Ecological Modelling 222 (2011) 1253–1261

Contents lists available at ScienceDirect

Ecological Modelling

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

A management oriented competitive model with two time scales: The case of sardine fishery along the Atlantic coast between Cantin Cape and Blanc Cape

Najib Charouki[a], Nadia Raïssi[b], Pierre Auger[c], Rachid Mchich[d,*], Hmida Atmani[a]

[a] Institut National de Recherche Halieutique, 2 rue de Tiznit, Casablanca, Morocco
[b] Laboratoire EIMA, Faculté des Sciences, Université Ibn Tofaïl, B.P. 133, Kénitra, Morocco
[c] UMI 209 IRD & UPMC UMMISCO, Centre de Recherche d'Ile de France, 32 avenue Henri Varagnat, 93143, Bondy Cedex, France
[d] Dépt de Gestion, Ecole Nationale de Commerce et de Gestion, B.P. 1255, 90000, Tangier, Morocco

ARTICLE INFO

Article history:
Received 4 September 2010
Received in revised form
26 December 2010
Accepted 30 December 2010
Available online 1 February 2011

Keywords:
Fishery model
Sardina pilchardus
Atlantic coast
Aggregation of variables
Equilibrium points
Stability
Parameters estimation
Fisheries management

ABSTRACT

This work is proposing a dynamic model governing the evolution with respect to time of the sardine (Sardina pilchardus) stock in the Atlantic coast between Cantin Cape and Blanc Cape in the North West Africa, which is harvested by two different fishing fleets. We assume that the sardine stock is distributed on two closed zones and targeted by a composite fleet: The Moroccan purse seiners which can move between the fishing regions and a fleet of deepsea trawlers composed mainly of foreign vessels and operating in the southern zone. The model is a set of 5 Ordinary Differential Equations (ODE) with two components: a stock component which describes the sardine evolutions in its 2 zones of distribution, and a component governing the dynamics of the fishing efforts. By using some aggregation methods, we reduce the system to a set of 4 ODE, and then we study analytically the existence and the asymptotic stability of the equilibrium points. The parameters of the stock dynamics and harvest are then estimated using models fitting techniques based on a set of available data. The conditions leading to sustainable fisheries are then simulated. Interpretations of our results can be used by the authority responsible of fishery management, as general recommendations for a better management of Moroccan fisheries.

1. Introduction

The North African Atlantic coast is one of the richest areas of the world in marine resources. Indeed, it is characterized by a large continental shelf which can reach 60 nautical miles in some regions, a geographical situation and an orientation along the dominant winds which privilege it to be among the four upwelling ecosystems of the world (Smith, 1984; Wooster et al., 1976). In fact, the upwelling phenomenon activates a rise of cold water by a mechanical process and permits to enrich the habitat of the marine resources by the nutriments and primary production necessary for all trophic levels. With more than 70% of small pelagic fish landed, the sardine (Sardina pilchardus) fisheries dominate the fishing activity in the Moroccan Atlantic coast. In addition to the fishing intensity, the sardine dynamic is governed by the variability and seasonality of the upwellings in the region (Belvèze, 1991; Kifani, 1991; Nykjaer and Van Camp, 1994; Roy, 1991; Smith, 1984). The most obvious revelation of this variability is the stock collapse that occurred in 1997, when the biomass decreased from 5660 to 1130 thousand tons, although the catches were maintained at a normal level (Charouki et al., 2004). The complexity of these species requires, thus, a regular follow-up and a rational management, taking account of its biological, economic and social aspects. The major aim of the manager then is to optimize the activity and to increase its profitability, setting as goal the maintenance of the landings at a level closed to the maximum sustainable activity (FAO, 2001–2007).

In this context, this paper presents a contribution to sardine fisheries modelling in the Moroccan Atlantic coast. Modelling is based on knowledge and data available on its dynamics and harvest. Indices of acoustic biomasses, which are used to describe the natural stock dynamic, were estimated during acoustic surveys conducted onboard the Norwegian research vessel "Dr. Fridtjof Nansen" which was operating in the region since 1995–2006 (Cruise reports, 1995–2006). Data related to the harvest are drawn from official statistics on the sardine landings while the commercial knowledge is based on the bioeconomic studies carried out on the small pelagic fish in the region (Kamili, 2006; Lamhaidi, 2003).

The aim of this study is to present a general and simple model for the sardine fishery along the Moroccan Atlantic coast in two main fishery zones, the central and south zones. We have made the choice to consider a simple global model for which any parame-

* Corresponding author. Tel.: +212 6 63 03 62 38; fax: +212 5 39 31 34 93.
E-mail addresses: charouki@hotmail.com (N. Charouki), n.raissi@lycos.com (N. Raïssi), pierre.auger@bondy.ird.fr (P. Auger), racmchich@yahoo.com (R. Mchich), atmani@inrh.org.ma (H. Atmani).

0304-3800/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolmodel.2010.12.022

ter, whether it is biological or economic, could be estimated from the available data. So, we present a competitive model between two fleets operating on two fishing grounds. Competition is a very interesting concept when dealing with fisheries. It can be studied using game models (Arnason et al., 1999; Merino et al., 2007; Sumaila, 1997). In our case, we have chosen to consider a classical model rather similar to classical fishery model (Smith, 1969) and which can be analyzed and simulated numerically. Therefore it allows to draw general conclusions and recommendations about the fishery management which we hope it to be useful for end users.

The manuscript is organized as follows. In Section 2, we present an overview of the sardine fishery along the Atlantic coast of Morocco. Section 3 introduces the mathematical model and its analysis. We prove the existence of an interior positive equilibrium and we give its stability analysis. Section 4 is devoted to parameters estimation of the mathematical model from the available data. In Section 5 we present some numerical simulations of the model using the estimated parameters, then we discuss our results and give some some general recommendations for the sardine fishery in Morocco. Finally we give a conclusion with some perspectives of this work in the Section 6.

2. Characteristics of the sardine fisheries in the Moroccan Atlantic coast

2.1. Stock identity

Stocks identity is a paramount question in the fisheries modelling. Studies were recently conducted to identify the sardine stock in the Moroccan Atlantic coast, using genetic characterizations by allozymic markers (Chlaida et al., 2005) and DNA analysis (Atarhouch et al., 2006), and using biometric studies by the analysis of the morpho metric parameters. Since these studies are still in development to lead to conclusive results (FAO, 2001–2007), the configuration retained is the existence of two closed stocks of the sardine (FAO, 2001–2007) (see Fig. 1). The central stock, often called stock (A + B), which extends between Cape Cantin (32°30N) and Cape Boujdor (26°N) and the southern stock, called stock C, which extends from Cape Boujdor to Cape Blanc (21°N). The southern extension of stock C can reach the Mauritanian waters to Cape Timris (19°N) depending on the seasonal variability and the hydrological conditions. Sardine is also present in the northern part of El Jadida (33°N), but in proportions much less important compared to the two main stocks mentioned above.

The assumption of disconnection of the stocks (A + B) and C was also tested by a diagnosis of the sardine distribution maps drawn up during the acoustic surveys (Cruise reports, 1995–2006). The maps reveal an area of discontinuity of the spatial distribution, more or less important from one year to another, which persists at Cape Boujdor (26°N) (see Fig. 2). Indeed, this area is characterized by a thermal front (Charouki et al., 2004; Ould-Dedah et al., 1998) which seems to be not favorable for the sardine.

2.2. Fisheries and fleets

Sardine in the Moroccan Atlantic coast is targeted mainly by two fleets whose fishing pressure can be characterized by two physical properties. Their engine powers and their loading capacities, expressed by the Gross Tonnage (GT):

- A fleet of Moroccan purse seiners: Their powers vary generally between 80 to 550 CV and their Gross Tonnage between 30 and 120 GT (Kamili, 2006; Lamhaidi, 2003). These coastal vessels are not equipped with freezing or refrigerating systems; they are thus constrained to do short fishing travels of about a day. The effort is expressed in terms of positive fishing days (FAO, 2001–2007).

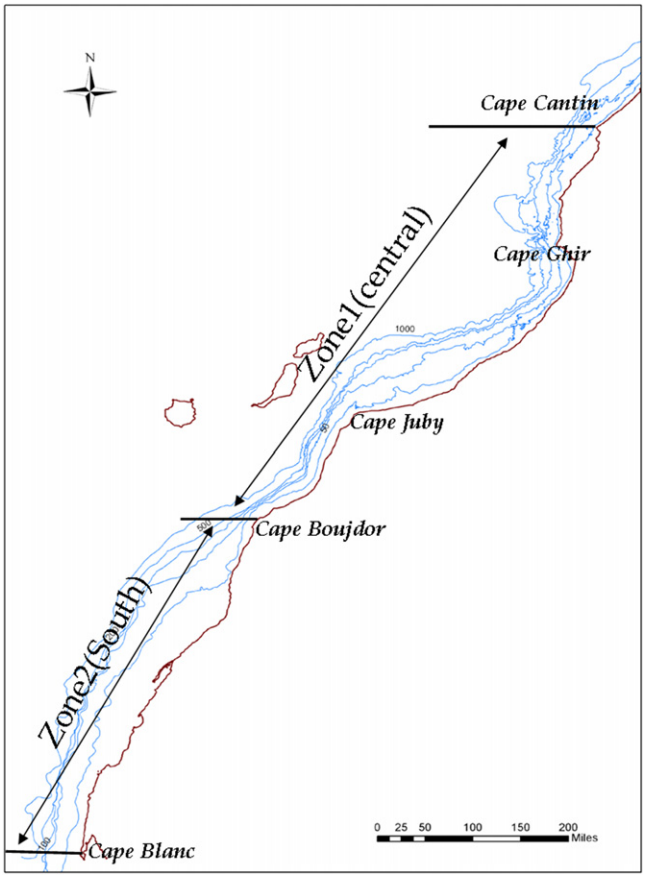

Fig. 1. Identity of the sardine stock of the Moroccan Atlantic coast: the central stock (A + B) between Cantin cape and Boujdour cape and the southern stock (C) between Boujdour cape and Blanc cape.

During the last years, one can note a global trend of the effort operating in the central area towards the southern region, leading to a configuration in which the two areas would be connected through the vessels migrations. This is related to the availability of the resources in these areas and the establishment of the infrastructures necessary for landing and for fishing industries.

- A fleet of deep-sea trawlers composed mainly of industrial foreign vessels working within the framework of freighting and fishing agreements with the European Union and the Eastern European countries. This fleet, which we will call hereafter the industrial fleet, is characterized by the diversity of its vessels. Indeed, it contains the so called "RSW" (Refrigerated Sea Water system), a vessel of relatively small size but equipped with refrigerating systems. There are also the big industrial trawlers whose engine power and Gross Tonnage can exceed respectively 5000 CV and 4000 GT (Lamhaidi, 2003). Due to managing reasons based on the configuration assumed in Fig. 1, this fleet is operating exclusively in zone C.

2.3. Commercial parameters of sardine

The fishing costs are divided into two parts and differ according to the fleets: the first part represents the operating expenses such as the crew's salaries, fuel, food, maintenance and commercialization taxes (Kamili, 2006). The second part relates to the annual costs such as the dry docking, insurances and licences taxes. For the coastal purse seiners, as stated by Kamili 2006, the crew expenses are of about 60% of the total costs. This part of charges is different for the deep-sea fleet whose costs would be related more to the fuel and annual charges.