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Effect of oceanographic parameters on daily albacore catches in the Northeast Atlantic

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ABSTRACT

In recent years, albacore (*Thunnus alalunga*) catches decreased strongly in the Eastern part of the Bay of Biscay. In order to understand the drivers of local albacore catches by fisheries in this area, we analyzed the influence of temperature, salinity and trophic parameters on albacore daily catches by three fleets (baitboat, trolling line and pelagic trawling) traditionally operating in the Bay of Biscay and its surrounding waters. For this, we used oceanographic data obtained from the operational model Regional Ocean Model System (ROMS), for each catch date and location. A Principal Component Analysis performed on these oceanographic data, on Julian day, latitude and longitude, yielded three synthetic variables used as explanatory variables in Generalized Additive Models (GAMs). The first one synthesized most of the variability related to temperature, plankton concentration and longitude. The second one synthesized most of the variability related to surface mixing associated with a seasonal trend. The third one synthesized most of the variability related to salinity and latitude. GAMs revealed a non-linear effect of salinity and latitude on daily catches for all fleets. The effect of mixing was negative for surface gear catches and positive for trawl catches. The trophic and planktonic component had a clear influence only on baitboat and trolling catches. The results are discussed in terms of albacore habitat preferences, vertical distribution and feeding behavior. We suggest that these environmental influences should be considered when using albacore catch data for stock assessment and extrapolating the effects of climate change on albacore abundance in the Bay of Biscay.

1. Introduction

Albacore (*Thunnus alalunga*) is a highly migratory large pelagic species widespread in the whole North Atlantic Ocean, from 5°N to 52°N (Santiago, 2004). In summer, adults spawn in tropical regions of the Atlantic, while juveniles move northwards. This polewards displacement of juveniles is considered a feeding migration (Santiago, 2004). Some adult individuals also appear sporadically in temperate regions after the spawning season, in late summer and autumn.

In the North Atlantic, albacore are exploited mainly in the Bay of Biscay, Celtic Sea shelf break and to a lesser extent in the Azores area during their summer migration, by three surface and subsurface gears: trolling line and baitboat (mainly Spanish vessels), and pelagic trawl (French and Irish vessels). In the last decade catches by the aforementioned gears represented 80–90% of the total North Atlantic albacore catch (ICCAT, 2013). The majority of the albacore caught by these three gears are juveniles, in particular of age-classes 2 and 3 years, that correspond roughly to modal weights of 5–6 kg and 8–10 kg respectively. Age-1 (< 4 kg) and age-4 (12–14 kg) individuals are also caught, in lesser amounts, by the three fleets in the latest part of the fishing season. Adult individuals are seldom caught.

Few studies so far have identified the environmental factors that affect albacore production. However this is paramount due to the wide spatial distribution of this species and its associated fisheries (Arrizabalaga et al., 2015). In recent years, in the Northeast Atlantic, catches of this species were very low in usual zones East from the 9°W meridian i.e. in the inner Bay of Biscay. This anomaly highlights the need for a better understanding of the oceanographic factors driving albacore catches for these three major fisheries. Catches are determined by stock abundance, fishing effort, and catchability, which is defined as the fraction of the stock which is caught by a standardized (effective) unit of effort (ICCAT, 2000). It is also used as the constant of proportionality that relates effective effort to fishing mortality (ICCAT, 2000). We follow this terminology in the present study. Catchability is affected by fish availability (both

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geographical and vertical) and by their vulnerabilty to the fishing gear. In the case of albacore, their seasonal migration influences the local abundance that is available to the gears in the Northeast Atlantic. When present, vertical distribution of albacore determines their availability to surface (troll, baitboat) and deeper (pelagic trawling) gears. Moreover, their feeding behavior and gear avoidance determine their vulnerability to baited and active gears, respectively.

In order to deal with the multiple and collinear variables contemplated, this study used multivariate indices derived from a Principal Component Analysis (as in Hémery et al., 2008) as explanatory variables for albacore daily catches. The aim of this study is to assess the effects of a series of oceanographic parameters on the daily albacore catches in the Northeast Atlantic by the three main fisheries. We expect that this work will contribute to elucidate the key drivers of albacore availability in this area.

2. Materials and methods

2.1. Environmental data

The high resolution 3D model Regional Ocean Model System (ROMS, Shchepetkin and McWilliams, 2004) was used to get environmental data associated with each zone and day of albacore catch. The model covers all the Bay of Biscay and extends between 40,5°N and 52,5°N and between the coast and 13°W (Fig. 1). This model uses mass conservation equations to simulate the variability of oceanic processes, including high frequency (tides, daily thermal cycles, and precipitations), low frequency (atmospheric perturbations, mesoscale variability) and seasonal scales (river runoffs, winter convection and summer stratification). The model ROMS has already been applied successfully to several systems, as the Benguela (Penven et al., 2001) or Humboldt (Penven et al., 2005) systems. The current configuration for the Bay of Biscay is an extension of a configuration initially limited to the southern Bay of Biscay (Ferrer et al., 2009). The ROMS model is coupled to a biogeochemical N2P2Z2D2-type model, taking into account nitrate and ammonium, two phytoplankton size classes, two zooplankton size classes and two detritus. After 1 year of run (1997) to obtain a preliminary balance, the simulation covers the period 1998–2009, with time steps of 15 min.

In terms of hydrology, the simulated 12-years monthly mean SST and SSS has been compared to monthly climatologies from AVHRR and CTD in-situ data, using Taylor diagram and P*bias* (Chifflet et al., in preparation). The model reproduces the overall seasonal cycle of SST in the Bay of Biscay. The model also reproduces local processes: cold band water along the Atlantic French coast in winter, warming and north-south gradient in spring, Galician upwelling, Ouessant front and cold slope band in summer, as well as rivers plumes. The comparison of the simulated surface chl*a* to MODIS images, from 2003 to 2009, indicates a well captured seasonal and interannual variability by the model (Chifflet et al., 2012). However, the spring bloom is simulated earlier (about 2–3 weeks) in the season compared to observations.

Surface and subsurface temperature, salinity and biotic variables (Table 1) were used for these analyses. The depth of the 15 °C isotherm is considered indicative of the depth of the summer thermocline. The choice of these variables is based on previous works in the Atlantic, Indian and Pacific Ocean relating albacore catches and sea surface temperature, mixed layer depth, chlorophyll concentration and salinity (Goñi and Arrizabalaga, 2005; Zainuddin et al., 2008; Dufour et al., 2010; Sagarminaga and Arrizabalaga, 2010; Lan et al., 2012; Arrizabalaga et al., 2015: Sagarminaga and Arrizabalaga, 2014).

2.2. Catch data

Logbooks of trollers and baitboats from Bizkaia and Gipuzkoa (Spanish Basque Country), and of pelagic trawlers from the sector

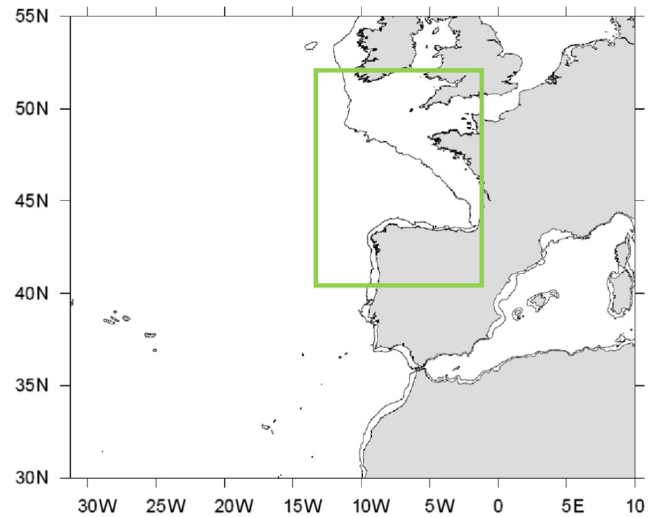

Fig. 1. Northeast Atlantic with 200 m isobaths, and sector corresponding to the ROMS data locally used.

Table 1
Environmental variables used from the model ROMS.

Environnemental variables	Units	Abbreviations
Temperature at 2 m depth	°C	**T2m**
Temperature at 30 m depth	°C	**T30m**
Salinity at 2 m depth	g/kg	**S2m**
Salinity at 30 m depth	g/kg	**S30m**
Chlorophyll A at 2 m depth	$mgChla/m^3$	**Chl2m**
Chlorophyll A at 30 m depth	$mgChla/m^3$	**Chl30m**
Zooplankton at 2 m depth	mgC/m^3	**Zoo2m**
Zooplankton at 30 m depth	mgC/m^3	**Zoo30m**
Depth of 15 °C isotherm	meter	**Depth15**
Temperature gradient between 2 m and 30 m	°C	**G**

Table 2
Period and number of catch events corresponding to the catch data by trolling line, baitboat and pelagic trawl fleets used in this study.

Fishing gear	Period	Number of events
Trolling line	1998–2006	7842
Baitboat (1st dataset)	1998–2005	7743
Pelagic trawl	2002–2009	699
Baitboat (2nd dataset)	2005–2009	6653

of Bayonne (French Basque Country) were used (Table 2, Fig. 2). A daily time-scale was used and ICES statistical rectangles (ICES, 1977) were considered as catch locations. Only positive catches were available for this study, and the period 1998–2009 could not be fully covered for each fleet (see Table 2).

The albacore catches of the trolling fleet are the most widespread among the catches considered in this study (Fig. 2) and correspond to 45–60% of the total (essentially Spanish) trolling catches in the study period. The albacore catches of the baitboat fleet have a similar geographical extension as trolling catches in terms of fishing events but the majority of the catch occurs between 2°W and 6°W longitudes (Fig. 2). These catches represent more than 90% of the total baitboat catches in the study period. The catches of the pelagic trawling fleet correspond to 35–45% of the total international (mainly French and Irish) pelagic trawling catches in the study period, and are distributed mainly along the shelf-break (Fig. 2). All fleets operated from June to early November. The trolling fleet targets exclusively albacore in these months. The Spanish baitboat fleet and the French pelagic trawl fleet also targeted bluefin tuna in these months during the study period, generally deploying separate fishing efforts for each of the two species.