Fisheries Research 171 (2015) 12–19

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Harvest control rules for data limited stocks using length-based reference points and survey biomass indices

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ARTICLE INFO

Article history:
Received 22 April 2014
Received in revised form
18 November 2014
Accepted 20 November 2014
Handling Editor A.E. Punt
Available online 24 December 2014

Keywords:
Data limited stocks
Risk
Survey indices
Length frequencies
Harvest control rules
Life History

ABSTRACT

There are a large number of commercially exploited stocks lacking quantitative assessments and reliable estimates of stock status. Providing MSY-based advice for these data-limited stocks remains a challenge for fisheries science. For many data-limited stocks, catch length composition and/or survey biomass indices or catch-per-unit effort (cpue) are available. Information on life history traits may also be available or borrowed from similar species/stocks. In this work we present three harvest control rules (HCRs), driven by indicators derived from key monitoring data. These were tested through simulation using two exploitation scenarios (development and over-exploitation) applied to 50 stocks (pelagic, demersal, deep sea species and *Nephrops*). We examine the performance of the HCRs to deliver catch-based advice that is risk adverse and drives stocks to MSY. The HCR with a biomass index-adjusted *status quo* catch, used to provide catch-based advice for several European data-limited stocks, showed the poorest performance, keeping the biomass at low or very low levels. The HCRs that adjust the *status quo* catch based on the variability of the biomass index time series was able to drive most of the stocks to MSY, showing low to moderate biological risk. The recovery of biomass required asymmetric confidence intervals for the biomass index and larger decreases in *status quo* catch than increases. The HCR based on length reference points as proxies for the F_{SQ}/F_{MSY} ratio was able to reverse the decreasing trend in biomass but with levels of catch below MSY. This HCR did not prevent some of the stocks declining when subject to over-exploitation. For data-limited stocks, the empirical HCRs tested in this work can provide the basis for catch advice. Nevertheless, applications to real life cases require simulation testing to be carried out to tune the HCRs. Our approach to simulation testing can be used for such analysis.

1. Introduction

The majority of worldwide commercially exploited fish and shellfish stocks do not have a formal stock assessment, due to insufficient data to estimate stock sizes and fishing mortality (Rosenberg et al., 2014). In the Northeast Atlantic, more than half of the 200 stocks for which ICES provides advice lack a quantitative assessment and estimates of stock status (ICES, 2013a). These stocks are classified by ICES as data-limited stocks (ICES, 2012a). In the absence of estimates of stock status, providing quantitative MSY-based advice remains a challenge for fisheries science, while for management bodies it continues to be a key topic for increasing the sustainable harvesting of marine resources (Anon., 2013, 2008, 2007, 2006).

The last five years have seen an increase in the development and testing of assessment methods to estimate sustainable yields and harvest levels for data-limited stocks (Rosenberg et al., 2014; Martell and Froese, 2013; Wetzel and Punt, 2011; MacCall, 2009). The category of data-limited stocks, in the sense of stocks without an analytical assessment, includes stocks with a considerable amount of information, although not always available or compiled. For example, life history parameters exist for most stocks exploited commercially (see fishbase.org), length frequencies of landings are cheap to collect, and scientific surveys catch more species than those for which abundance indices are traditionally derived. In such

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http://dx.doi.org/10.1016/j.fishres.2014.11.013
0165-7836/

cases the problem tends to be related to the difficulty to evaluate the quality of the data, and/or the costs of processing the information, and/or the short time series available. In European waters, all stocks caught by European fleets are covered by the European Data Collection Framework (Council Regulation (EC) No 199/2008) and, hence, such information exists. Moreover, data sets are growing every year, which will contribute to moving stocks upwards in the level of information available.

Geromont and Butterworth (2014) used simulation testing to check the robustness to uncertainties about resource dynamics, of simple empirical TAC-based harvest control rules (HCRs). These authors considered two data-poor scenarios for data availability: a data-limited scenario in which the stock had historical catch data and information on the mean length of the catch, and a data-moderate scenario where a direct index of abundance was also available for the stock. The empirical management procedures investigated by Geromont and Butterworth (2014) set future TACs by adjusting the previous year's TAC upwards or downwards, depending on whether the recent mean length is above or below a target mean length. In the case of the data-moderate stocks, the TAC adjustment was based on the recent slope of the abundance series (cpue) and on the difference between the recent cpue and a target level.

Since 2012, ICES has applied a framework to provide catch advice for the European data-limited stocks (ICES, 2013a) within a precautionary approach. For stocks where historical catch data and surveys or other relative abundance indices are available, catch advice is based on the application of an HCR using biomass or abundance index adjusted *status quo* catches (ICES, 2012b). Within this HCR, it is quite common to adopt a comparison of the averages of the two most recent index values with the three preceding ones, although the number of years to be used to compute these averages may vary among stocks, in order to account for inter-annual variability of surveys or cpue series. Simulation testing has shown that this HCR does not ensure conservative catch advice when a stock is over-exploited, while it's performance deteriorates when a well-managed stock becomes over-exploited (ICES, 2013b).

The work presented here has three main objectives: (i) to develop and test generic HCRs for stocks for which the amount and quality of data is insufficient to perform quantitative assessments; (ii) to understand the mechanisms that drive the performance of these HCRs; and (iii) to suggest a simulation procedure based on Management Strategies Evaluation (MSE; Butterworth et al., 1997; Cooke, 1999; Butterworth and Punt, 1999; Kell et al., 2005; Punt and Donovan, 2007) to be used for data limited stocks.

The simulation procedure and the HCRs proposed here provide a framework for designing and testing management plans for data limited stocks. However, when dealing with a real-life application, it is important to tune the candidate HCRs to the specific stock and fishery (not attempted here) and test its implementation with simulations.

2. Methods

Two alternatives to the harvest control rule set by (ICES, 2012a) were developed. One uses survey information and the statistical characteristics of the biomass index, while the other uses catch length compositions and life history parameters. These HCRs were developed taking into account common indicators derived from fisheries monitoring programmes and in themselves define different levels of data limitation. Survey information is independent of the fishery and constitutes a direct observation of the trends in biomass. It's an expensive type of information, but also a good source about the trends in biomass, if the survey is performed following the good practices of data collection and the index derived with sound statistical methods. On the other hand, the length distributions of the catch is fishery-dependent information. It is cheaper to collect than survey information, and once a link is established between an exploited stock's expected length composition and its spawning potential ratio (Hordyk et al., 2014) it constitutes an indirect observation of the stock status. Due to their data requirements, these HCRs can be applied to a wide range of stocks with distinct levels of data limitations, standing between catch-only type approaches (Martell and Froese, 2013) and full analytical approaches.

The simulation procedure uses life history parameters and information about the fishery's selectivity to create a simulation environment for testing HCRs. Although some assumptions are required, these simulations can provide insight into the relative effect of different HCRs and their robustness to common uncertainties, like those about stock recruitment relationships, implementation error, etc.

2.1. Simulations and MSE

The stocks used in the current study were simulated based on life history traits that loosely represent the biology of the species (Table 1), covering a wide range of life history characteristics. There were 50 stocks: 3 pelagic stocks (2 species: Herring and Sandeel), 36 demersal stocks (17 species: Cod, Haddock, Whiting, Pollack, Megrim, Anglerfish, Plaice, Sole, Striped red mulet, Lemon sole, Brill, Dab, Redfish, Golden redfish, Greenland halibut, Turbot and Witch), 6 deep sea stocks (4 species: Ling, Blue ling, Greater silver smelt and Roundnose grenadier) and *Nephrops* in the shellfish grouping (Table 1). The life history M/K ratio of the simulated stocks ranged from 1.09 to 4.20, with the exception of the deep sea stock 'rng-comb' that presented a high M/K ratio of 8.98 (Table 1 and Fig. 1).

An age-structured population dynamics model with recruitment governed by the Beverton–Holt stock-recruit function with steepness, h, of 0.75 (to simulate stocks with medium productivity) and virgin biomass, Bv, of 1000 t was adopted. The h value was adapted from Myers et al. (1999), who indicated a median of 0.71. Natural mortality for each stock was computed following Gislason et al. (2010) and was assumed to be time-invariant. Fish growth was modeled with the von Bertalanffy function, with parameter's given by ICES (2012b). Fleet selectivity was modeled with a double normal distribution (Hilborn et al., 2003) with the mode equal to the the age of 50% maturity, while survey selectivity was modeled with an asymptotically flat top curve with maximum retention at age 10. Fig. 2 shows an example for a stock with age of 50% maturity of 5.4 years. Both selectivity functions were set constant over time.

Simulations were performed for two distinct trends in fishing mortality to test the HCR's performance in 'development' and 'over-exploitation' fishery scenarios. For the 'development' phase the stocks were subject, during years −14 to 0, to a linear increasing fishing mortality from $F = 0$ to $2F_{MSY}$. The 'over-exploitation' phase was obtained by keeping fishing mortality at $2F_{MSY}$ for 25 years (years: −24 to 0), although only the last 15 (years: −14 to 0) were used for the simulation study. In both cases, the HCRs were applied for 25 years (years: 1–25).

Uncertainty was introduced in:

- the operating model conditioning, through catch-at-age and the stock-recruitment relationship;
- the observation error model, through the observation of the index or the ratio M/K;
- the implementation error model, through the realized catches, making it differ from the advised catch.