Initial Results from a Fisheries Configuration of The Madingley Model

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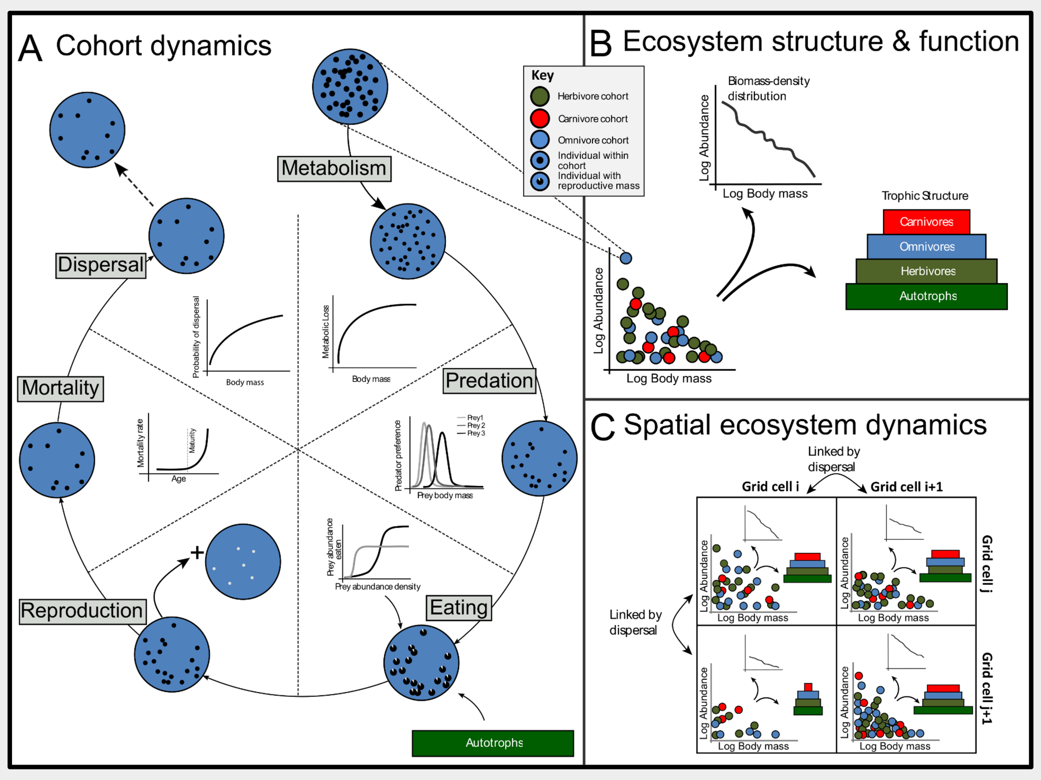
Abstract

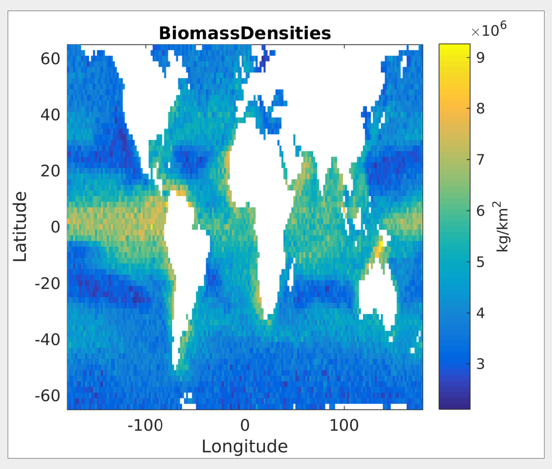
Around 12% of the global population depend on fish for their livelihoods (FAO, 2016). The value of exported fish on the world's markets was US $148 billion in 2014. Fisheries are being overexploited (Pauly & Watson, 2009). More informed management of marine living resources is required to safeguard the supply of food and income to human societies. However, many questions regarding the relationship between human activities and ecological processes remain unanswered. Here we present initial results from a unique model configuration based on the Madingley General Ecosystem Model (Harfoot et al, 2014). The aim is to develop a deeper understanding of the stability of marine ecosystems in the face of fishing pressure. We look at the relationship between fishing pressure and available biomass to explore the question of whether a small reduction in fishing pressure can have a big impact.

The Madingley Model (see **Box 1**) was originally developed as part of a joint collaboration between UNEP-WCMC and Microsoft Research (Harfoot et al., 2014). As part of this project, the code has been completely reimplemented in C++. This is so that it will run more efficiently on Linux and any High Performance Computing cluster.

Box 1. The Madingley General Ecosystem Model

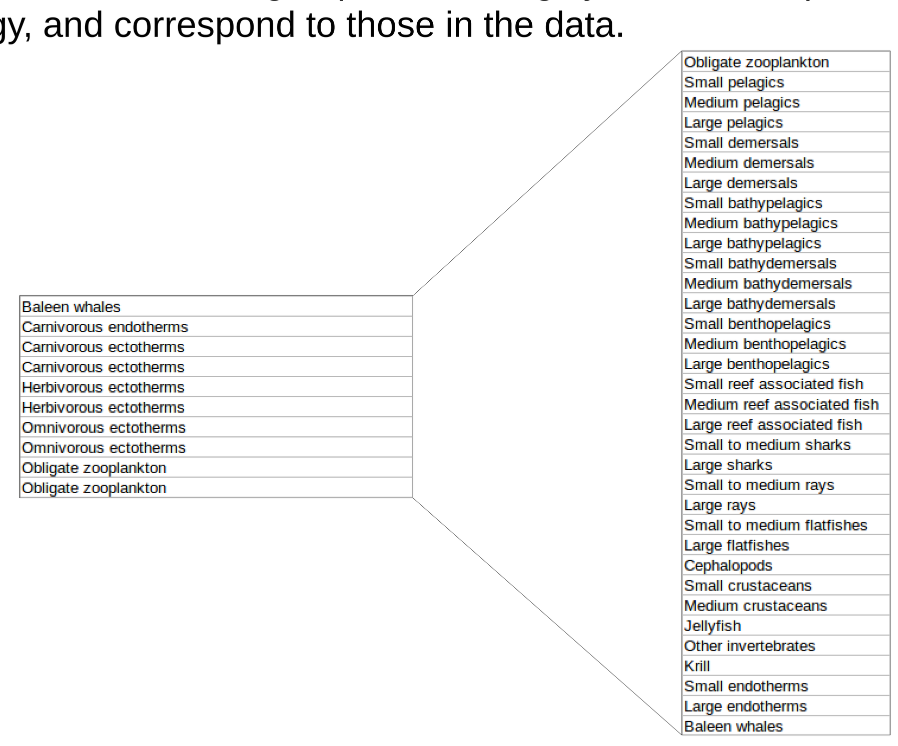


Emergent Marine-Only Result:

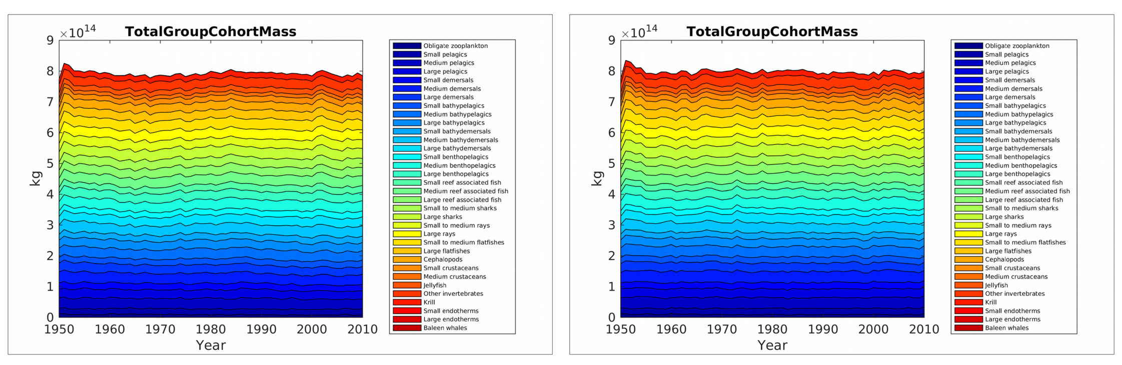


Model Features:
- Global, spatially configurable (limited by input data)
- Mechanistic
- Individual-based
- Size-based
- Functional Types
- Emergent behaviours

A major objective of this project was to integrate the Sea Around Us fisheries catch data (see **Box 2**). This was achieved by expanding the marine functional groups in Madingley to better represent the ecology, and correspond to those in the data.

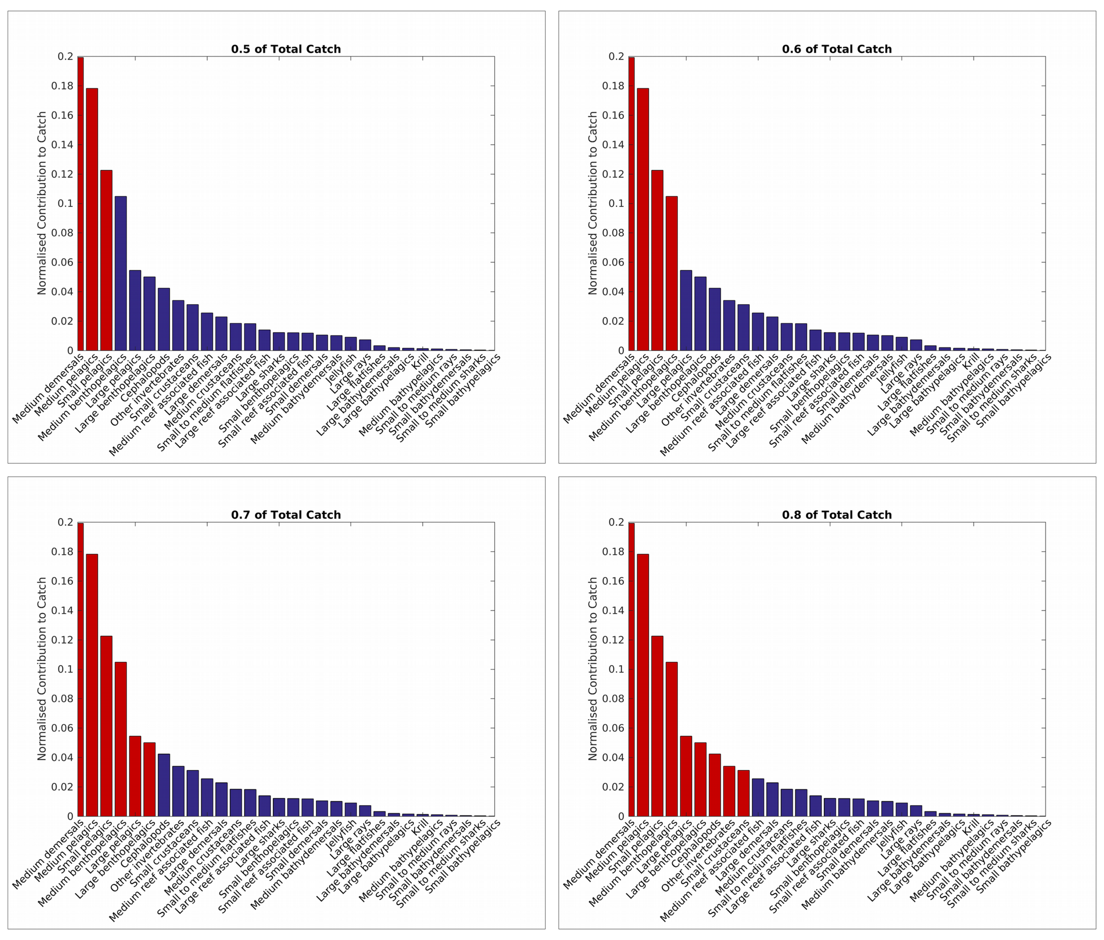


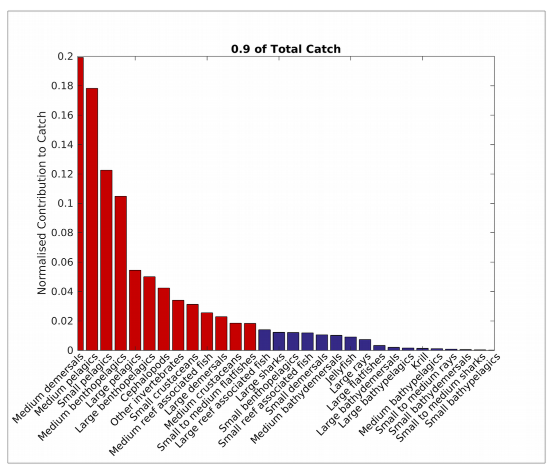
It was initially assumed that the system would respond to fishing pressure by decreasing in heterotrophic biomass. This was not the case. Some configurations showed an increase in biomass following the application of fishing pressure.



The plots above show the mass of each functional group with fishing pressure applied (left) and without (right). The system appears unresponsive to fishing. However, these data show a time series. Further analysis was required to determine if a system response was visible at a different scale.

As can be seen from the time series of catch (in **Box 2**), fishing is not consistent across functional groups. Some groups are exploited much more heavily and consistently than others. The differences between exploitation levels on different groups can span many orders of magnitude. For this reason, five fractional contributions to the total catch were chosen to determine which functional groups contribute to the available biomass.

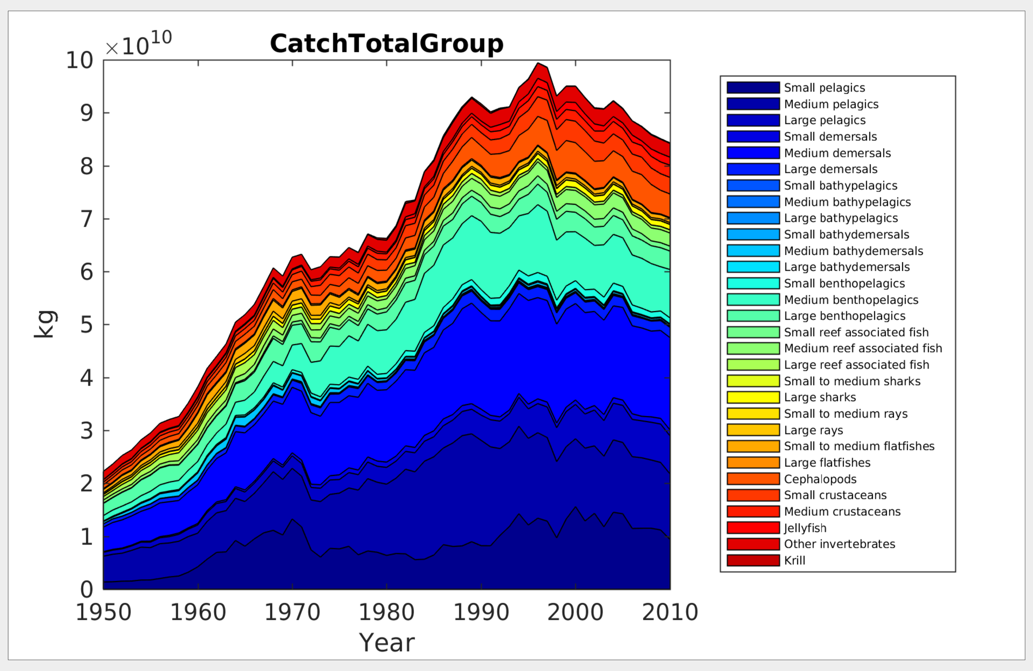




Functional groups that determine the available biomass are marked in red. Functional groups marked in blue experience exploitation levels that are too low to be considered a contributor to the available biomass. These are dropped from the following analysis.

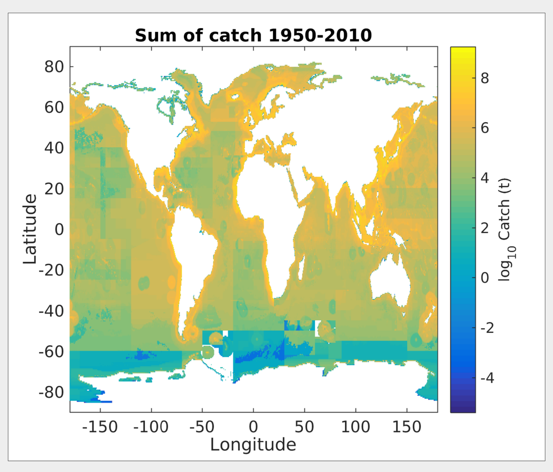
In addition, coefficients on fishing pressure were also considered. This is to explore the relationship between fishing pressure and available biomass. In this way, the potential for Madingley to answer the question of whether a small reduction in fishing pressure can have a big impact on the available biomass is considered

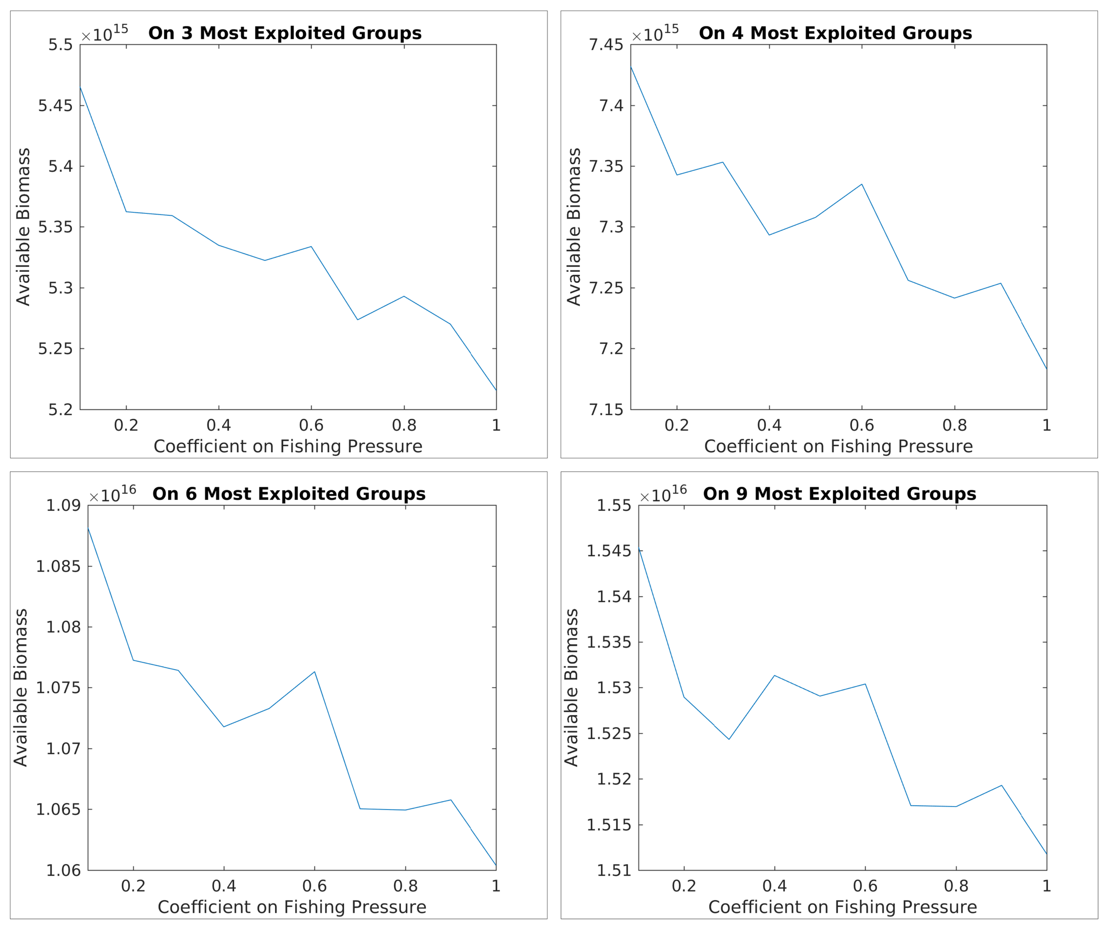
Box 2. The Sea Around Us Catch Data

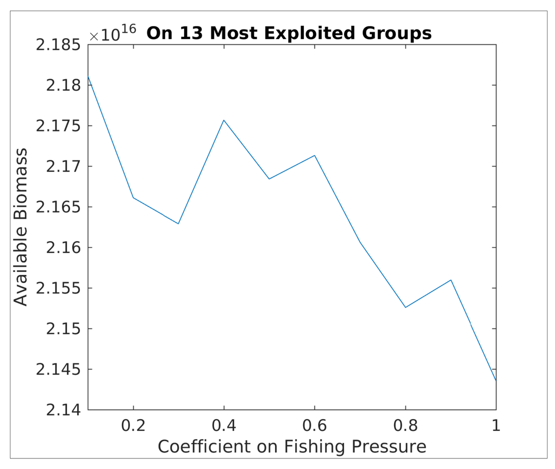


Data Features:
- Global, at 0.5deg resolution
- Functional Type View
- Augmented FAO reported data with illegal and by-catch.
- Now 1950 to 2014

Sum of Cell-Based Data:



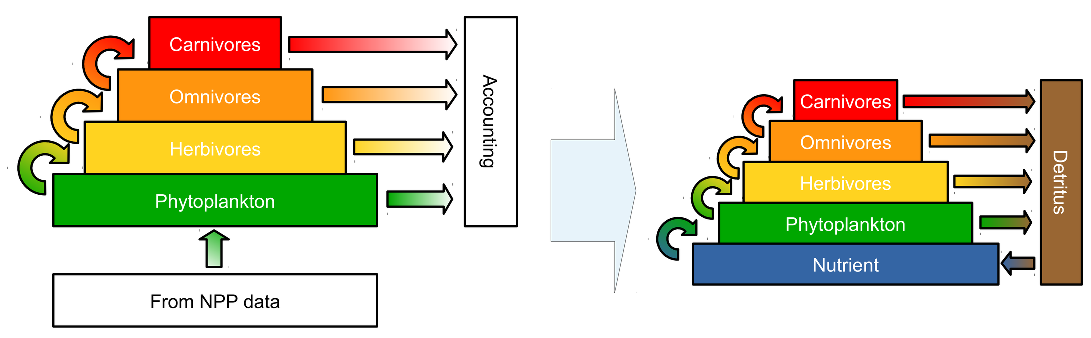




For each of the five functional group sets that contribute, these plots show the sum of available biomass across the entire spatiotemporal resolution of the model for ten coeffecients on fishing pressure.

When summed across the full spatiotemporal resolution of the model, it is clear that the model ecosystem does respond to fishing pressure. It can also be seen that the model response to the coefficients on fishing pressure is suggestive of a non-linear relationship. However, it should be noted that Madingley is a stochastic model, and these are results from single runs at each coefficient on fishing pressure. To confirm this finding, the model would need to be run many more times to explore different permutations and to build a more robust ensemble result.

There are a several areas in progress with this model. There are two parallelised versions currently under development (OpenMP and OpenMPI). These will help generate outputs from higher spatiotemporal model configurations in less real-time. Primary production is currently driven by NPP data, making the system materially open. A simple NPZD is being integrated in to the model for material closure and to ensure productivity is made a function of the model ecosystem activity.



There are also improvements to input data that will bring the model in-line with the Fish-MIP protocol and position it for contribution to the next round of comparisons.

References

FAO. 2016. The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome, 200 pp.

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