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Exploring fisheries strategies for the western English Channel using an ecosystem model

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ABSTRACT

An ecosystem model of the western English Channel ecosystem in 1994 was used to explore the effects of the use of a fishing policy optimization routine on profits, number of jobs and ecosystem structure. The optimization for single objective led to the specialization of the fishing fleet, with some fleet types being almost excluded. The profits and mainly the job optimizations led to big changes in the ecosystem structure, with loss of diversity, but the overall biomass of all vertebrate groups represented in the model increased considerably. For the objective focusing on ecosystem structure, there was an increase in biodiversity, with many long-lived groups predicted to increase, although the overall vertebrate biomass suffered just a small increase. An "ideal" mixed policy configuration was found when slightly greater weight was given to ecosystem structure than was given to profits and jobs. This scenario led to an overall reduction in effort but also to increased profits and biodiversity, while keeping the number of jobs at the same level as the baseline estimates. The results of the optimizations showed that the average trophic level of the catches is quite resistant to changes in the underlying system structure. On the other hand, despite the high level of aggregation of the model structure, a biodiversity index estimated by the model presented large changes as a function of the weights placed on the single policy functions, reflecting the changes in the system structure. The output of the application of the fishing optimization presented here should be considered in qualitative rather than in quantitative terms as an aid and part contribution to the complicated discussions on future long term management actions. Nonetheless it points to an overall reduction in fishing capacity, an objective widely accepted within the scientific community, while keeping the fishery in a profitable state.

1. Introduction

Ecosystem models play an important role in the ecosystem approach to fisheries and the interest in the development of such models is not new. The ecosystem model of Andersen and Ursin (1977) is an example of a relatively early attempt to set fisheries into an ecosystem context. However, its complexity, large input data requirements and perhaps the lack of accessibility to computer facilities have precluded its use. The progress of computation facilities that has occurred in the last 10–15 years has allowed the spread of more complex methodologies, even in the context of single-species assess-

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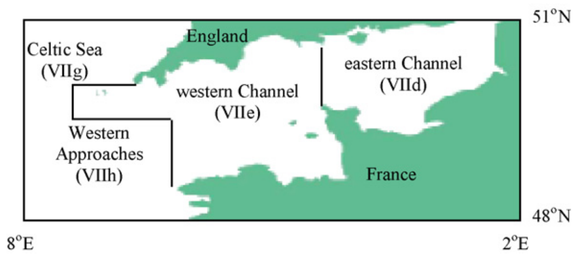

Fig. 1 – The western English Channel and adjacent waters. Roman numerals represent ICES areas.

ments (Hilborn, 2003), and has allowed the use of very different sources of information and of modelling approaches dealing with many aspects of a fishery system in a unified framework (Hilborn, 2003; Christensen and Walters, 2004a).

Ecosystem models can be used as a tool to tackle a number of problems. They provide a framework to identify potential changes in complex systems that cannot be identified with single-species models, such as counterintuitive changes in abundance when species interactions outweigh the effects of fishing impact or climate change. Ecosystem models can also be used to reveal otherwise unknown system properties, and to emphasize the need to improve knowledge about specific parts of the system. Further uses are to "test" the compatibility of data sets and to serve as a useful basis for the elaboration and/or exploration of scientific hypothesis about system dynamics and functioning (Vasconcellos et al., 1997; Christensen and Pauly, 1998; Jørgensen, 1994; Pauly and Christensen, 2002; Fulton and Smith, 2004; Walters and Martell, 2004; Araújo et al., 2006). The Ecopath with Ecosim (EwE) software (Christensen et al., 2005) is currently the most used and tested ecosystem modelling tool for addressing the issues of how ecosystems are likely to respond to changes in a fishery and to the influences of climate at the ecosystem level (Christensen and Walters, 2004a; Plagányi and Butterworth, 2004; Araújo et al., 2006; Guenette et al., 2006). Fulton and Smith (2004) compared the results of detailed simulations for Port Phillip Bay, Australia, from EwE with two other ecosystem-modelling tools and concluded that they lead to the same general conclusions.

The fisheries of the English Channel have been studied in some detail in the last decade. Economic, technical interactions and biological aspects have been described and have been subjected to modelling studies. The fishery system may be regarded as a large and diverse multi-country, multi-gear and multi-species artisanal fishery (Ulrich et al., 2001, 2002; Stanford and Pitcher, 2004). The model developed by Ulrich et al. (2002) explores the technical interactions by dividing the fishery in different sectors or "métiers" (gear × target species × fishing area) but does not account for trophic interactions. Stanford and Pitcher (2004) developed EwE models for the English Channel (Fig. 1) as a whole and explored the issue of fisheries policy optimization for the system with a previous version of the EwE software. They recognized that "there would certainly be a rationale for making two models, separating the western from the eastern Channel, because of their distinctiveness". To take into account the unique features of the western English Channel system, Araújo et al. (2005, 2006) developed EwE models to comprehensively describe the system's properties and to explore the effects of modelling food web interactions, variation in plankton production and fisheries. Here we use model structure and parameters estimates for the western English Channel ecosystem from Araújo et al. (2005, 2006) to explore the effects of different fishing policies on economic, social and ecosystem structural aspects.

2. Methods

2.1. The modelling software

Christensen et al. (2005) and Christensen and Walters (2004a) give a detailed description of the Ecopath with Ecosim (EwE) software, and critical analyses of the approach can be found in Aydin (2004), Plagányi and Butterworth (2004) and Fulton and Smith (2004).

The EwE model (Christensen et al., 2005) is built on a system of linear equations describing the average flows of mass and energy between the species groups during a period of time, normally a year.

The flow to and from each functional group is described by the following equation:

$$B_i\left(\frac{P}{B}\right)_i - \left(\frac{P}{B}\right)_i B_i(1-EE_i) - Y_i - E_i - BA_i - \sum_{j=1}^{n} B_j\left(\frac{Q}{B}\right)_j \cdot DC_{ji} = 0$$

where B_i is the biomass of i, P/B_i the production/biomass ratio, Y_i the total fishery catch rate, E_i the net migration rate (emigration−immigration), BA_i the biomass accumulation rate, EE_i the "ecotrophic efficiency", the proportion of the production that is utilized in the system, B_j the biomass of consumers or predators j, $(Q/B)_j$ the consumption per unit of biomass of j and DC_{ji} is the fraction of i in the diet of j.

Ecosim is the time dynamic version of Ecopath. It can be used to simulate the ecosystem effects of fishing mortality changes and environmental forcing over time. The process is based on the set of linear equations used in Ecopath, isolating the biomass accumulation term, and setting up a set of differential equations of the form:

$$\frac{dB_i}{dt} = g_i \sum_j Q_{ji} - \sum_j Q_{ij} + I_i - (M_i + F_i + e_i)B_i$$

where dB_i/dt represents the growth rate of group (i) during the time interval dt in terms of its biomass B_i, g_i is the net growth efficiency (production/consumption ratio), M_i is the non-predation $((P/B)_i B_i(1-EE_i))$ natural mortality rate, F_i is fishing mortality rate, e_i is emigration rate, I_i is immigration rate (and $e_i B_i - I_i$ is the net migration rate). The two summations estimate consumption rates, the first expressing the total consumption by group (i), and the second the predation by all predators on the same group (i).

2.2. The western English Channel model

The 1994 western English Channel food-web model described in Araújo et al. (2005) was used here to explore the effects of different fishing policies on economic, social and ecosys-