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Short communication

Fecundity regulation strategy of the blue jack mackerel, *Trachurus picturatus* (Bowdich, 1825), off Madeira Island (NE Atlantic)

Joana Vasconcelos[a,b,c,*], Graça Faria[a], Rita Freitas[d], Leonel Serrano Gordo[e,f]

[a] Direção de Serviços de Investigação, Direção Regional de Pescas, Estrada da Pontinha, 9004-562, Funchal, Madeira, Portugal
[b] MARE – Marine and Environnemental Sciences Centre, Estação de Biologia Marinha do Funchal, Cais do Carvão, Promenade da oral Marítima do Funchal, 9000-107 Funchal, Madeira, Portugal
[c] Universidade da Madeira, Faculdade das Ciências da Vida, Campus Universitário da Penteada, 9020-105 Funchal, Portugal
[d] CIDEHUS – Centro Interdisciplinar de História, Culturas e Sociedades da Universidade de Évora; Morada: Largo do Marquês de Marialva n.° 8, 7000-809 Évora, Portugal
[e] MARE – Marine and Environmental Sciences Centre, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal
[f] Faculdade de Ciências da Universidade de Lisboa, Departamento de Biologia Animal, Bloco C 2, Campo Grande, 1749-016 Lisboa, Portugal

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ABSTRACT

This contribution intends to verify the type of fecundity regulation of the blue jack mackerel. For this purpose, the oocyte development process was analysed. A total of 158 ovaries were sampled between January 2009 and April 2010 from purse-seiners operating in the Madeira Island waters, NE Atlantic Ocean. Histological analysis and visual image analysis system were used to study the four main criteria applied for fecundity type determination: (1) presence of a hiatus between pre-vitellogenic and vitellogenic oocytes; (2) number of standing stock of advanced vitellogenic oocytes over the spawning season; (3) mean size of standing stock of advanced vitellogenic oocytes over the spawning season; and (4) the incidence of atresia over the spawning season. The analysis of the oocytes size frequency distribution showed that no distinct hiatus could be observed between pre-vitellogenic and vitellogenic oocytes during the spawning season. Considering the whole spawning period but the last month that was poorly sampled, the number of standing stock of advanced vitellogenic oocytes showed no decrease trend along the spawning season, the mean diameter of cortical alveoli oocytes and of the advanced stock of vitellogenic oocytes did not increase over the spawning season and the relative intensity of atresia was always high throughout this period. These findings suggest the blue jack mackerel displays an indeterminate fecundity.

1. Introduction

The blue jack mackerel, *Trachurus picturatus* Bowdich, 1825, is a pelagic gregarious species, which occurs between the Southern Bay of Biscay and Mauritania including Azores, Madeira, Canaries and the Western part of the Mediterranean (Smith-Vaniz and Berry, 1981). The blue jack mackerel can also be found in the South-eastern Atlantic at Tristan da Cunha and Gough Islands (Shaboneyev and Ryazantseva, 1977; Smith-Vaniz, 1986) and in the Pacific, north and south coasts of America, from California to Valparaiso, and even in the seas of China (Letaconnoux, 1951). *Trachurus picturatus*, the only *Trachurus* species being targeted in the Madeira archipelago, is traditionally caught by three coastal purse-seiners targeting small pelagic fish (mainly *Scomber colias* and *T. picturatus*), which generally operate around the main island, Madeira (Fig. 1). These fishes are attracted to the net by chumming, which is made of a mixture of triturated raw fish, and by intense spotlights, a very efficient method to catch pelagic species (G.T. Jesus, pers. comm.). In 2015, about 439 tons (346 thousand Euros) of blue jack mackerel were landed representing approximately 5.03% (2.49%) of the total landings of the Madeira Archipelago, in weight and value, respectively. Although it fetches a low price in the market, it is an important component in the diet of local population and it is also used as bait to catch tuna fish, the second most important local fishery.

The blue jack mackerel, like most marine fish species of commercial importance, presents a reproductive strategy characterized by being iteroparous, gonochoristic, oviparous and showing no sexual dimorphism (Murua and Saborido-Rey 2003; Gordo et al., 2008). Information on the reproductive parameters such as size at matu-

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* Corresponding author at: Direção de Serviços de Investigação – Direção Regional de Pescas, Estrada da Pontinha, 9004-562 Funchal, Madeira, Portugal.
E-mail address: joana.pr.vasconcelos@madeira.gov.pt (J. Vasconcelos).

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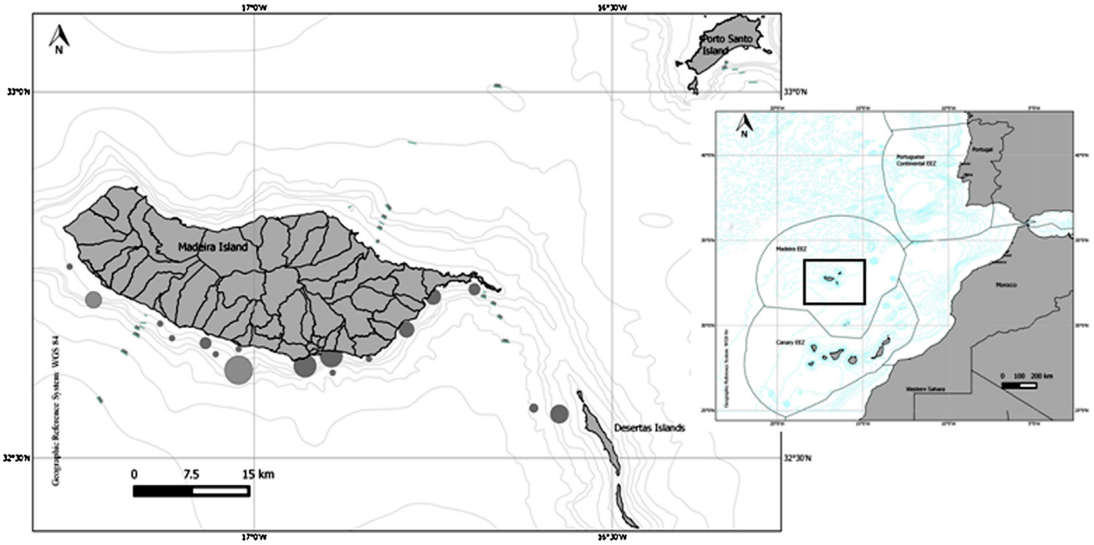

Fig. 1. Madeira archipelago (Northeast Atlantic) map showing the location of some of the fishing zones (gray spots) for *Trachurus picturatus,* according to positional data available from DSI. Mainland and Madeira Portuguese and Canary Islands extended EEZ as proposed by the Portuguese Government.

rity, spawning season, sex ratio and fecundity, are fundamental elements required for the proper assessment and management of fish stocks. Regarding the blue jack mackerel, information on age and growth is available from the Madeira Island (Vasconcelos et al., 2006) and Azores (Isidro, 1990). Other studies including information on reproduction parameters such as size at maturity and spawning season are already available from Azores (Garcia et al., 2015), Canary Islands (Jurado-Ruzafa and Santamaría, 2013) and Mar del Plata, Argentina (Cousseau, 1967) but no information exists for reproductive strategy.

The knowledge of the reproductive strategy and spawning pattern is essential to understand the population dynamics of any fish species (Hilborn and Walters, 1992) being fecundity one of the reproduction parameters that should be analysed (Murua et al., 2003). Improved understanding of these factors will provide the knowledge of the population sustainability to fishing pressures. In addition, awareness on the fecundity and particularly the fecundity type is of great importance in fisheries since it determinates the method of choice for estimating the egg prodution method that should be used to provide fishery-independent estimates of spawning biomass in fisheries assessment (Jennings et al., 2001; Ganias, 2013). In this context, this paper aims to provide new information on the fecundity type of the *T. picturatus*, an issue included in a broader study dealing with the identification of the population units of blue jack mackerel in the southern Northeast Atlantic.

2. Materials and methods

During the spawning season, between January and April, in 2009 and 2010, 158 female individuals in the spawning capable stage (Brown-Peterson et al., 2011) were collected monthly from the commercial purse-seine fleet landings in Madeira Island (Table 1). Ovaries were removed and preserved in a 10% buffered formaldehyde solution and embedded in Technovit 7100 resin, following standard protocols. Histological sections (3–5 μm) were made on the anterior, middle and posterior regions of the ovary and as no significant differences were found on the oocyte distribution among areas, sections were then made on the middle region of the ovary, stained with toluidine blue and digitized using a visual image analysis system (Leica DFC 290). The four lines of evidence to identify whether the fecundity is determinate or indeterminate, suggested by Hunter et al. (1992), Greer-Walker et al. (1994), Murua and Saborido-Rey (2003) and Armstrong and Witthames (2012) were investigated, namely: (1) presence of an hiatus between previtellogenic and vitellogenic oocytes; (2) number of standing stock of advanced vitellogenic oocytes (VTG3, GVM and GVBD, considering Brown-Peterson et al., 2011 terminology) over the spawning season; (3) mean size of standing stock of advanced vitellogenic oocytes over the spawning season; and (4) the incidence of atresia over the spawning season.

Table 1
Number of specimens of blue jack mackerel, *Trachurus picturatus*, used in this study.

Month	2009	2010
January	35	33
February	15	25
March	9	24
April	8	9

For the first line of evidence, 140 ovaries were used and oocyte diameter measurements were performed on 1331 oocytes with a visible nucleus using the software Leica application suite version 3.1.0. For the second and third lines of evidence, the gravimetric method was applied to 15 ovaries per month, from fish of different length classes. After weighing the ovaries, three subsamples of approximately 0.02-0.05 g were extracted from different parts of the ovary lobe. Each sub-sample was then placed in a tube on a magnetic stirrer in order to be gently stirred, and assist separation of the smaller oocytes. The resulting sub-sample was then passed through a sieve, with a diameter equivalent to that of cortical alveoli (125 μm), with the help of a wash bottle, to remove the smaller oocytes. The remaining oocytes were placed in a Petri dish and photographed with the software Leica application suite. The number and the mean size of standing stock of advanced vitellogenic oocytes were registered and the differences tested with an one-way ANOVA (H_0: no statistical differences between the mean number and mean size over the spawning season). Post-hoc comparison of means was performed with Tukey's test. All statistical analyses were performed using R software (R Core Team, 2015). Cortical alveoli and vitellogenic oocytes were distinguished by measuring the oocyte diameter.

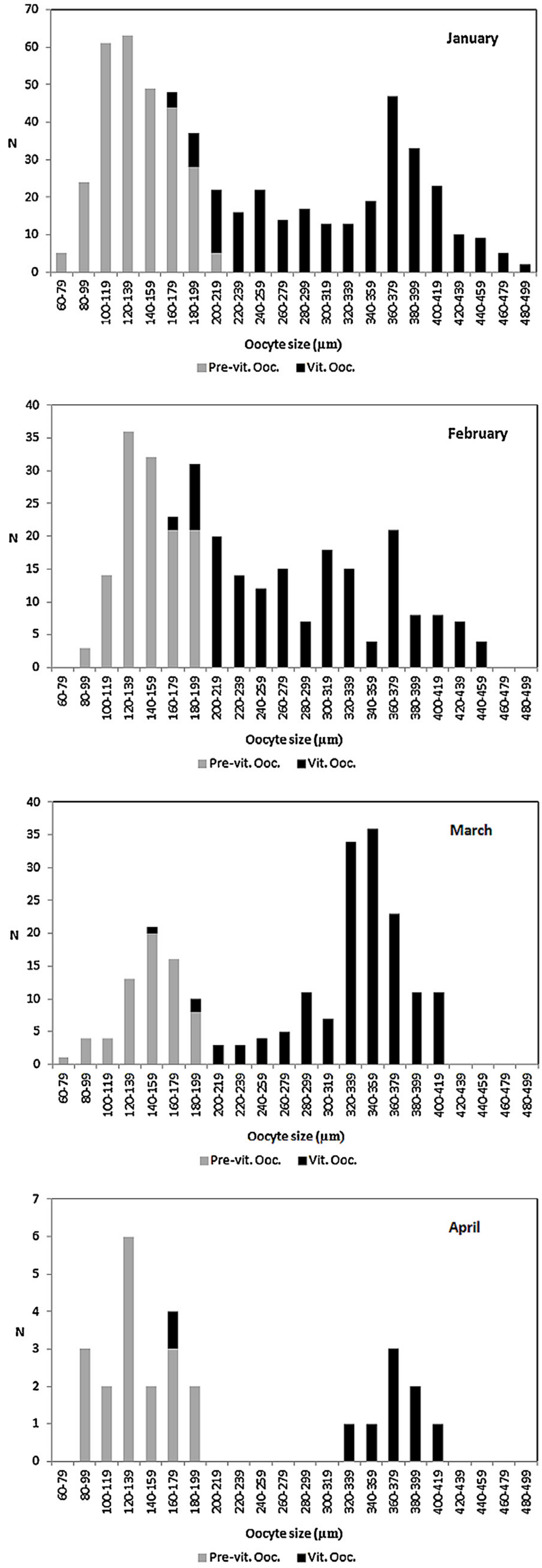

Fig. 2. *Trachurus picturatus* oocyte size-frequency distribution in pre-spawning ovaries, per 20-μm-diameter class, through the spawning period, from January to April (Pre-vit Ooc. = pre-vitellogenic oocytes; Vit. Ooc. = vitellogenic oocytes; N = number of individuals).

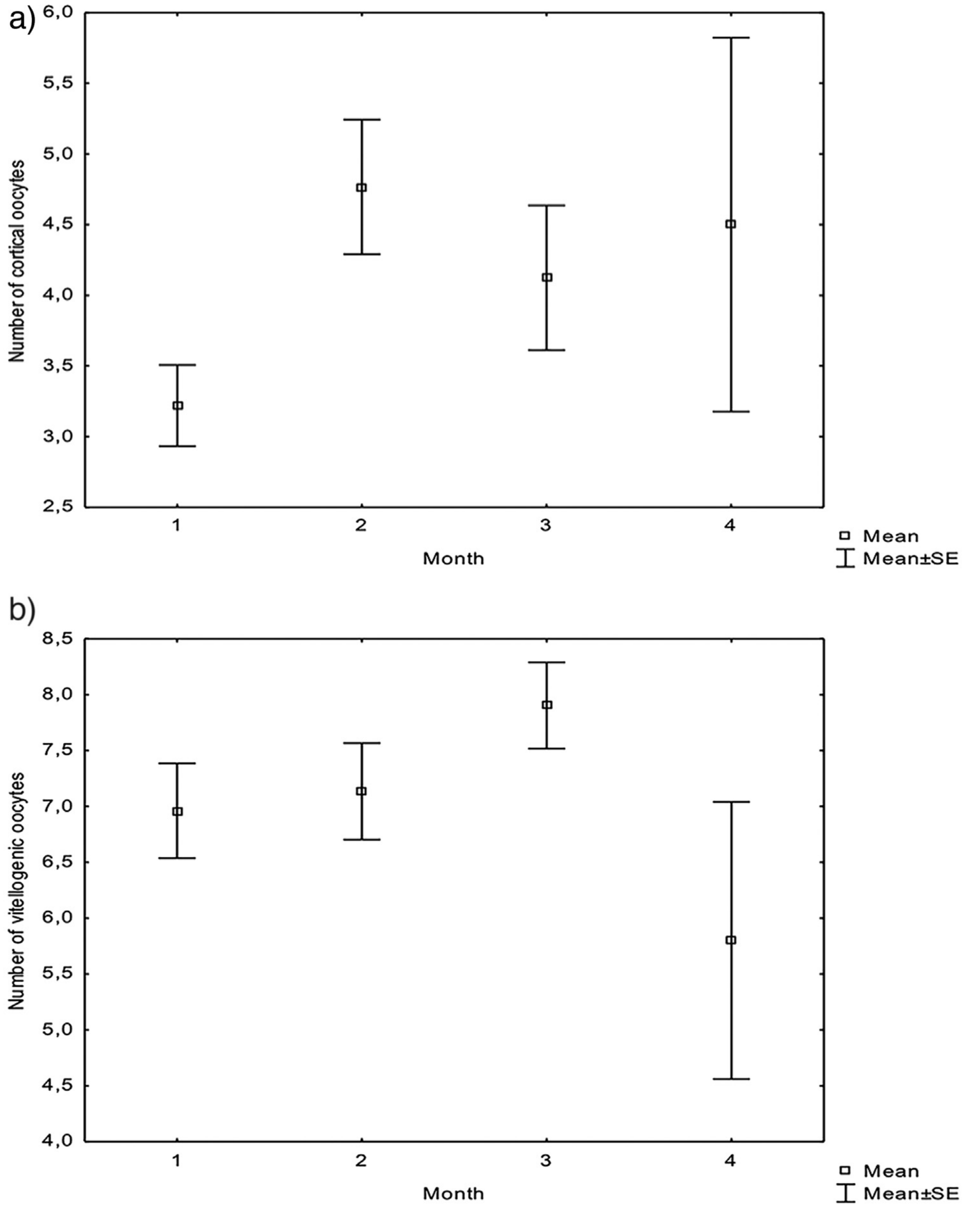

Fig. 3. Monthly variation of the mean and standard error of the number of cortical alveoli oocytes (a) and advanced stock of vitellogenic oocytes (b).

The incidence of alpha atresia stage in yolked oocytes was calculated as percentage of α-atretic stage oocytes in the total number of oocytes present in the ovary (Grande et al., 2012). The prevalence of atresia (defined as the proportion of females with alpha atresia stage oocytes in the total number of females) was also investigated.

3. Results

In *T. picturatus* the oocyte development is asynchronous, the ovary showing oocytes at all stages of development without the presence of a dominant oocyte cohort. Fecundity type was analysed under the four above-mentioned criteria.

Fig. 2 shows the oocyte size frequency distribution where one can see that the pre-vitellogenic oocytes constituted between 30% (March) and 67% (April) of the total number of the oocytes and ranged in diameter from 71 to 213 μm. Vitellogenic oocytes ranged from 126 up to 493 μm. No hiatus exists between pre-vitellogenic and vitellogenic oocytes. No dominant cohort progressing through time was evident in the oocyte size-frequency distribution of *T. picturatus* during the main spawning season.

Furthermore, there was no clear decreasing tendency between January and April, in the mean number of cortical alveoli oocytes (ANOVA; $p = 0.31$; $F = 1.22$) (Fig. 3a) and in the mean number of the standing stock of advanced vitellogenic oocytes (ANOVA; $p = 0.29$; $F = 1.27$) (Fig. 3b).

Regarding the third line of evidence, the mean size of both cortical alveoli (Fig. 4a) and the standing stock of advanced vitellogenic oocytes (Fig. 4b) were analysed. The mean diameter of the cortical alveoli oocytes did not increase over the spawning season (ANOVA; $p = 0.58$; $F = 0.66$). In the case of the standing stock of advanced vitellogenic oocytes there were significant differences along the spawning season (ANOVA; $p < 0.01$; $F = 10.87$). The post-hoc Tukey test showed that February was the month responsible for the differences found.

The incidence of α-atresia stage was high (between 24.52% and 31.20%) through the first months of spawning season with an

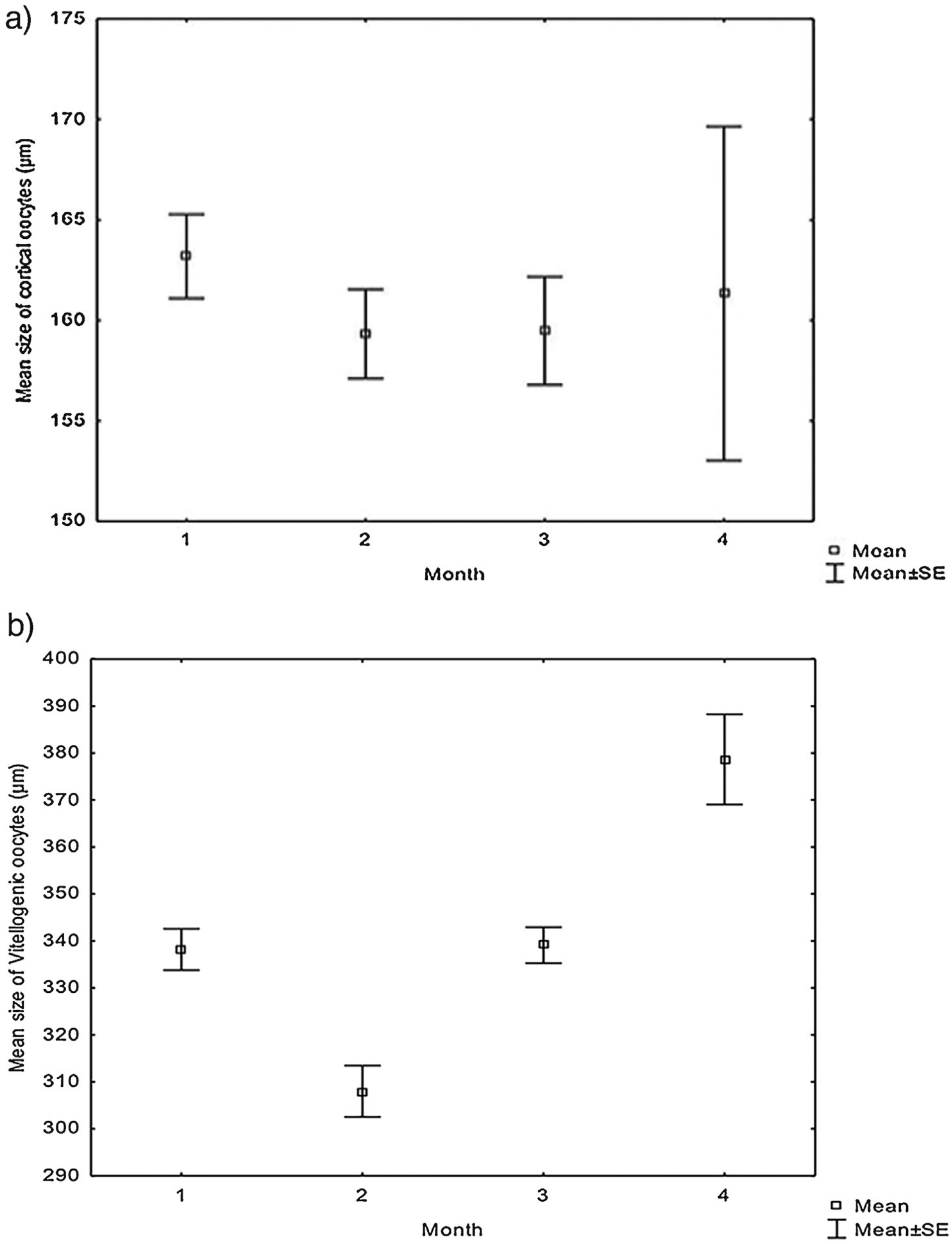

Fig. 4. Monthly variation of the mean size and standard error of cortical alveoli oocytes (a) and advanced stock of vitellogenic oocytes (b) through the spawning season for *T. picturatus*.

increase towards the end, attaining 44.08% in April (Fig. 5) (ANOVA; p = 0.04; F = 2.98). The prevalence of atresia was 71.97%.

4. Discussion

In the present study all lines of evidence to access fecundity type were analysed for the first time in this species. First, the presence of a distinct hiatus in the oocyte size frequency distribution between pre-vitellogenic and vitellogenic oocytes indicates that fecundity is determinate whereas the absence of such hiatus usually means that fecundity is most probably indeterminate (Murua and Saborido-Rey, 2003). In the present work the analysis of oocyte size frequency distribution showed that no hiatus was present between pre-vitellogenic and vitellogenic oocytes, indicating that blue jack mackerel might have an indeterminate fecundity. The presence of the hiatus in April is most probably due to the low number of fish sampled. Secondly, the mean diameter of cortical alveoli oocytes and of the advanced stock of vitellogenic oocytes did not increase over the spawning season since there was no dominant oocyte size class progressing through time. The unexpected higher value obtained in April (the end of the spawning period) for the advanced stock of vitellogenic oocytes is most certainly a bias due to the lower number of ovaries sampled. Another hypothesis explaining such result is that by the end of the spawning season the rate of recruitment of the new unyolked oocytes would be too low (or even null) to compensate for the development in size of the most advanced batches in the ovary and, as a result, the mean oocyte size increases. Thirdly, the mean number of cortical alveoli oocytes and of the advanced stock of vitellogenic oocytes did not decrease, or vary in statistical terms.

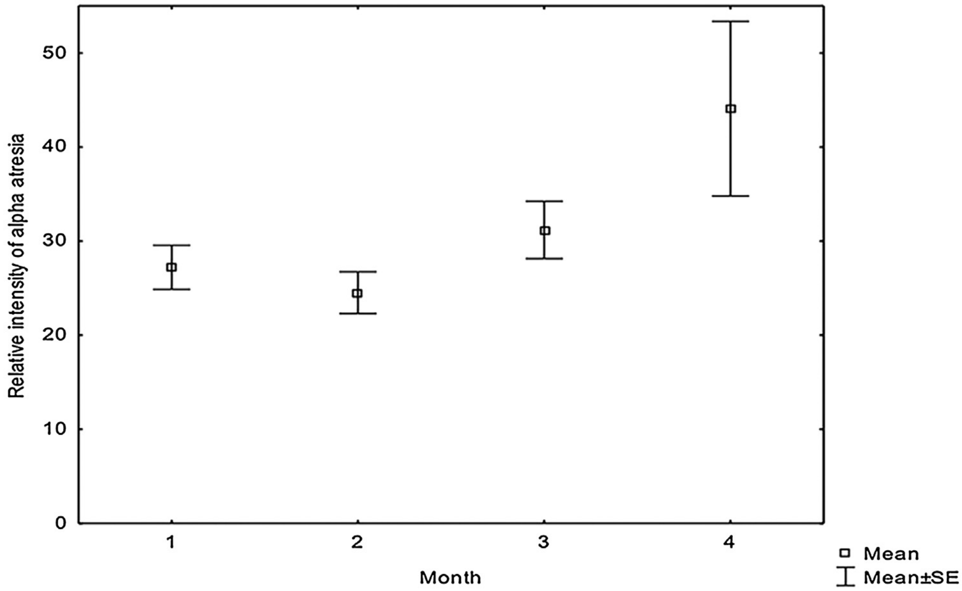

Fig. 5. Monthly variation of the mean and standard error of incidence of alpha atresia stage through the spawning period for *T. picturatus*.

The initial increase of the number of cortical alveoli oocytes may be due to a larger recruitment of those oocytes due to a better condition of the fish in the beginning of the spawning season. The apparent decrease in the number of the advanced stock of vitellogenic oocytes in April may be related to the end of the spawning season. At this time, the majority of the advanced stock of vitellogenic oocytes may have entered atresia (cf. higher intensity of atresia observed in April, Fig. 5) and those that remained could possibly constitute the last cohort that will be shed in the near future. In species with determinate fecundity, a decrease in the number of vitellogenic oocytes is expected during the spawning season since no oocytes are recruited to replace those that are shed (Murua and Saborido-Rey, 2003). Finally, and according to Hunter et al. (1992), in fishes with determinate fecundity, atresia rarely is generalized and if present, usually presents low levels. In this study, atresia was observed in high percentages during the spawning period attaining a higher incidence in April, which is likely associated with the end of the spawning season, and consistent with an indeterminate type of fecundity (Gordo et al., 2008).

The results obtained in this study strongly suggest blue jack mackerel has an indeterminate fecundity type. The knowledge of the type of fecundity contributes to a better understanding of the reproductive potential and allows defining the better methodology to use in the future estimation of the annual fecundity, essential to calculate spawning stock biomass. Finally, this study contributes to a better knowledge of the reproductive strategy of this poorly studied species which, together with other studies that are being or should be implemented in the near future among the countries involved in the geographical distribution of the blue jack mackerel, will allow establishing the stock structure of the species in the Northeast Atlantic in order to improve the assessment of this resource.

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