available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/ecolinf

A computational approach to ecological and economic sustainable harvest management strategies in a multi-species context, with implications for cod recovery plans

*Richard Stafford**

Centre for the Environment, Fisheries & Aquaculture Science (Cefas), UK

ARTICLE INFO

Article history:
Received 9 May 2007
Received in revised form
28 November 2007
Accepted 4 December 2007

Keywords:
Genetic algorithm
Optimisation
Maximum sustainable yield
Ecosystem approach to fisheries management

ABSTRACT

Multi-species models consider interactions, particularly predation, between and within species. Traditional harvest management strategies, such as maximum sustainable yield do not account for these interactions. The exploitation of a single species can be maximised, but this does not mean that the entire ecosystem is being harvested sustainably or at its economic maximum. I present a computational technique (evolutionary algorithms) that can simultaneously optimise harvest management strategies of many species and can easily be modified to allow for factors such as stock recovery, sustainable yields or maximum levels of economic sustainable exploitation. I demonstrate that in an ecologically sustainably managed system where a stock is recovering, maximum economic yield is identical to the maximisation of yield by mass. These findings may have important implications for long term conservation aims and long term profits by fishers.
© 2007 Elsevier B.V. All rights reserved.

1. Introduction

Developing an ecosystem approach to fisheries management is currently an important topic (e.g. Brodziak and Link, 2002). Multi-species interactions are considered important in establishing mid- to long-term management advice for fisheries. Many studies have shown large and important differences in mid- to long-term predictions from single-species and multi-species models (reviewed by Hollowed et al., 2000). The application of single-species harvest rules such as maximum sustainable yield (MSY) to multi-species models suggests that estimates from single-species sources are not adequate (Walters et al., 2005), yet the Johannesburg declaration sets a target for all fish stocks to be managed at maximum sustainable yield from 2015, implying that between species interactions need to be considered (United Nations, 2002).

Estimating sustainable harvest rules for multi-species communities is a difficult mathematical task since the optimisation of harvest control rules for one stock or species directly effects the other stocks (but see progress by Matsuda and Abrams, 2006). Essentially it can be considered as a multi-dimensional problem with an optimal solution. Interaction between the species implies that yields for each species need to be estimated simultaneously. Mathematically this is a complex problem, however, many computational heuristic techniques exist to address these type of problems (e.g. Holland, 1992; Reeve, 1993; Corne et al., 1999).

This study uses a computational technique (evolutionary algorithms) to estimate a range of harvest control options in a simple multi-species model with a high degree of interaction between species. The technique is shown to be powerful in its ability to calculate multi-species yields and flexible, in that modifications can easily be made to address specific concerns. The economic implications of the study, as well as limitations of the technique and suitable modifications to address these limitations are discussed.

* Current Address: Department of Natural and Social Sciences, University of Gloucestershire, Cheltenham, GL50 4AZ, UK. Tel.: +44 1242 714681.
E-mail address: rstafford@glos.ac.uk.

1574-9541/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecoinf.2007.12.001

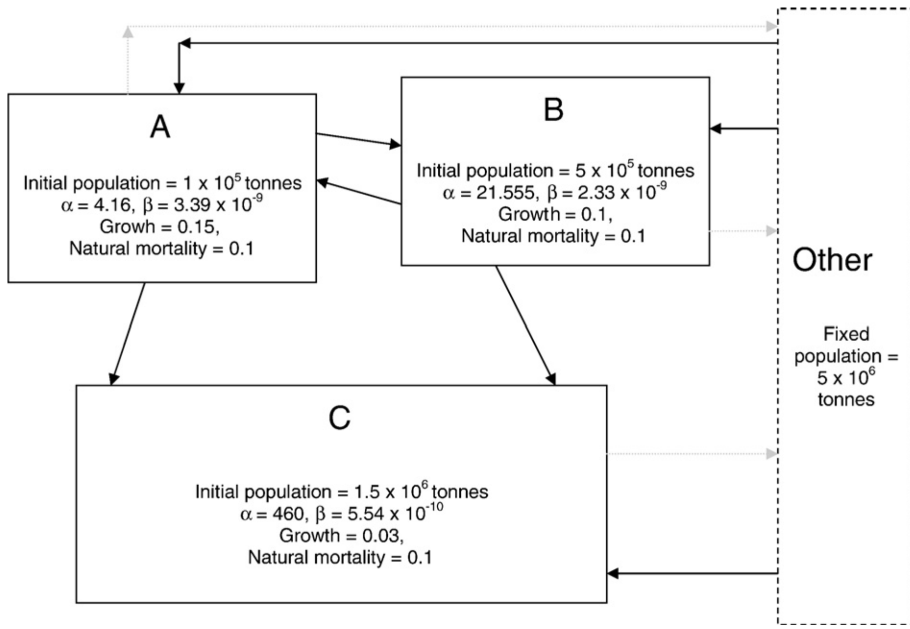

Fig. 1 – Interactions in the multi-species model. Arrows point from predator to prey. Black arrows represent interactions explicitly modelled. Grey dotted arrows represent interactions which are not modelled since 'Other' species are of fixed biomass.

2. Multi-species model

The model is a three species model with interactions occurring between all species (Fig. 1). Species *C* is a prey species, which is predated on by both species *A* and species *B*. Species *A* and *B* also consume and are consumed by each other. A further group of 'other' species has a fixed biomass, but is both consumed and consumes all three species (since the population size of 'other' species is fixed there are no mathematical relationships based on species *A*, *B* or *C* consuming 'other'). Initial population biomass, growth and mortality rates (excluding predation and fishing) as well as recruitment parameters for Ricker stock recruitment relationships (Ricker, 1954) are given in Fig. 1. The recruitment equation is:

$$R = \left(\alpha B.e^{-(\beta.B)}\right)/w$$

where *R* is recruitment in kg, *B* is biomass in kg and *w* is a constant to convert between number and biomass of recruits. *w* is 15 for species *A* and *B* and 303 for species *C*, estimating the weight of a recruit to be 66g for *A* and *B* and 3.3g for species *C*. These values are roughly equivalent to weights of gadoid and sandeel recruits as representative predator and prey species.

Predation between two species is modelled as the product of the population sizes of the two species and a predation coefficient, given in Table 1. For example, the predation by species A on species *B* is given by:

$$\text{Biomass}_A \times \text{Biomass}_B \times \text{Constant}_{AB}$$

Fishing yield occurs at the rate imposed by the Evolutionary Algorithm (EA) (see below), and subtracted from the number of individuals at yearly intervals. The basic equation for biomass for any species, except 'other' which remains constant, is:

$$\text{Biomass}_{t+1} = \text{Biomass}_t + \text{Recruitment}_t + \text{Growth}_t - \text{Predation}_t - \text{Mortality}_t - \text{Fishing}_t$$

where *t* is the current time in years.

The model is simplified to focus on the techniques of harvest management optimisation. As such there is no size or age structure and recruitment is based on estimates of total biomass rather than spawning stock biomass. The model is run over a 20 year period — a timeframe considered appropriate to the long term management of fish stocks by the UK government (e.g. DEFRA, 2007).

3. Evolutionary algorithm (EA)

This study uses an evolutionary algorithm previously used to optimise other problems (Stafford and Rind, 2007). The only differences between the current study and previous studies is

Table 1 – Coefficients describing the predator/prey interactions between pairs of species

Predator	Prey	$\text{Constant}_{\text{PredPrey}}$
A	B	2.05×10^{-9}
A	C	8.0×10^{-10}
B	A	2.0×10^{-10}
B	C	2.0×10^{-10}
Other	A	2.0×10^{-11}
Other	B	2.0×10^{-11}
Other	C	3.0×10^{-11}

Download English Version:

https://daneshyari.com/en/article/4375361

Download Persian Version:

https://daneshyari.com/article/4375361

Daneshyari.com