



Trawling frequency (purple most trawling)

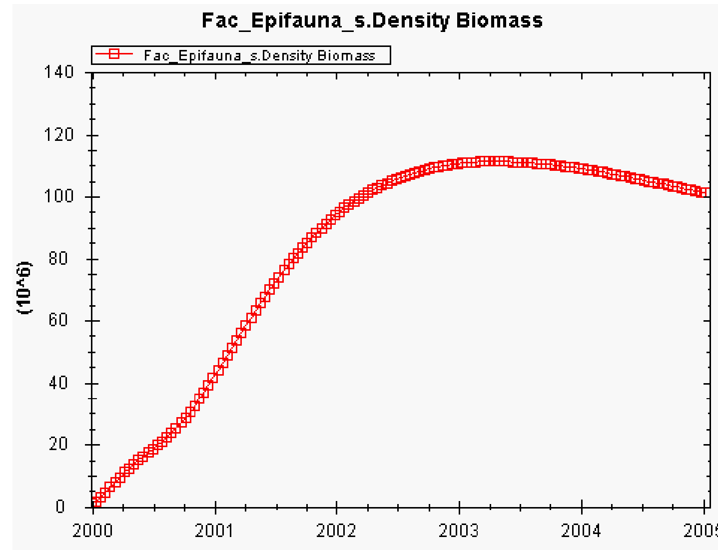
Model Dynamics

A test model was developed with popu - lations of meiofauna, small infauna, large epifauna, infauna, motile fauna and predators. The dynamics of the biomass of some of these groups are shown opposite.

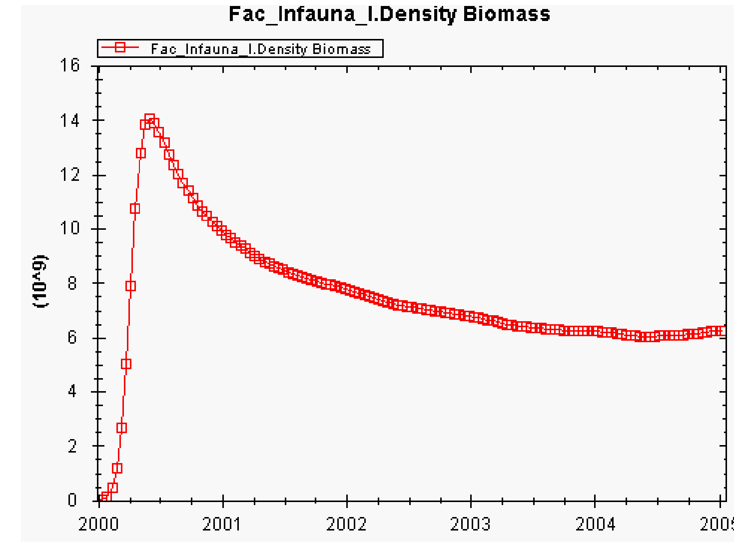
The motile fauna are facilitated by the epifauna group. The predator population has a source outside of the model ecosystem, causing stable predator-prey dynamics.

Biomass distribution between size classes is determined by growth transition rates. Biomass in groups decays depending on mortality, with transitions caused by space limits of colonization (panel c).

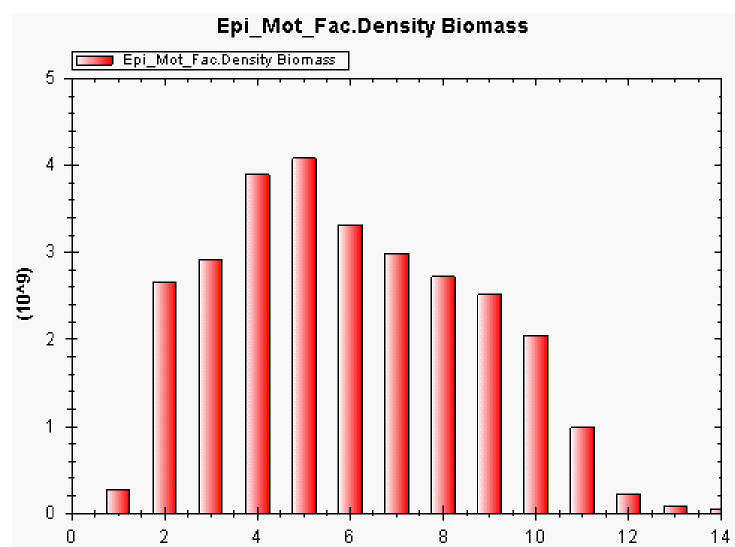
Facilitation allows increased growth of groups living in biogenic habitats created by the epifauna.

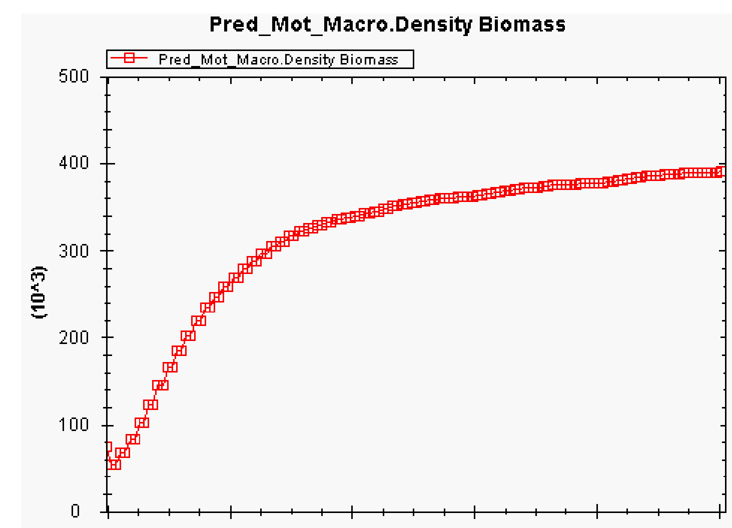


a) Epifauna



b) Large Infauna





c) Motile Fauna

d) Predators

Mapping the result of Benthic Disturbance

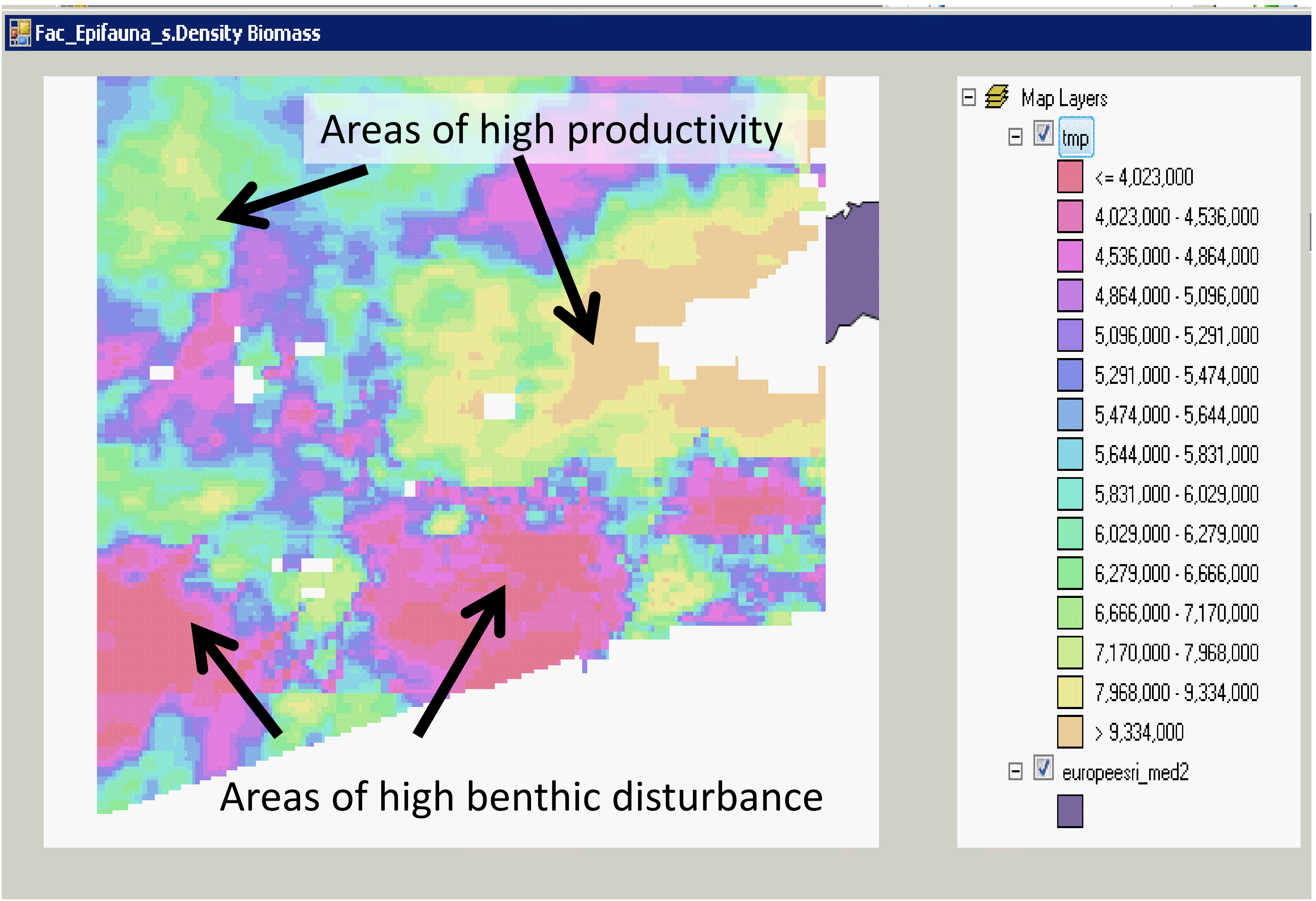
The Built in GIS system and the ability to run large models allows the state of the benthic community and the effect of human impacts to be assessed at large spatial scales, and for the outputs to be presented as maps.

We examined the map of standing biomass of epifauna, assuming transport of motile larvae but not nutrients.

Standing biomass predictions reflect primary production and mirrors the pattern of beam trawling impacts which is concentrated in a few areas.

Ongoing work will make use of an extensive field program to refine assumptions and calibrate and validate the model.

Example of biomass distribution for epifauna group



In the future we intend to develop the model into a tool that can be used to support spatial management and to predict the impacts of fisheries and management actions on benthic communities at large spatial scales.

Acknowledgements

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