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Editorial

Placing fisheries in their ecosystem context, an introduction☆

Abstract

This contribution, which serves as introduction to a special issue of *Ecological Modelling* briefly discusses some of the implication for research of the widely heard calls for a transition toward ecosystem-based management of fisheries. Notably, the case is made that the research required for this transition does not need, in order to be useful at all, to explicitly address the full complexity of ecosystems. Indeed, the EU-funded project, which led to the most of the contributions in this thematic issue all contribute useful insights on the structure and functioning of the marine ecosystem they covered, and in many cases, on their fisheries impact on these ecosystems. This could be done under the constraints of available data sets because of the software used by all, Ecopath with Ecosim (EwE), whose mass-balance assumption lead to food web description, and to temporal and spatial simulations that can be robust even in data-sparse environments. Two additional contributions, on the methodology of EwE point to potential pitfalls, and to issues of uncertainty.

Keywords: Ecosystem; Ecopath with Ecosim; Fisheries

1. Introduction

This issue of *Ecological Modelling* may well be mentioned favorably when the history of the incorporation of ecosystem considerations into fisheries management is written some day. This issue, indeed, is one of many manifestations of the trend toward ecosystem approaches to fisheries, documented by a wide range of official declarations, and gradually showing up in national and international guidelines, and even in national legislations. But how is this going to impact research, and management 'on the ground'? When consulted about this, many fisheries scientists still insist that "the uncertainty involved in the traditional stock assessment, being formidable, we cannot even conceive of including ecosystem considerations into fisheries management". This view is based on a failure to distinguish between stock assessment which is tactical, and mainly intended to generate stock-specific annual total allowable catches (TAC), and policy exploration, which is strategic, and can be designed to explicitly consider the ecosystem effects of fishing. Thus, ecosystem-based fisheries management is not meant to replace stock assessments, indeed the ecosystem-based approaches often rely on stock assessment for information. Rather it is meant to provide a context for the assessments and the criteria with which to choose TAC's. Hence, assessments and ecosystem-based management have different data requirements, purpose and problems with uncertainty.

Over the last decade considerable effort has been worldwide devoted to the development of mass-balance models describing the status and trophic interactions in aquatic ecosystems—with a nearly even split between developing and developed countries, itself a notable fact. This development has to a large degree been made possible by the formulation and dissemination of a ecosystem modeling approach and software called Ecopath, based on work by Jeffrey Polovina at the South West Fisheries Center, USA (Polovina, 1984), subsequently developed by Daniel Pauly, Villy Christensen, and Carl Walters of the Uni-

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versity of British Columbia, Canada (Christensen and Pauly, 1992; Walters et al., 1997, 1999, 2000).

The Ecopath software has been widely distributed since 1990, and now has more than 2500 registered users in 124 countries, while more than 150 models of aquatic ecosystems have been published. One of the first milestones of this development was an edited volume "Trophic Models of Aquatic Ecosystems", which provided models of 35 ecosystems (Christensen and Pauly, 1993).

2. A concerted action

This special issue represents another milestone. It is based on the work of scientists from 31 institutions working together over a three-year period in order to develop mass-balance models of marine ecosystems in Pacific and Atlantic (including Caribbean) waters (Christensen et al., 2002). The work was facilitated through a project or 'Concerted Action' of the African-Caribbean-Pacific/European Union (ACP/EU) Fisheries Research Initiative (http://europa.eu.int/comm/development/development_old/research/0intr-en.htm), designed to support research leading toward ecosystem-based management of fisheries, itself supporting the broader aims of the ACP/EU Fisheries Research Initiative, the implementation of a strategy for the conservation of Large Marine Ecosystems by coastal states and the international community. As part of this, resources have to be assessed, the dynamics of ocean/coastal resource interactions understood, resource management mechanism developed, and sustainable yields ensured. Methodologies for reaching these aims still have to be further developed, and this issue of *Ecological Modelling* has a contribution to make toward these aims (Christensen and Walters, 2004; Kavanagh et al., 2004).

An important issue, in this context is that research be focused on analyses and management of exploited ecosystems, not just on management of their components. Thus, the experience gained during our Concerted Action shows that in order to construct mass-balance models, information is needed on resources at all trophic levels. The process of obtaining such information strengthens inter- and intra-institutional cooperation; as well, the scientists involved in modeling of exploited systems gain knowledge on both ecosystem functioning and management, leading to insights very different from what would be obtained from traditional fisheries management. This is illustrated here by several studies, notably Gasalla and Rossi-Wongtschowski (2004), Manickchand-Heileman et al. (2004), and Sánchez and Olaso (2004).

As preparation for the work presented here four training courses and workshops on ecological modelling were held on four continents, starting in South Africa, December 1997, Costa Rica in April 1998, Denmark in August 1999, and ending in Brazil, December 1998. The results were then presented at an international symposium at the Charles Darwin Research Station, Galápagos, Ecuador, in December 2000 (Christensen et al., 2002). It is the contributions from the Galápagos Symposium that have formed the backbone of the current issue.

Ecopath models, representing the food web of a given ecosystem at a given time are but snapshots of changing interrelationships. However, they can be put in to temporal context by constructing a number of models, each covering a different time period, and subsequently comparing their attributes (Heymans et al., 2004). Indeed, such inter- and intra-system comparisons provide an important scientific tool for gaining new understanding of ecological and fishing-related processes (see, e.g. Brando et al., 2004; Manickchand-Heileman et al., 2004). This is an approach for which network analysis provides an analytical framework, as demonstrated notably by publications in *Ecological Modelling*, (see, e.g. Christensen, 1995; Perez-Espana and Arreguin-Sanchez, 1999; Heymans and Baird, 2000; Perez-Espana and Arreguin-Sanchez, 2001; Vega-Cendejas and Arreguin-Sanchez, 2001; Arias-González et al., 2004; Brando et al., 2004; Heymans et al., 2004; Neira et al., 2004). The next step, obviously, is to investigate how this comparative approach could be used for more applied research, notably for fisheries management.

The major step in this direction was taken through the development of a dynamic simulation module, Ecosim, integrated in the Ecopath with Ecosim (EwE) software (Walters et al., 1997, 2000). Fig. 1 illustrates the main modules of EwE and how the contributions in the present issue have been based on these modules, while Christensen and Walters (2004) review the methodology as a whole.

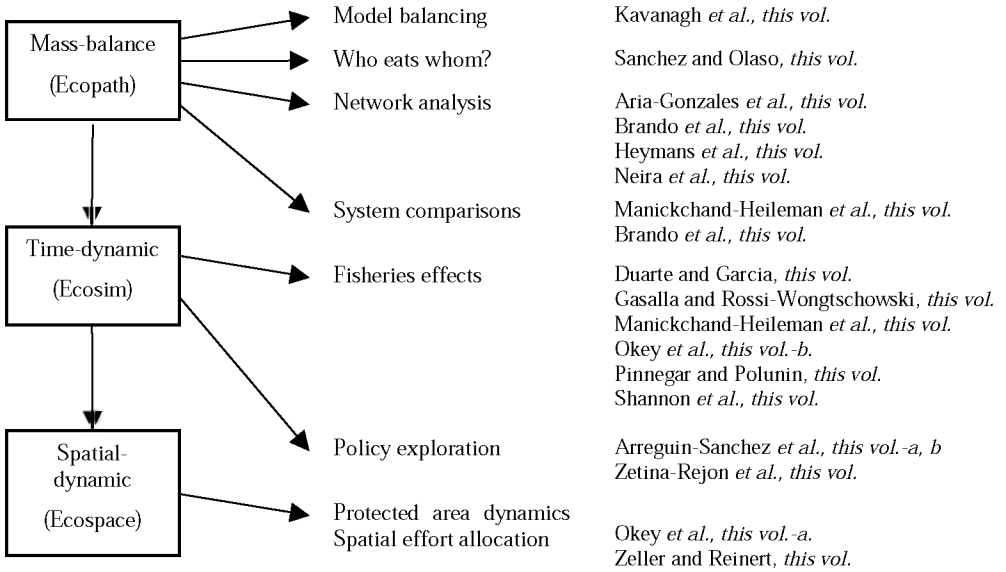

Fig. 1. An overview of the main modules of Ecopath with Ecosim (EwE), indicating study areas and how contributions in the present issue relate to them. This issue also contains a review of the EwE methodology (Christensen and Walters, 2004).

In Ecosim the system of coupled linear equations underlying each Ecopath model is re-expressed as a system of coupled differential equations, allowing simulations of ecosystem perturbation over time. In Ecosim this is done by varying fishing effort, fishing mortality or environmental factors over time (Duarte and García, 2003; Okey et al., 2004b; Pinnegar and Polunin, 2004; Shannon et al., 2004).

Through exposure to a large number of applications Ecosim has developed to being of use for addressing a wide range of topics related to evaluating ecosystem effects of fishing (Pauly et al., 2000). This includes studies of relationship to more traditional stock assessment (e.g. Cox et al., 2002), accumulation of persistent pollutants through the food web (Watkinson, 2001), and model stability (Vasconcellos et al., 1997) to mention but few.

3. The next steps

Emphasis for development of Ecosim is presently focused on quantification, using time-series analyses, of the impacts of fisheries compared to that of environmental; and using simulation models for addressing policy questions. Thus, the policy optimization module of Ecosim, which allow evaluating fishing effort while incorporating economical, social, legal and ecological constraints was the focus of a joint FAO/UBC workshop in 2000 (Pitcher and Cochrane, 2002), and it has since seen continued development (Christensen and Walters, in press), with a few, preliminary studies now available (Arreguín-Sánchez et al., 2004a,b; Zetina-Rejón et al., 2004).

Spatial considerations, notably in connection with the use of marine protected areas as tool for ecosystem-based fisheries management can be incorporated in modeling through the Ecospace module of EwE (Walters et al., 1999). Here, the use of spatial modeling to address issues of protected area dynamics and fishing effort allocation is documented by Okey et al. (2004a) and Zeller and Reinert (2004).

It is probably the first time that such a wide range of marine ecosystem modeling issues have been dealt with by the application of a single conceptual approach, as embodied in EwE. We are aware of the pitfalls and tunnel vision this may imply. However, we hope the readers—our colleagues—will also appreciate the strength that this approach embodies, and

perhaps even feel motivated to help in developing it further.

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