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Optimising sustainable management of mixed fisheries: Differentiating and weighting selective strategies

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ABSTRACT

The three main pillars of the European Common Fisheries Policy, reformed in 2013, consist of minimizing ecological impacts; implementing sustainable exploitation defined by maximum sustainable yield (MSY) for regulated species and introducing landing obligations aimed at reducing the wasteful practice of discarding unwanted catches. These three key elements constitute major challenges for fisheries, their management and fishery scientists whose goal is to provide objective advice. We demonstrate that limiting sustainable catch options may pose rigorous constraints on fishing activities, in particular on so-called mixed fisheries targeting more than one individual stock. In a situation where there are complex restrictions comprising multiple management goals which are sometimes conflicting (e.g. the 'choke effects' of reduced catch opportunities due to specific stock conservation needs or market conditions), we propose the application of specific measures for specific fisheries, i.e. deviation from traditional fishery selection patterns, as an option to avert significant losses in yield and economic revenue. Fisheries-specific contributions to general management goals, including unwanted effects, shall be evaluated. Individual fisheries may benefit accordingly through multi-annual management plans with regional-scale reconciliation of sustainable exploitation of living natural resources, food security and socio-economy as potential key elements.

1. Introduction

Fisheries represent an intensive use of European maritime regions and are managed according to the common fisheries policy (CFP; EU, 2013), with restoration and sustainability of the biological resources (UN, 2002) and biodiversity as major management goals. The CFP also stipulates access rights and other basic provisions for European and non-European fisheries in the marine areas of national jurisdiction, i.e. territorial and exclusive economic zones following the mandates dictated by the United Nations Convention on the Law of the Sea (UNCLOS; http://www.un.org/depts/los/convention_agreements/texts/unclos/closindx.htm) and beyond to be considered within regional management organisations. In addition to adopting a maximum sustainable yield (MSY) for exploited stocks as a general management goal for no later than 2020, the recent reform of the CFP, as agreed by the European Parliament and Council, demands an ecosystem-based approach to fisheries management (EBFM) with enhanced regionalisation using multi-annual management plans (Salomon and Holm-Müller, 2013). MSY is a term used in fishery management to describe the highest average catch that does not reduce a stock's abundance over time, taking into account the stock's reproductive and growth capacities under prevailing environmental conditions. MSY is typically determined for a single species, thereby ignoring effects on or from other species. Environmental impacts of fishing activities are to be avoided and reduced as far as possible, and the wasteful practice of discarding unwanted catches is to be phased out entirely by 2019. Primarily, an EBFM aims to sustain healthy marine ecosystems, including the fisheries they support (Pikitch et al., 2004). Keeping fishing mortality rates low enough to prevent ecosystem-wide overfishing, avoidance of bycatch and protecting habitats from destructive fishing practices were considered to be the first phase of this approach (Hilborn, 2011). Recently, Froese et al. (2016) proposed three simple rules to assist fisheries management: (1) take less than nature by ensuring that mortality caused by fishing is less than the natural rate of mortality; (2) maintain population sizes above half of natural abundance, at levels

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where populations are still likely to be able to fulfil their ecosystem functions as prey or predator; (3) let fish grow and reproduce, by adjusting the size at first capture such that the mean length in the catch equals the length where the biomass of an unexploited cohort would be maximum.

Among the world's marine capture fisheries European production ranks at fifth with a landing weight of about five million tonnes per year (FAO, 2014). Europe is the world's leading trader of fisheries and aquaculture products (net importer) reaching 45.9 billion Euro in 2014 (EU, 2016). Projections indicate an increased demand for seafood products in the European Union. The average per capita consumption by the 28 countries is projected to increase from 22 kg/year in 1998 to 24 kg/year in 2030 (FAO, 2007). The state of the exploited stocks in the North-East Atlantic and adjacent waters has recently improved from very few to about half of the assessed stocks being sustainably exploited (STECF, 2016). European fisheries management takes into consideration scientific advice based on assessments of stock productivity and sustainable management reference points, which provide information on the status and exploitation of individual ecosystem components. However, the ecological risks that affect living and exploited components remain poorly evaluated and considered, because methods have usually been too restrictive, often attempting to develop a single set of indicators and fail to take an integrative approach with stakeholder involvement (Fletcher et al., 2005).

Mixed fisheries, which harvest different species and stocks using the same fishing gear at the same time, present a combination of high uncertainty, high political sensitivity and complex science and governance. They constitute a challenge for fisheries management because some gears are more selective than others, resulting in an assortment of species and sizes, often involving bycatch and discards that can jeopardize the recovery of overexploited stocks (Kell et al., 2004). Many important fisheries in Europe are mixed fisheries, so finding more effective ways to govern such fisheries is a high priority for the European Union and its Member States. For many reasons, mixed fisheries present an immensely more difficult challenge for fisheries management than single species fisheries do. Less productive stocks in a mix of stocks may suffer unsustainable mortality, while more-productive stocks are able to continue withstanding sustainable catches. Stocks harvested together may each be at a very different status relative to one another in terms of safe biological limits, which would make different harvest strategies necessary in the same fisheries. In the long term, it would be desirable to give advice that accounts for mixed-fishery effects, but in the short term there is a need for approaches to resolve the conflicting management advice for individual species within the same fishery, and to generate catch or effort advice that accounts for the mixed-species nature of the fishery (Vinther et al., 2004). In order to better manage mixed fisheries, we need new methods for collectively assessing the effects of, and interplay between, technical interactions, multispecies interactions, and the environmental effects of fishing (Thorpe et al., 2016).

In northern and western European fisheries, seeking to achieve and maintain sustainable exploitation, one of the most important management tools is the *total allowable catch* (TAC). There are also numerous other fishing effort restrictions and technical conservation measures such as, e.g. fish landing sizes, closed areas or closed seasons. However, TACs – which are generally enforced as landing restrictions and through technical measures – were one of a number of factors that precipitated significant discarding of unwanted catch components due to, for example, over-quota catches or under-sized fish. Discards of unwanted catches, misreporting and high-grading (i.e. the selective landing of fish so that only the best-quality fish are brought ashore), which have all taken place since the introduction of restrictive quotas in the mid-1970s, imply a high risk of missing management goals, in particular for mixed fisheries (Poos et al., 2010), which simultaneously target a variety of species at the same time, each one subject to different conservation goals that depend on their assessed productivity and stock status.

A full catch quota system, i.e. the obligation to land all catches of regulated species including unwanted catch fractions, will be implemented until 2019 for all European fisheries with a few minor and controlled exemptions for discarding (EU, 2013). We believe that this major amendment to the regulatory mechanism has not been fully evaluated prior to being set in place; nor has adequate assessment been made of the ecological or socio-economic consequences, including control perspectives. Borges (2015) provided an overview of the evolution of the discard policy in Europe, for which a transitional implementation time of six years is allowed. Heath et al. (2014) highlighted the cascading ecological effects of eliminating fishery discards, as species interactions may dissipate or negate objectives. However, if a discard ban such as this is not properly enforced, the quota restrictions do not necessarily result in the intended decrease in discarding as the fishery continues to fish while discarding the over-quota catch and least valuable size classes caught (Batsleer et al., 2016).

In this contribution, we introduce a new and simple management strategy evaluation (MSE) model that tests the management process using performance measures derived from sustainable operational objectives. This MSE model simulates the implementation of sustainable fisheries management regulated by allocated maximum catch-quota opportunities, catch uptakes without discarding and resource responses including ecological density effects (Sainsbury et al., 2000). Two different fisheries with different exploitation patterns are simulated to initiate sustainable fishing strategies while targeting two virtual stocks under varying management targets. Conflicting sustainable fishing strategies based on different stock productivity and consistent conservation measures or different management limits potentially impede optimum exploitation. Such a sub-optimum exploitation could be mitigated by changing the exploitation patterns of the fisheries involved in the fishery system.

2. Material and methods

2.1. Stochastic medium-term prediction model

Two virtual stocks S1 and S2 are generated, and their medium-term developments for a period of 10 years are predicted under different conditions (scenarios). For each scenario, the model conducted an iterative process of 100 iterations based on a predefined parameter variation in order to support evaluation of the robustness of the numeric model results. Parameter values and allowed variation are defined in Sections 2.2 (on specific ecology) and 2.3 (fisheries system), respectively.

Age specific stock and exploitation input data are processed within a Dynamic Pool Model Type II (Shepherd and Pope, 2002; medium-term forecast) for a medium-term period of 10 years. The following functions define the estimation of essential stock and fishery parameters to simulate the consequences of various exploitation strategies with varying natural and fishing mortality.

The coefficients for the instantaneous annual rates of natural mortality (M) and fishing mortality-at-age (F) (Pope, 1972), are defined as follows:

$$M_{y,a} = -\ln\left(N_{y+1,a+1} / N_{y,a}\right) - F_{y,a}\,, \tag{1}$$

$$F_{y,a} = -\ln\left(N_{y+1,a+1} / N_{y,a}\right) - M_{y,a}\,, \tag{2}$$