Deep-Sea Research II 107 (2014) 54–63

Contents lists available at ScienceDirect

Deep-Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

Relationship of Northeast Atlantic albacore juveniles with surface thermal and chlorophyll-a fronts

Y. Sagarminaga *, H. Arrizabalaga

AZTI Tecnalia, Herrera Kaia z/g 20110, Pasaia, Gipuzkoa, Spain

ARTICLE INFO

Available online 12 December 2013

Keywords:
Thunnus alalunga
Northeast Atlantic
Sea surface temperature fronts
Chlorophyll-a fronts
MODIS AQUA Satellite
Spatio-temporal distribution

ABSTRACT

When the spring seasonal warming starts, North Atlantic albacore (*Thunnus alalunga*) juveniles and pre-adults perform a trophic migration to the northeastern Atlantic, to the Bay of Biscay, and to the southeast of Ireland. During this migration, albacore juveniles are mainly exploited by Spanish trolling and baitboat fleets. The present study analyzes the relationship between the albacore spatio-temporal distribution and the upper surface horizontal fronts in their migration paths and destinations. For this, albacore catches from personal fishing logbooks from Basque trolling and live-bait fleets and daily MODIS AQUA Chlorophyll-a and SST products covering the period 2003–2005 have being used. Gradients have been calculated with the front algorithm proposed by Belkin and O'Reilly (2009). The approach used to study the relationship of catches location with frontal areas is based in the comparison of distributions of gradient magnitude around catch locations versus gradient magnitudes in a Monthly Occupation Area. The results obtained show that there is a high spatio- temporal variability of SST and Chl-a fronts in the area. SST and Chl-a fronts are not coincident in time or in space. However, there is a clear seasonal pattern of SST and Chl-a frontal activity in the area with a peak in July for SST gradient magnitudes and a peak in April for Chl-a gradient magnitudes. The relationship of albacore juvenile catches with high gradient magnitude areas is different according to the months and fleets analysed. In general, there is no evidence of consistent adherence of albacore catches to areas with higher SST gradients. However, results suggest a potential association between both fleets catches and Chl-a high gradient magnitude areas in August and September.

1. Introduction

Albacore tuna (*Thunnus alalunga*, Bonn 1788) is a highly migratory species widely distributed in the three oceans (Collete and Nauen, 1983). There are three distinct populations in the Atlantic: the northern Atlantic, the southern Atlantic and the Mediterranean (Arrizabalaga et al., 2004; Montes et al., 2012; Albaina et al., 2013). During winter months, North Atlantic albacore (both adults and juveniles) inhabit the central Atlantic waters. When the spring seasonal warming starts, adults perform a reproductive migration to the North-western Atlantic (in front of the Venezuelan coast and in the Sargasso sea, Nishikawa et al., 1985). Meanwhile, juveniles and pre-adults (1–4 years old) perform a trophic migration to the Northeastern Atlantic into the Bay of Biscay (Fig. 1) and the southeast of Ireland (Ortiz de Zárate and Cort, 1998; Arrizabalaga et al., 2002; Goñi and Arrizabalaga, 2010; Dufour et al., 2010).

During their trophic migration to northeast Atlantic waters, juvenile albacore are exploited by surface gears from June through October (mainly by Spanish trolling and baitboat fleets, representing more than 50% of the total catch in the last decade). The development of the swimming bladder (Gibbs and Collette, 1967) as well as the higher thermoregulation capacity allows adult albacore to occupy deeper waters than juveniles that are bound to stay in surface layers (0–50 m) preferably close to the thermocline level (Cosgrove et al., 2014).

Tuna pelagic habitat has been delimited according to physiological tolerance studies to critical ambient variables such as temperature and dissolved oxygen (Brill, 1994). In particular for northeast Atlantic albacore several studies have reported surface thermal preferential ranges between 16 °C and 18 °C (Havard Duclos, 1973; Leroy, 1990; Santiago, 2004; Sagarminaga and Arrizabalaga, 2010), which is in accordance with the observations reported for albacore in other areas (Clemens, 1961).

In addition, several authors suggest that albacore show a preference for ocean fronts with strong horizontal gradients in either temperature, salinity, chlorophyll or micronekton (Sund et al., 1981; Laurs et al., 1984; Fiedler and Bernard, 1987; Ramos et al., 1996; Domokos et al., 2007; Zainuddin et al., 2008). The hypotheses supporting the association between tunas and fronts include the following: confinement to a physiologically optimum temperature

* Corresponding author. Tel.: +34 943 004800; fax: +34 943 004801.
E-mail address: ysagarminaga@pas.azti.es (Y. Sagarminaga).

0967-0645/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.dsr2.2013.11.006

range (Sund et al., 1981), use of frontal gradients for thermoregulation (Neill et al., 1976), and the availability of proper food (Pinkas et al., 1971; Domokos et al., 2007; Zainuddin et al., 2008) associated with waters with a differentiated thermal signature (i.e. cold upwelled waters). For northeast Atlantic albacore this relationship has been described by several authors (Leroy, 1984; Ramos et al., 1996; Santiago et al., 1996). On the other hand, cases of weak association with thermal fronts have also been reported for northeast Atlantic albacore (Santiago, 2004, Sagarminaga and Arrizabalaga, 2010). In addition to this, most of the studies suggesting potential relationships between North Atlantic albacore distribution and fronts are only based on visual interpretations of the spatial location of catch events and strong surface fronts, usually defined by mesoscale structures like upwelling, eddies and river plumes, observed at specific dates. In general terms, there is a lack of quantitative statistical analyses using automatic front detection and characterisation techniques (i.e. Royer et al., 2004; Schick et al., 2004).

The objective of this study is to analyse quantitatively and thoroughly the relationship between juvenile albacore catches and surface Chlorophyll-a and SST frontal areas in the NE Atlantic and Bay of Biscay, from June to October.

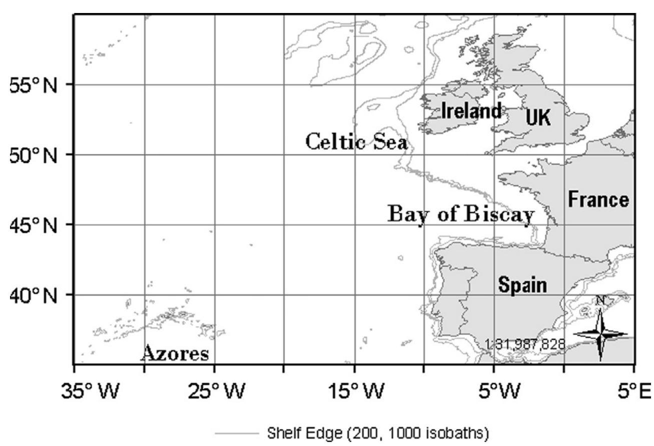

Fig. 1. Area of study.

2. Data and methods

2.1. Fishery data

The fishery data used in this work are the catch data registered in personal logbooks by skippers of the Basque trolling and live bait fleets during the 2003–2005 period. The variables recorded in the logbooks and used in this work include the date and latitude and longitude of catch locations. These catch locations may represent, depending on the skippers methodology, a single haul position, or at worst, an average daily location of catches. In total, they sum 15,572 catch events, 9137 from trolling fleet and 6435 from live bait fleet.

2.2. Front data

Sea surface temperature and Chlorophyll-a concentration fronts were calculated using the algorithm proposed by Belkin and O'Reilly (2009). IDL code (version November 2010) provided by these authors was run on daily, 4.6 km, Level-3 Aqua-MODIS "Chlorophyll concentration" and "SST 4 μ nightime" obtained from oceancolour website (http://oceancolor.gsfc.nasa.gov/). The global images downloaded were previously clipped to a geographical window extended between 35°W and 25°E and between 20°N and 70°N. Daily gradient magnitude images have been averaged to obtain monthly gradient images that have been used to visualise frontal spatio-temporal distribution in the area and period of study.

2.3. Data analysis

A preliminary data mining process has been done to eliminate catch data outside the NE Atlantic area (i.e. data in the Mediterranean Sea or without valid values of latitude and longitude). The "Total Occupation Area" (hereafter mentioned as TOA) has been framed around these data to use it as a mask for gradient values extraction from satellite images. Apart from this, "Monthly Occupation Areas" (hereafter mentioned as MOA) have been calculated and framed, using dissolved buffers of one geographical degree radius around monthly catches (cf. Fig. 2). One degree was found to be the best distance buffer to accomplish two conditions: (i) get a continuous polygon without "islands" between catches and (ii) adjust as much as possible the edges of the polygon to the

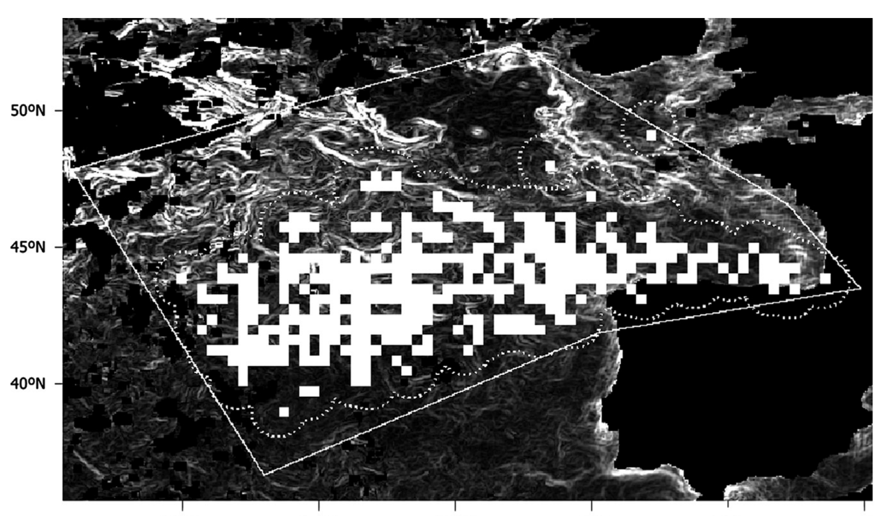

Fig. 2. SST gradient magnitude image for June 2004 overlaid with Total Occupation Area (TOA) polygon (white continuous line), Monthly Occupation Area (MOA) polygon for June (white dotted line) and 9 × 9 pixel search windows (white squares) for June 2004 catch locations.