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New insights in the spatial dynamics of sardinella stocks off Mauritania (North-West Africa) based on logbook data analysis

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ABSTRACT

Sardinella spp. are the main species fished in Mauritanian waters. Logbook data (1991–2009) were used to standardise CPUE. This clearly revealed that the abundance of sardinella peaked in the warm season (July–September) which is the main, if not the only significant spawning season for round sardinella.

This study does not directly confirm or falsify the common belief that the adults migrate from the Senegalese EEZ up to north of the 21° N latitude, but it presents a variety of new hypotheses. If a single transboundary stock exists, part of its individuals, or a sub-stock, is probably more sedentary and remains in the permanent upwelling area located in northern Mauritania and southern Morocco.

Between years, changes in abundance index are dominated by a decrease from 1996 to 2006, depending on the months taken into account, and especially whether or not the warm (spawning) season is considered. For a given month, the spatial distribution of sardinella shows limited differences between years. In the southernmost latitudes of the Mauritanian EEZ the seasonal pattern, which is dominated by high catch rates during the warm season, is much stronger after the year 2001, and then tended to increase year after year.

Changes in species distribution and abundance during the twenty-year study period are difficult to relate to environmental dynamics. However, an inversion of the upwelling trend was observed in 2001, matching a change in the seasonality of sardinella catches, although the causality between the two phenomena could not be established. The increase in the abundance index of sardinella in the last five years, particularly during most of the core fishing season (July–September) might be due to favourable oceanographic conditions (higher upwelling index) and/or changes in the fishing strategies or efficiency. Before annual indices of abundance can be used in the future, it will be necessary to better understand possible changes in catchability during the warm/spawning season.

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1. Introduction

Eastern boundary upwelling ecosystems (EBUE) are among the most productive marine areas due to the high flow of nutrients coming from bottom waters and to the intense winds favourable to Ekman transport (Mackas et al., 2006). The high levels of primary production encountered in EBUEs favour higher tropic levels, due in particular to the high abundance of forage fish such as sardine and sardine-like species (e.g. genus *Sardinops*, *Sardinella* and *Ethmalosa*), anchovy, small carangids and small scombridae. As a result, EBUEs provide one fifth of the marine fish global catch and contribute significantly to securing food and livelihood strategies in many developing countries (Fréon et al., 2009). Among the four EBUEs, namely the Benguela, the California, the Canary and the Humboldt Current systems, the Canary Current is second to the Humboldt Current as far as fish catches are concerned. In the three North West African (NWA) countries – Morocco, Mauritania and Senegal – national or, in the case of Mauritania foreign distant fleets from Western and Eastern Europe, make the most catches. Despite its above-mentioned importance and unlike other EBUEs, not much is known about the Canary Current EBUE, particularly along the NWA coast. This hampers management efforts on national and regional scales (Fréon et al., 2009). The recent global increase in fishing pressure on small pelagic stocks (including the development of fishmeal-oriented extraction) as observed in the last two

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decades, may be endangering the sustainability of the exploitation (Tacon and Metian, 2009; Naylor et al., 2009; IMROP, 2010; FAO, 2011).

Sardinella (*Sardinella aurita* and *Sardinella maderensis*) play an important role in NWA fisheries and marine ecosystems (Fréon et al., 1982; Ould Taleb Sidi, 2005; Fréon et al., 2009; Braham, 2010; FAO, 2011). In the period from 1990 to 2009, catches of sardinella in the NWA area accounted for 26% (450,000 tonnes per year) of the total catch of small pelagic, with 28% of *S. maderensis* and 72% of *S. aurita*, commonly called round sardinella (FAO, 2011). This latter percentage increased during the last 4 years and now stands at 80% (FAO, 2013). Until the late 1990s, distant, large-vessel fleets working under various access regimes in Mauritania accounted for most of the catches. Most vessels did not land their catches in Mauritanian harbours. The artisanal fishery using canoes equipped with purse seines has become established in Mauritania during the last two decades with an increase in landings from 15,000 tonnes in 1994 to over 114,000 tonnes in 2009 (IMROP, 2010). Meanwhile, a European fleet of modern trawlers began fishing in the Mauritanian Exclusive Economic Zone (EEZ) in 1996, first under private agreements and under a EU fisheries agreement since 2002.

Although regular international assessments have highlighted the risks of overfishing (FAO, 2013), the NWA area fish stocks have not benefitted from intense and regular scientific programmes and the various bases of stock assessments (stocks structures and migration, spawning and recruitment periods and areas) must be consolidated. Scientific surveys at sea remain limited in time and space. Until 2006 the R/V Dr Fridtjof Nansen carried out acoustic surveys in November each year, covering the entire NWA area (IMROP, 2010). Since then, an echo-integration survey has been carried out annually in the Mauritanian EEZ. It is usually being done at the end of the year (Braham et al., 2012). Fisheries statistics recorded in the logbooks have been the most important source of spatio-temporal information since 1990. They have not, however, been subject to any in-depth analysis. One of the reasons is probably that commercial catch rates must be standardised for use as an index of relative/apparent abundance (Hilborn and Walters, 1992; Maunder and Punt, 2004). The main objective of the present paper is thus to extract meaningful and up-to-date knowledge on sardinella biology from standardised catch rates.

A long series of publications (e.g. Robson, 1966; Gavaris, 1980; Laurec and Fonteneau, 1979) discusses the question of the standardisation of catch rates to account for vessel effects (fishing power), spatial effects (fish distribution together with fishing effort allocation) and temporal effects (stock dynamics combined with technical and knowledge improvements of fishermen). In essence, all these techniques relate to linear models, the differences being in the structure of the data (qualitative versus quantitative, distribution free versus parametric, spatio-temporal versus spatial and temporal with additional interactions). The present paper is a contribution to the estimation and the analysis of fishing power and abundance index.

The Mauritanian EEZ is strongly influenced by a recurrent, though variable, upwelling. The variability of the abundance index obtained from our model output for the period between 1990 and 2009 is compared with the dynamics of the coastal ocean (upwelling, surface temperature and chlorophyll index). Even though they are not well known, the ecology of sardinella and in particular their migration and their reproduction strategies, are important clues for the analysis of fishery statistics. The results and therefore the data can equally provide new insights into the dynamics of stocks. Model outputs are used to develop new insights in the life history traits of sardinella in the Mauritanian area.

2. Material and method

2.1. Material

Logbook data are available from 1991 to 2009 for pelagic vessels fishing sardinella in the Mauritanian EEZ. All vessels fishing in the Mauritanian EEZ are obliged to write daily logbook entries reporting daily catches by species or group of species (kg), daily fishing effort (number of operations), the ship administrative code and the statistical square where fishing operations took place. Boats that

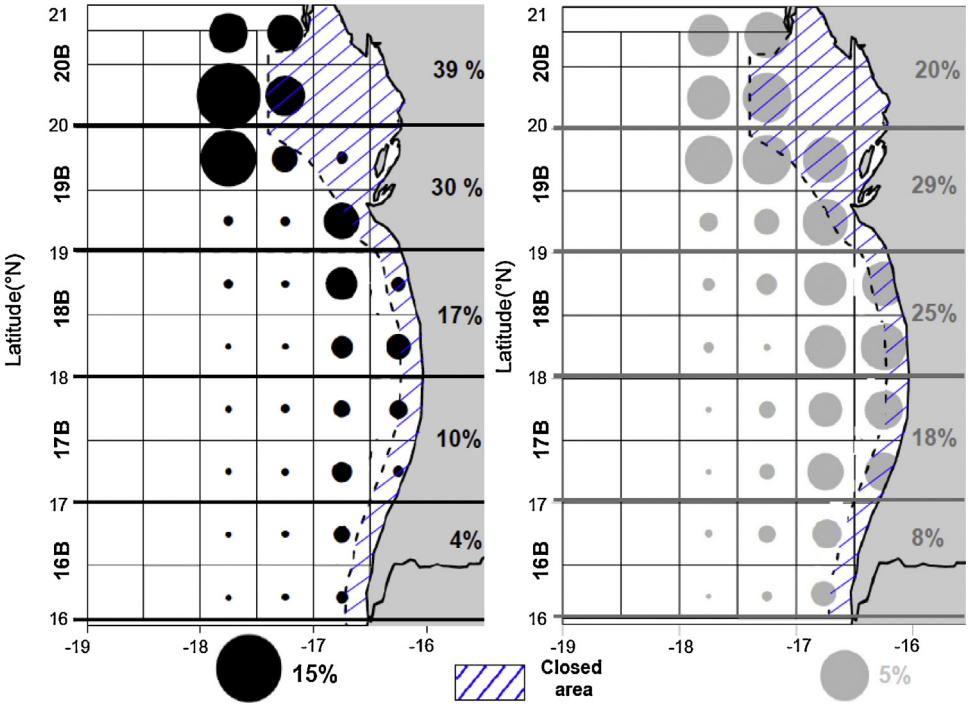

Fig. 1. Averaged percentages of catches declared by statistical squares (left) and of abundance index (right) of sardinellas from 1991 to 2009. Results are indicated by blocks of 1° of latitude. The blue dashed line shows the limit of the closed area.

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