Integrating reproductive ecology, early life dynamics and mesoscale oceanography to improve albacore tuna assessment in the Western Mediterranean

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ABSTRACT

Albacore tuna is a pelagic top predator of high ecological and commercial relevance worldwide. Despite the importance of this species, there is only limited knowledge of its life cycle, reproductive dynamics and early life ecology. In the Mediterranean, where the assessment is based on data-poor methods, the status of the albacore population remains uncertain. Here we combine information from commercial fisheries, ichthyoplankton surveys and oceanographic data in the Western Mediterranean Sea to identify the geographical location of the main spawning areas and larval habitats. We applied this information to develop a habitat-corrected larval abundance index providing information on early life dynamics. The larval index was compared with fisheries-dependent indices used for the stock assessment of the Mediterranean albacore. The results allowed the identification of the main spawning grounds, located around the Balearic Sea, and the role of oceanographic conditions when studying larval abundances. The larval abundance index shows a significant negative trend during the last decade, indicating a potential reduction in the spawning stock biomass, which is consistent with the trend observed from the fisheries-dependent indices. We discuss how the systematic integration of information from ichthyoplankton surveys and hydrography to improve assessment is an example of operational fisheries oceanography in practice.

1. Introduction

Albacore (*Thunnus alalunga,* Bonnaterre, 1788) is a pelagic top predator of high commercial and ecological relevance. Six independent stocks are assumed to be distributed in the three major oceans and the Mediterranean Sea, between latitudes 50 °N and 40 °S (Collette and Nauen, 1983). Current catches represent 4% of the global tuna fisheries (ISSF, 2017) and there is only limited knowledge of the life cycle, reproductive dynamics and early life ecology of this species despite its socio-economic and ecological relevance. This lack of information limits the capability to identify and study the key variables controlling relevant aspects of the albacore ecology that are crucial for the management of the stocks, such as the habitat preferences for spawning in

relation to the environment and the spatio-temporal dynamics of mature adults and their offspring (Nikolic et al., 2016). Therefore, better understanding of these processes could improve current assessments and the design of better management approaches.

The Mediterranean albacore stock is managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT) that conducted assessments of this species in 2011 and 2017. Taking into account the lack of information on biological and fisheries data, the assessments were performed using methods for data-poor stocks (ICCAT, 2017a). Currently, the status of the Mediterranean albacore remains highly uncertain and it is exploited without any specific limitations such as total allowable catches or minimum lengths. Within the Spanish fishing waters (North-Western Mediterranean), albacore is mainly
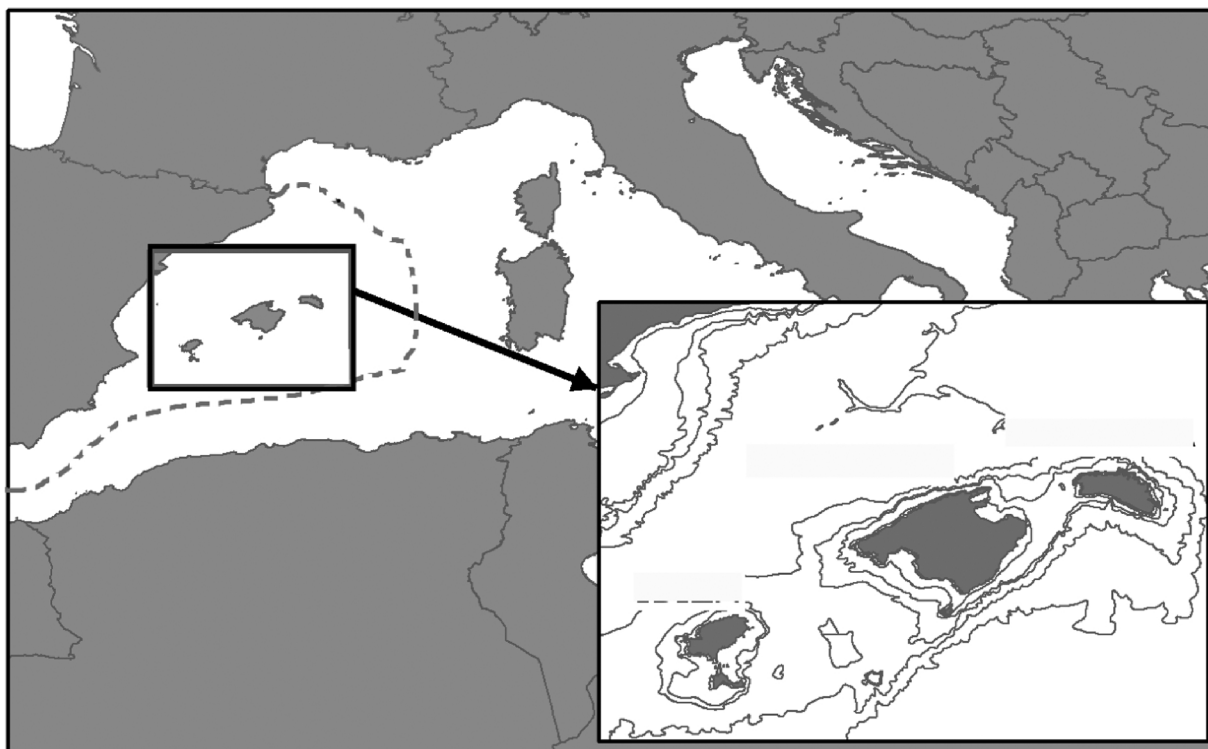

Fig. 1. Western Mediterranean. Black box delimitating the Balearic Sea (sampling area of ichthyoplankton surveys) and grey dashed line indicating the Spanish fisheries zone.

caught by the longline fishery during the reproductive season during June–July, as characterized from the analyses of gonads (Saber et al., 2015; Karakulak et al., 2016). Contrary to the limited knowledge on the early life stages of this species in other regions worldwide, the studies directed to identify environmental factors shaping larval ecology are better developed in this area. Evidence of eggs and the systematic presence of larvae captured during the last two decades, in addition to the absence of larvae in other areas in the Western Mediterranean (Sabatés et al., 2007; Olivar et al., 2010), indicates that this area presents the adequate larval habitats for albacore. Futhermore, annual monitoring of ichthyoplankton communities and mesoscale oceanographic conditions around the Balearic Sea have enabled the identification of the main hydrographic factors driving albacore eggs and larvae distributions (Alemany et al., 2010; Reglero et al., 2012, 2017). Adding information on the spatial distribution of mature adults from commercial fisheries to data obtained from the ichthyoplankton surveys and mesoscale oceanography in this region will help identify how larval and spawning habitats overlap and confirm whether the Balearic Sea acts as a restricted spawning ground for albacore as it is for bluefin tuna (*Thunnus thynnus*) (Muhling et al., 2017). This analysis provides a unique opportunity to investigate questions related to the reproductive and early-life dynamics of albacore and to develop a larval abundance index. If the Balearic Sea is functioning as a major spawning ground within the region, such an index could be applied as a proxy to assess the temporal trends of the spawning stock biomass for the Spanish Mediterranean fisheries area.

Larval abundance indices based on standardized larval densities from ichthyoplankton surveys provide a valuable fishery independent source of information in the assessment of tuna stocks. Larval indices in the Gulf of Mexico have been included in the assessments of various species such as bluefin tuna, skipjack (*Katsuwonus pelamis*) and little tunny (*Euthynnus alletteratus*) (Ingram, 2014, 2017; Ingram et al., 2010). Recently, a bluefin tuna larval index from the Balearic Sea (Ingram et al., 2013, 2015, 2017) has been developed and included in the last stock assessment of this species (ICCAT, 2017b). The bluefin

tuna larval index of the Balearic Sea was designed to incorporate the variability on local oceanographic conditions by standardizing larval captures according to the spatio-temporal distribution of the larval habitat. Integrating oceanographic conditions to calculate bluefin tuna larval abundances has opened an innovative approach for linking early life dynamics and environmental variability, improving the knowledge on the processes driving the ecology of the early life stages and the quality of the information for the fisheries assessment (Alvarez-Berastegui, 2017; Ingram et al., 2017).

Three main questions have to be solved to assess the annual trends of albacore larval abundances in the Balearic Sea and to advance on its application as fisheries-independent index. First, it is necessary to confirm that the Balearic Sea is a major spawning ground for the species in the region, second, larval abundances from ichthyoplankton surveys must be appropriately standardized given the spatio-temporal variability of the larval habitat, which depends on oceanographic conditions (Alemany et al., 2010; Reglero et al., 2017), and third, it is necessary to assess the link between larval and adult abundances, which could be biased due to the high stochasticity that affects the early life stages of fishes (Simon et al., 2012; Cury et al., 2014; Szuwalski et al., 2015). In order to address to these questions, we investigate the location of the albacore spawning grounds in the Western Mediterranean Sea from the spatial distribution of mature individuals, and develop a habitat-corrected larval index for albacore to evaluate the inter-annual changes of larval abundance considering the oceanographic effects on the larval habitat distribution. In order to explore the links between albacore larval and adult abundances, we compare the resulted larval index with the temporal trends of fisheries-dependent indices, used currently in the framework of ICCAT for the stock assessment of the Mediterranean albacore.