Cod in a web:
a partial-ecosystem approach to modelling cod in the North Sea

University of Strathclyde
Science

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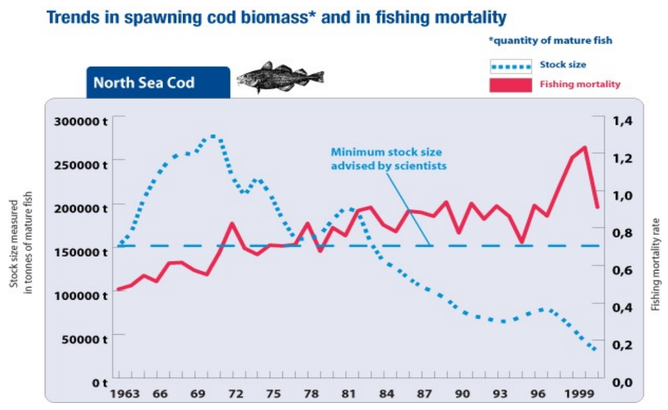
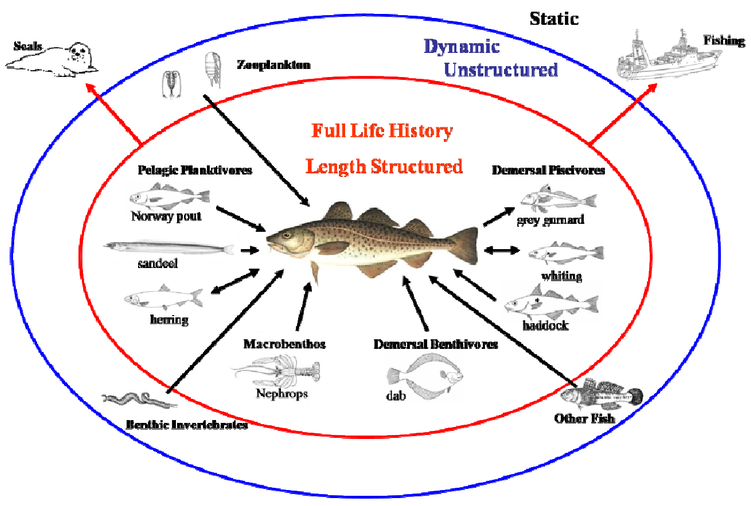
Introduction

Overfishing is a problem in fisheries worldwide. Cod in the North Sea are at historically low levels, and the prospects for recovery are uncertain. Current management ignores the fact that cod live in a complex food web involving predators and prey, many of which are themselves exploited. To understand better the effects of these interactions on the cod fishery we developed a new modelling approach that incorporates egg-to-adult life history detail for cod and the species with which it interacts with most strongly.





Methods

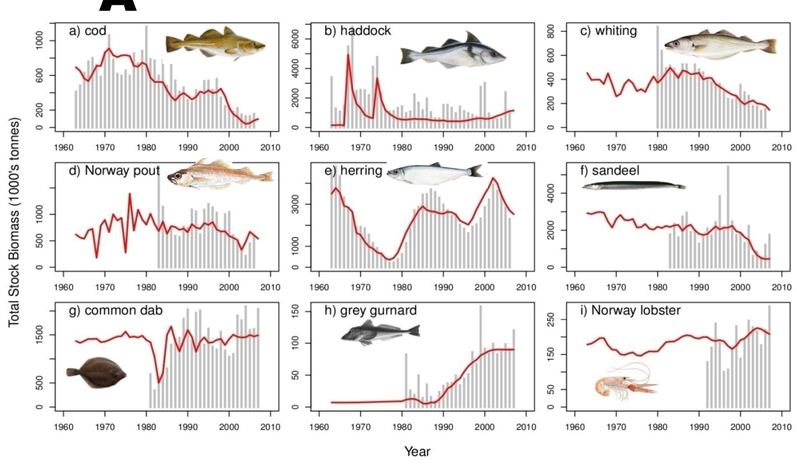
Our computational method uses discrete time and discrete length classes to model coupled length-structured fish populations. The model includes a target set of fish species (those within the red ellipse in the figure) which are modelled with full length structure from egg to adult. The rest of the ecosystem is represented dynamically, but in a highly simplified way, without modelling individual species or life history (outside the red ellipse, but within the blue one). The food requirements for growth, maintenance and reproduction are used to calculate predation mortalities on the prey. Fishing mortality rates, obtained mainly from annual International Council for the Exploration of the Seas (ICES) stock assessments act as time-dependent external drivers to the biological system.

Results

Model output includes times series of stock biomass (Figure A, model in red, stock estimates as grey bars), recruitment and landed catch, length distributions (Figure B), and the proportion of different prey in the diets of predators. Numerical experiments showed that the good match for cod only occurred when herring predation on cod eggs was included.

If fishing mortality is constant an equilibrium yield of cod is obtained. Figure C shows how this equilibrium changes depending on *both* cod fishing mortality and herring fishing mortality. Cod yield is greater when herring is fished hard, and the position of the maximum sustainable yield also changes. Running the model forward under current fishing mortalities (Figure D) predicts a twenty year timescale for stock recovery (black line), but cod extinction if herring recruitment increases back to pre-2000 levels (red dashed line).

A



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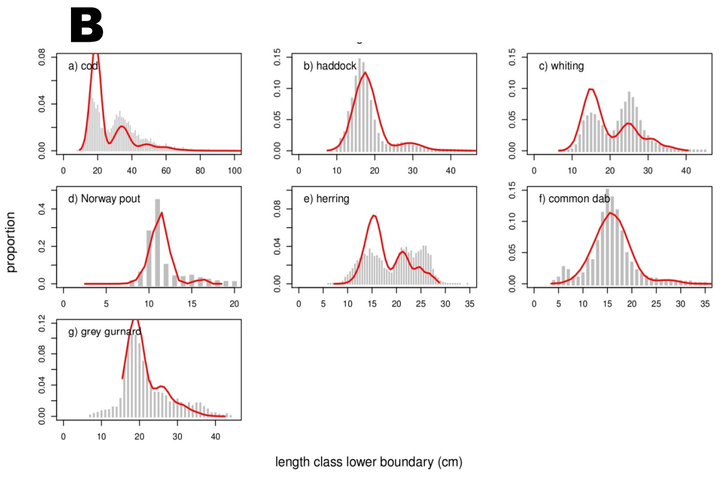
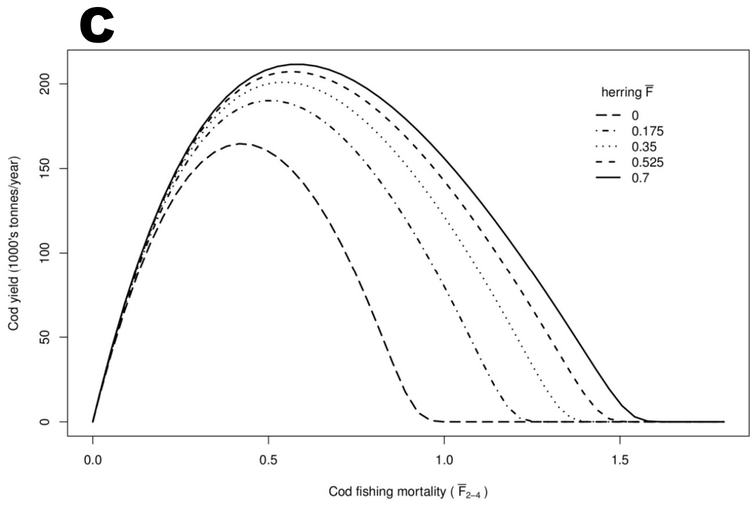


C



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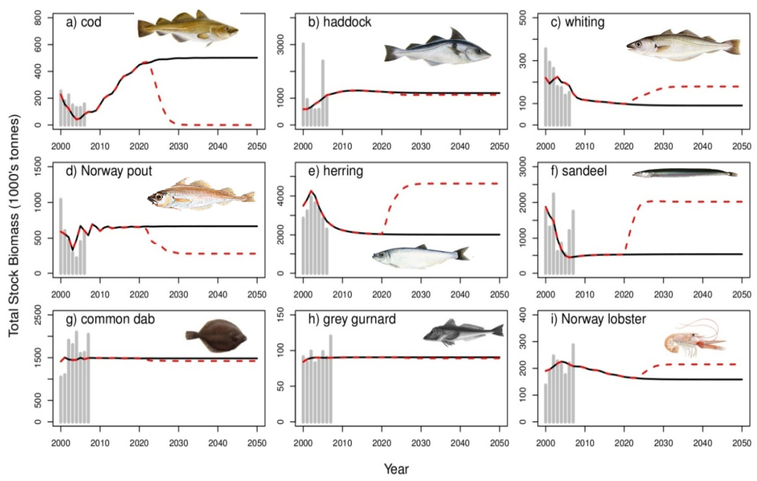

Conclusions

- Herring predation on early life history stages of cod is dynamically important.
- High herring abundance may play a role in the decline of stocks even during periods of declining fishing pressure.
- The maximum sustainable yield of cod is strongly dependent on herring abundance.
- Current levels of cod exploitation may become unsustainable if herring recruitment returns to historical high levels.

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