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Fisheries management responses to climate change in the Baltic Sea

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ABSTRACT

The long term management plan for cod in the eastern Baltic Sea was introduced in 2007 to ensure the full reproductive capacity of cod and an economically viable fishing industry. If these goals are to be fulfilled under changing environmental conditions, a readjustment of the current management plan may be needed. Therefore, this paper investigates the economic impacts of managing the cod, sprat and herring stocks in the eastern Baltic Sea, given on-going climate change, which is known to affect cod recruitment negatively. It is shown that climate change may have severe biological and economic consequences under the current cod management plan and that the negative effects on the economic performance of the fishermen as well as on the abundance of cod can be mitigated by reducing the target fishing mortality rate of cod. These results are obtained by simulating three management scenarios in which the economic consequences of different management objectives for the fishing fleets are assessed through a dynamic multi-species and multi-fleet bio-economic assessment model that include both species interactions and climate change.

Introduction

With the introduction of the multi-annual management plan for cod stocks in the Baltic Sea (EC, 2007), the European community aims to achieve stock levels that ensure the full reproductive capacity and the highest long term yields of cod. At the same time, EU fisheries management aims to achieve efficient fishing activities within an economically viable and competitive fisheries industry (EC, 2007). One of the measures used to obtain these goals is to gradually adjust the allowed fishing mortality rate towards a specified sustainable target level. The current long term management plan for Baltic cod was established against the background of prevailing environmental and climatic conditions, but on-going climate change may alter the predicted effects of such management plans. The implications of climate change for economic as well as biological sustainability are still uncertain for fisheries managers and climate change may have implications for decisions regarding how to regulate fisheries in the future. In the eastern Baltic Sea, climate change is expected to affect the recruitment of cod as a result of declining salinity and oxygen levels (MacKenzie et al., 2007b) and may result in a long term decline in the cod stock biomass. This will have an impact on the economic performance of fishermen who fish in the Baltic Sea. Therefore, if the goal is to maintain the economically important cod stock biomass at the current level or to maximise economic performance indicators for the fishing fleet, a readjustment of the current management plan may be needed.

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This paper presents an age-structured bio-economic model aimed at assessing the impact of climate change on the long term management of Baltic cod. Although the effect of climate change is expected to decrease the economic fleet performance as a result of reduced reproduction opportunities for cod, the expected economic loss may be reduced as a consequence of lower cod predation on sprat and herring, leading to higher production potential for these species. The model, which is outlined in Section "Method", has been extended to include the effects of species interactions as well as climate change and is applied to the Baltic Sea fleets which target cod, sprat and herring. The long term economic (revenue, profit, net present value) and biological (stock biomass) effects of three management scenarios are presented by simulating the long term dynamics of the fishing fleets.

Economic studies of climate change in fisheries

Cod is an economically important species in the northern hemisphere and the impacts of climate change on cod have therefore been the subject of several studies (Lorentzen and Hannesson, 2005; Arnason, 2007; Eide, 2008). The economic effect of climate change on the cod fisheries in the Barents Sea was estimated by Eide (2008) and included both a cooling effect on water temperature due to the weakening of the Gulf Stream and a direct warming effect due to a warmer climate. Eide concludes that the economic effect of climate change is insignificant compared to the economic effect of normal environmental fluctuations in the Barents Sea and compared to the economic impact of different management regimes. Another study (Lorentzen and Hannesson, 2005) found that the effect of climate change on the Norwegian cod fisheries of the Barents Sea would be an increase in stock abundance of about 100,000 tonnes per year, corresponding to more than one billion Norwegian Kroner per year. The potential cooling effect resulting from a weakening of the Gulf Stream is excluded in this study.

A number of studies have been conducted into the impact of climate change on the ecosystems of the Baltic Sea (Möllmann et al., 2003; Neumann, 2010; Margonski et al., 2010; Lindegren et al., 2010; Voss et al., 2011; Meier et al., 2011; Voss et al., 2012). However, few have studied the economic effects of climate change in the Baltic Sea. Brandt and Kronbak (2010) investigated the stability of fishery agreements under climate change in the Baltic Sea using an age-structured bio-economic model. The authors used a Beverton Holt recruitment function with three different recruitment parameter values for cod, corresponding to low, medium and high impacts of climate change, to estimate the net present value over 50 years and concluded that climate change will lead to reduced reproduction, thereby reducing the likelihood of stable cooperative agreements. While the latter study was applied to one species, Nieminen et al. (2012) include cod, sprat and herring in an age-structured multi-species bio-economic model for the Baltic Sea, including interactions between different species. They assess different management scenarios and either use current fishing mortality rates or fishing mortalities that maximise the net present values, under "good" and "bad" environmental conditions respectively. The study shows large differences in net present values and fishing mortalities in the four management scenarios.

The present paper also assesses the economic impacts of management scenarios for cod, sprat and herring, and includes species interaction as well. However, the present study differs from the study by Nieminen et al. (2012) in that it includes salinity predictions from a recent climate model for the Baltic Sea (Meier et al., 2011) in the applied bio-economic model. Furthermore, the present model differs from the one used by Nieminen et al. (2012) in that it includes multiple fleet segments with detailed information regarding the cost structure, by including investment and disinvestment opportunities for the fleets and by including age-disaggregated prices.

The effect of climate change on the Baltic Sea cod

The increasing number of models that attempt to measure the main dynamics of marine ecosystems has also led to studies of the effect of a changing climate on these ecosystems and the resulting economic consequences for the fisheries (Margonski et al., 2010; Neumann, 2010; Norman-López et al., 2013). The effects of climatic change range from increasing sea surface temperatures (SSTs) and reduced ocean acidification (pH) to rising sea levels and varying frequencies and amplitudes of rainfall, storms and cyclones (Hobday et al., 2008; Bates et al., 2008). In Northern Europe, the observed volume and intensity of precipitation increased during the period 1946–1999, which has increased runoff to water bodies and the risk of flooding (Bates et al., 2008). Runoff is expected to increase by 9–22% by the 2070s (Bates et al., 2008), which will increase the discharged volume of brackish water into the Baltic Sea (Schinke and Matthäus, 1998). One of the consequences of this is reduced salinity concentrations in the Baltic Sea, which is also a result of a reduction in major saline water inflows from the North Sea through the Danish straits and the Belt Sea (Matthäus and Lass, 1995; Schinke and Matthäus, 1998; Schinke and Matthäus, 1998; Meier and Kauker, 2003; Matthäus et al., 2008; Neumann, 2010). Moreover, regional ocean models show that increasing sea surface temperatures of 2–3 °C are expected for the Baltic Sea by the end of the 21st Century (MacKenzie et al., 2007a; Meier et al., 2011), which is directly caused by air–sea interaction (Dippner et al., 2008).

The present study focuses on how climate change will affect cod recruitment and the resulting economic consequences for the fishing fleets. Therefore, the climatic effects on salinity levels are of special concern since they are found to be positively related to oxygen, which again is positively related to the success of cod recruitment (Wieland et al., 1994; Vallin et al., 1999; Koster et al., 2005). Because Baltic cod eggs are positively buoyant in saline waters and negatively buoyant in the bottom layers in fresh waters, periods with low salinity levels will mean that the cod eggs will sink to the deeper more