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Evaluation of the bioeconomic sustainability of multi-species multi-fleet fisheries under a wide range of policy options using ISIS-Fish☆

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ABSTRACT

In order to provide reliable scientific advice and support for fisheries management, it is necessary to evaluate the biological and economic sustainability of complex fisheries, such as multi-species multi-fleet fisheries. Existing policy-screening modelling tools are not fully suitable in this purpose due to either an over-simplified description of population dynamics, or due to the lack of consideration of economic aspects.

In this paper, we present a package that enables quantitative bioeconomic assessment of management scenarios. Population dynamics is described through spatially- and seasonally-explicit models. Exploitation dynamics is characterized by several fishing activities with specific spatial and seasonal features, and practiced by several kinds of vessels with specific technical characteristics. Exploitation costs and revenues are considered at several levels: the fishing trip, the fishing unit (vessel and crew), and the vessel owner. The model is generic and can be used for different types of fisheries. A database is attached to the software for the storage and updating of information for each fishery. This includes the specification of model dimensions and of the parameters describing populations and exploitation. Several model assumptions regarding either population or exploitation may be adapted to suit a specific fishery. Both policies and corresponding fishers' response may be interactively specified through JAVA™ scripts. This version of ISIS-Fish allows for the calculation of biological and economic consequences of a range of policies, including conventional ones like catch and effort controls, and alternative policies such as marine protected areas. To facilitate policy-screening in a high-dimension parameter space, the software includes features, like interfaces for sensitivity analysis and simulation queues.

1. Introduction

Most fisheries are complex systems due to the range of species exploited and the variety of fishing activities targetting them. These multi-species multi-fleet fisheries (also termed mixed fisheries) form the majority of fisheries across the world, in particular in coastal areas and on continental shelves. Many coastal communities rely on the existence of such fisheries either for subsistence or commercial purposes, in general for both. Coastal areas are subject to increasing demographic pressure, and they host activities other than fisheries. Reversing loss of environmental resources while integrating principles of sustainable development is a challenge for the forthcoming years, as e.g. stated in the Millenium Goals (http://www.un.org/milleniumgoals). This requires identifying the management options that ensure fisheries biological and economic sustainability while satisfying constraints linked to other uses. This can be achieved by exploring the consequences of policies using e.g. simulation models of fisheries dynamics. Marine protected areas (MPA), including among other regulatory measures any restriction of fishing over space (and possibly time), constitute a key policy for the management of coastal fisheries and ecosystems, because zoning of uses is often indispensable to achieve a range of conflicting goals such as biodiversity conservation, sustainable development of economic activities, including fisheries.

There are few published models in fisheries science that enable to explore a wide range of management options including MPAs (see the review by Pelletier and Mahévas, 2005). For many models, the description of population dynamics and exploitation dynamics is not appropriate neither for investigating MPA design, nor for exploring mixed fisheries issues. Mahévas and Pelletier (2004)

☆ Integration of Spatial Information for Simulation to evaluate the impact of management measures on FISHeries.

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presented ISIS-Fish, a simulation tool for evaluating the impact of management measures on fisheries dynamics (ISIS-Fish 1.0), while Pelletier and Mahévas (2005) presented, among other things, version 1.5 of ISIS-Fish. In these versions, ISIS-Fish does not consider the economic viability of the fisheries, and investigations only rely on simulations of abundance, catch and effort trajectories under a range of policy options. However, it is important to appraise economic consequences of management scenarios, as a policy may be beneficial for resource status, but not economically viable. This is particularly true for MPAs where previous theoretical models have shown that it may be difficult in the case of no-take zones to establish conditions that guarantee a double payoff, i.e. an increase in both yield and biomass (Sanchirico and Wilen, 2001a; Boncoeur et al., 2002).

In this paper, we present version 3.0 of ISIS-Fish which encompasses a large number of new developments in the software and underlying model. Most importantly, this version contains a bioeconomic model of fisheries dynamics that enables the assessment of economic consequences of policy options and to calculate economic indicators of fisheries status and dynamics. By bioeconomic model, we mean a fisheries model that incorporates economic parameters or variables, either as forcing variables or endogeneous variables (i.e. variables with their own dynamics in the model). We could not find in the literature any other *generic* spatially-explicit bioeconomic model for quantitative assessment of fisheries management policies.

2. Model description

In the present paper, we briefly review the features existing in version 1.0 of ISIS-Fish presented in Mahévas and Pelletier (2004), and we mostly describe the new model developed to address economic issues, as well as the numerous new features introduced in the population model. The introduction of an economic component in ISIS-Fish resulted in comprehensive changes in the exploitation model where costs are now detailed (see Section 2.2). The new parameters and variables defined in this model may be used to code fishers' behaviours that depend on economic conditions.

The ISIS-Fish fishery model is a deterministic dynamic simulation model. It is time-discrete with a monthly time step.

The ISIS-Fish fishery model relies on three interacting submodels respectively pertaining to population, exploitation, and management. These interactions take place within the fishery area that is a spatially discrete mapping to a regular grid. The grid serves to define zones for each population, fishing activity and management measure. Defining the fishery area and the grid resolution is a first and important step in parameterizing an application of ISIS-Fish. It allows specifying zones that can then be used as population, exploitation or management zones. Note that all zones are independent from one another. At any time step (month), fisheries dynamics is determined by the extent of the spatial overlap (in cells) between population zones, fishing activity zones and management zones.

ISIS-Fish relies on an object-oriented modelling approach. The static model underlying ISIS-Fish may be represented with a class diagram (Fig. 1) that depicts model objects and the relationships between them. In ISIS-Fish, objects are natural objects of the fisheries system. Object attributes are listed in Table 1.

2.1. Population dynamics

For many fish populations, seasonal and spatial variations in population abundance, are dictated by large-scale ontogenic migrations such as migrations of spawners for reproduction, and migrations linked to habitat preferences such as nurseries or feeding areas. In the model, population zones and seasons are defined according to the timing and spatial patterns due to biological processes such as migrations, growth, reproduction and recruitment. Population dynamics is either stage-, length- or age-structured.

Although the model primarily focuses on complex dynamics inherent to mixed fisheries, such as interactions between fleets and incidental catch, it is sometimes necessary to account in addition for inter-specific relationships, e.g. predator–prey relationships

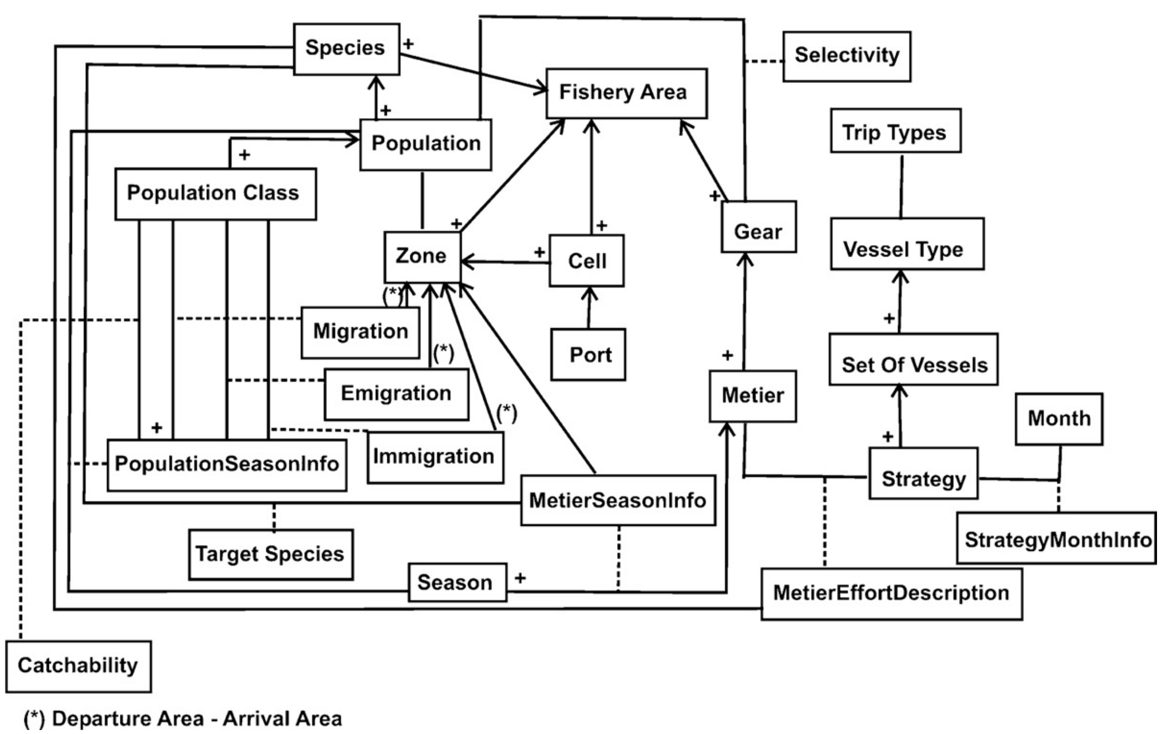

Fig. 1. Class diagram for ISIS-Fish model version 3.0. For sake of concision, object attributes were not detailed on the diagram; they are reported on Table 2. These objects may not fully match those of Table 1, which correspond to objects stored in the database attached to ISIS-Fish. A "+" sign indicates a cardinality equal to or larger than 1, e.g. a port is in only one cell, but a cell may comprise several ports.