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Population structure of the blue jack mackerel (*Trachurus picturatus*) in the NE Atlantic inferred from otolith microchemistry

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ABSTRACT

The blue jack mackerel, *Trachurus picturatus*, is an economically important fishery resource of the NE Atlantic, commonly captured around the Macaronesian islands of Azores, Madeira and Canaries, but also along coastal Portugal mainland. Despite this, information regarding the *T. picturatus* population structure is, at present, non-existent. One hundred and twenty individuals of *T. picturatus* were collected in 2013 from six important fishery regions of the NE Atlantic: Azores, Madeira, Canaries and Portugal mainland − Matosinhos, Peniche and Portimão. Elemental and isotopic signatures of whole sagittal otoliths were determined by inductively coupled plasma mass spectrometry and isotope ratio mass spectrometry, respectively. Elemental (Sr/Ca, Ba/Ca, Mg/Ca, Pb/Ca, Li/Ca, Fe/Ca and Mn/Ca) and isotopic ratios ($\delta^{18}O$ and $\delta^{13}C$) were analysed with univariate and multivariate statistics to determine whether these chemical signatures provide insight into regional population structure. Whole otolith signatures gave distinct regional signatures, mainly driven by spatial differences in Sr/Ca, Ba/Ca, Li/Ca and $\delta^{13}C$, namely between the Portugal mainland and the oceanic islands. Furthermore, the results suggest for the first time that Portugal mainland, Azores, Madeira, and Canaries should be regarded as different population units. The high re-classification success rate (an overall of 81%) for these regions obtained from the quadratic discriminant function analysis supports these findings, and suggests the management of this fishery in the NE Atlantic as different stocks.

1. Introduction

The blue jack mackerel *Trachurus picturatus* (Bowdich, 1825) is a migratory pelagic fish species widely distributed in the NE Atlantic from the southern Bay of Biscay to southern Morocco, including the Macaronesian archipelagos of Azores, Madeira and Canaries, Tristan de Cunha and Gough Islands and also in the western part of the Mediterranean Sea and the Black Sea (Smith-Vaniz, 1986; ICES, 2015). It is an economically important resource around the Macaronesian islands of Azores, Madeira and Canaries, and also in the coastal waters of Portugal mainland. This species is targeted by artisanal fleets using purse-seine nets; in 2015 the reported landings for Portugal reached 3675 t (INE, 2016). The catches in the NE Atlantic have shown regular fluctuations during the last ten years (FAO, 2016), which may be related, at least partially, to natural variations in abundance or recruitment. However, these fluctuations in the landings are difficult to explain since, at present, studies regarding the population dynamics, stock structure, fish movements and habitat connectivity are not available in the existing literature.

Some attempts to understand the population structure of *T. picturatus* have been done regionally and include studies based on growth and reproduction (Isidro, 1990; Jesus, 1992; Gouveia, 1993; Vasconcelos et al., 2006; Jurado-Ruzafa and Santamaria, 2013; Garcia et al., 2015), fish recruitment (Jurado-Ruzafa and Santamaria, 2011) and the use of parasites as biological markers (Costa et al., 2012, 2013; Vasconcelos et al., 2017). However, studies specifically addressing the existence of distinct population units within the species range have not been published. Growth rate, age at first maturity and reproductive season vary regionally, and, as in closely related species such as *T. trachurus* (Abaunza et al., 2008), the evidences suggest that the species is most likely divided into different population units (Isidro, 1990; Jesus, 1992; Gonçalves et al., 2013; Jurado-Ruzafa and Santamaria, 2013).

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At present, the International Council for the Exploration of the Sea (ICES, 2014) considers that this species is not in need of any special management plan, supported by: the data of commercial abundance; the presence of a stable biomass of juveniles; and an increase in the biomass of adults in the Azores region. Nevertheless, it does recognise that there is no direct surveying of the stock. Marine pelagic fishes, particularly migratory species such as *T. picturatus*, may be erroneously considered a homogenous population unit due to their usually broad geographic distribution, large population sizes and high migratory movements (Gonzalez et al., 2008). However, recent parasitological studies have reported differences between the fish populations of Azores and Canary islands (ICES, 2013), between the fish populations of Madeira and Canary islands (Costa et al., 2013) and among Peniche (located on the Portuguese coast), Madeira and Canary islands (Vasconcelos et al., 2017).

Fish population units, or stocks, can be characterized based on phenotypic characters, (e.g., meristic counts), morphometric measures, comparison of life-history traits, molecular and environmental markers (Begg and Waldman, 1999). Otoliths are regarded as natural tags because: they grow continuously throughout life; they remain chemically inert; and they preserve an uninterrupted record of the environment where fish lived (Campana, 1999). Therefore, otolith-based techniques have proven to be an effective method to assess the population structure in high gene flow systems where environmental heterogeneity exists (Bradbury et al., 2008; Smith and Campana, 2010; Correia et al., 2012b).

The aim of this work was to provide information about the stock structure of *T. picturatus* among four fishery regions – i.e, Azores, Madeira, Canaries, and Portugal mainland – in the NE Atlantic by using an otolith chemistry approach. Moreover, this study used both elemental composition and stable isotopes of whole otoliths (i.e., entire life-history prior to capture) to determine whether distinct chemical signatures were evident.

2. Material and methods

2.1. Fish collection

A total of 120 individuals were collected from four main fishery regions of NE Atlantic: Portugal mainland (three sites: Matosinhos, Peniche and Portimão), Azores, Madeira and Canary islands (Fig. 1).

Samples were collected by local fishermen in shallow coastal waters (up to 75 m water depth) using purse-seine nets during May and July 2013. An effort was made to ensure that the fish obtained from each region/site were from the same size class (as a proxy of age).

All fish were stored on ice after landing and transported to the laboratory to be processed. Each specimen was measured for total length (TL, 0.1 cm) and weighed (W, 0.0001 g) (Table 1). Sagittal otoliths were extracted with plastic forceps to avoid metallic contamination, washed with distilled water, dried with lint-free paper, differentiated to left and right otolith (according to the position of the sulcus acusticus and the rostrum), and stored in clean centrifuge tubes.

2.2. Otolith elemental analyses

The chemical compositions of the right whole otoliths were determined using solution based inductively coupled plasma mass spectrometry (SB-ICP-MS). Prior to the analyses, otoliths were cleaned in an ultrasonic bath with ultrapure water (Milli-Q water) for 5 min, followed by an immersion in 3% analytical grade hydrogen peroxide (H_2O_2) for 15 min to remove any remaining biological residue. Thereafter, otoliths were immersed in ultrapure 1% nitric acid (HNO_3) solution for 10 s to remove superficial contamination, followed by a triple immersion in Milli-Q water for 5 min to remove the acid (Rooker et al., 2001). Cleaned otoliths were stored in new decontaminated centrifuge tubes and allowed to dry in a laminar flow fume hood (Patterson et al., 1999). Otoliths were weighed on an analytical balance (0.0001 g) and dissolved for 15 min in 1 mL of 10% ultrapure HNO_3 diluted with Milli-Q water to a final volume of 10 mL (Correia et al., 2011a).

Otoliths were analysed using a double focusing magnetic sector field instrument ICP-SF-MS (Thermo ICP-MS X series, Thermo Electron Corporation). All measurements were performed at the medium resolution setting (m/_m = 4000) to avoid spectral interferences, particularly on Ni. The instrument was equipped with a microflow nebulizer (PFAAR35-1-C1E, Glass Expansion), operated in the self-aspirating mode (sample uptake rate $\sim 0.93\ L\ min^{-1}$). Quantification of trace elements was based on the external calibration method preparing multi-element standards containing the elements of interest in the expected concentration range (Merck KGaA). To remove the effect of any plasma fluctuations, different nebulizer aspiration rates or sample build-up on the cone orifices, ^{115}In was added at a known concentration to all samples and standards as an internal standard to adjust for instrument

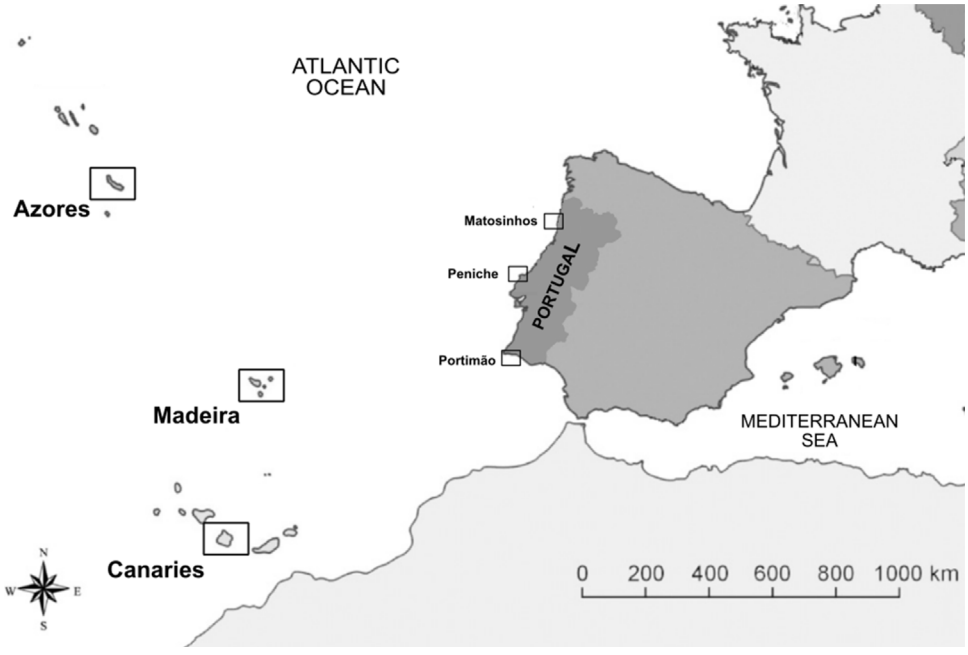

Fig. 1. Sampling location of *T. picturatus* individuals collected in 2013 in the Northeast Atlantic Ocean.