Resource and Energy Economics 32 (2010) 78–92

Contents lists available at ScienceDirect

Resource and Energy Economics

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

Non-cooperative exploitation of multi-cohort fisheries—The role of gear selectivity in the North-East Arctic cod fishery[☆]

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A R T I C L E I N F O

Article history:
Received 2 April 2009
Received in revised form 15 September 2009
Accepted 17 September 2009
Available online 25 September 2009

JEL classification:
C73
Q22

Keywords:
Differential game
Gear selectivity
Multi-cohort fisheries
North-East Arctic cod
Optimal harvest policies

A B S T R A C T

North-East Arctic cod is shared by Russia and Norway. Taking its multi-cohort structure into account, how would optimal management look like? How would non-cooperative exploitation limit the obtainable profits? To which extent could the strategic situation explain today's over-harvesting? Simulation of a detailed bio-economic model reveals that the mesh size should be significantly increased, resulting not only in a doubling of economic gains, but also in a biologically healthier age-structure of the stock. The Nash equilibrium is close to the current regime. Even when effort is fixed to its optimal level, the non-cooperative choice of gear selectivity leads to a large dissipation of rents.

1. Introduction

The Barents Sea is a rich and productive ecosystem. North-East Arctic cod (*Gadus morhua*) is by far the most valuable biological resource of this ocean. The fish stock, which is shared by Russia and Norway, is one of the world's largest populations of Atlantic cod. It is considered to be within safe biological limits (ICES, 2008) and the Joint Russian–Norwegian Fisheries Commission manages the exploitation of the resource by agreeing on an annual catch quota and on several technical regulations.

☆ We would like to thank Anne Maria Eikeset, Kjell Arne Brekke, an anonymous reviewer, and the editor for comments and suggestions. All remaining errors are our own. This work was in part financially supported through a stipend from the CEES as well as from the Norwegian Research Council via the project "Socio-economic effects of fisheries-induced evolution".

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doi:10.1016/j.reseneeco.2009.09.002

In spite of this, the resource appears to be over-exploited. Scientific analysis has repeatedly shown that the harvesting pattern is ''hugely inefficient'' (Arnason et al., 2004, p. 531). Not only have catches and quotas been consistently above scientific advice (Aglen et al., 2004), but catch by age has also been shifted towards younger age classes with industrial exploitation (Ottersen, 2008).

Here we identify prospective gains from improved management practice and contrast these to the result of a non-cooperative game. How does an optimal management regime look like and how is it limited by non-cooperative exploitation? To which extent could such a strategic international situation explain today's over-harvesting? In order to answer these questions, three scenarios have been simulated:

1. A continuation of the current harvesting pattern.
2. Optimal management of a hypothetical sole owner who maximizes economic gain.
3. Exploitation from two agents unable to make binding agreements.

The first scenario may be interpreted as the outcome where Russia and Norway face constraints from the political process and the behaviour of fishermen. The second scenario represents the first-best outcome that a social planner would employ and where the rents from fishing are divided by some unspecified transfer mechanism. The third scenario constitutes an intermediate case where both Russia and Norway are able to control perfectly their own exploitation but fail to jointly manage the fish stock in an efficient manner. This could be an appropriate description of the strategic situation as cooperative agreements are not enforceable in international relations and the actual harvesting decision is difficult to observe.[1]

There exists a large literature on the North-East Arctic (NEA) cod fishery (e.g. Hannesson, 1975; Steinshamn, 1993; Sumaila, 1997b; Armstrong and Sumaila, 2001; Sandal and Steinshamn, 2002; Arnason et al., 2004; Kugarajh et al., 2006). The Russian–Norwegian interactions have been analyzed by Armstrong and Flaaten (1991); Sumaila (1997a); Stokke et al. (1999); Hannesson (1997, 2006, 2007), but mainly in a cooperative setting. In general, game theory has been fruitfully applied to fishery economics (see Kaitala and Lindroos (2007) for an overview). Although the multi-cohort structure of the stock is taken into account by many analyses, there is, to the best of our knowledge, not any application of a non-cooperative differential game to an age-structured resource. For a general survey of age-structured optimization models in fisheries bioeconomics, see Tahvonen (forthcoming).

This is especially relevant as our work shows that the choice of gear selectivity is of paramount importance for the outcome. In fact, that the minimum size of fish could be a control dimension of great consequence has generally been overlooked so far, in spite of the early result from Turvey (1964, p. 74), that ''either mesh regulation or the control of fishing effort is better than nothing but that regulation of both is still better.''

Another important feature of this study is that it rests upon an ecological model which has been derived through statistical analysis of time-series data from the Barents Sea system (published in Hjermann et al., 2007). The economic model is essentially a simplified version of the one employed in Diekert et al. (2009). In order to highlight the effects of non-cooperative exploitation, we have concentrated on one gear type (trawl) and have made the players Russia and Norway symmetric. Because the state of the fish stock and the agent's exploitation decisions are only imperfectly observable, we postulate an open-loop information pattern and aim for Nash equilibria of this kind. A procedure that finds stable equilibria by iteratively updating best responses has been designed.

By this interdisciplinary approach, we are able to point out that the gains from optimal management could be substantial. In particular the choice of a larger mesh size than currently employed is taking the individual growth potential of the fish into account. However, the agents fail to do precisely this in a non-cooperative game. Rather, the nets are tightened to catch the fish before the respective opponent does. The outcome of the non-cooperative game is indeed close to the simulation of the current harvesting pattern. The article proceeds as follows: Section 2 develops the bio-economic model, Section 3 discusses the simulation approach, results are presented in Section 4, and Section 5 concludes.

[1] For example, illegal, unreported, and unregulated (IUU) fishing on a huge scale is a major problem in the area (Hjermann et al., 2007; Hannesson, 2007).