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Fecundity regulation strategy of the yellowfin tuna (*Thunnus albacares*) in the Western Indian Ocean

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ABSTRACT

The oocyte development process and fecundity regulation (i.e. whether yellowfin tuna shows determinate or indeterminate fecundity) were analyzed to investigate the reproductive strategy of yellowfin tuna, *Thunnus albacares*. A total of 819 yellowfin ovaries were sampled at sea and at the Seychelles cannery during 2009 and 2010 from purse-seiners operating in the Western Indian Ocean. Histological analysis and automated computer-controlled image analysis software were used to study four main criteria applied for fecundity style determination: (a) oocyte size–frequency distribution, (b) number of cortical alveoli and total vitellogenic oocytes in different ovary maturation phases, (c) differences in mean diameter of tertiary vitellogenic oocytes, and (d) seasonal development of atresia.

The results revealed an asynchronous oocyte development and a continuous oocyte size–frequency distribution throughout all ovarian developmental phases over the spawning season. The percentage and number of cortical alveoli and total vitellogenic oocytes remained constant through the spawning season. The mean diameter of tertiary vitellogenic oocytes decreased as spawning progressed. Also, the incidence of atresia was higher at the end of the spawning season as a consequence of over-recruitment of oocytes during this period. These findings revealed that yellowfin tuna exhibit indeterminate fecundity.

1. Introduction

Yellowfin tuna (*Thunnus albacares*) is a large epipelagic species widely distributed in the tropical and subtropical waters of the major oceans (Collette and Nauen, 1983). It is an important component of tuna fisheries worldwide and is one of the major target species for the tuna fishery in the Indian Ocean (Somvanshi, 2002). Due to its high demand, yellowfin is harvested widely, and many types of fishing gear are used. Contrary to the situation in other oceans, the artisanal fishery component in the Indian Ocean (mainly using pole and line, driftnet and hand line) is substantial, taking around 35% of the total yellowfin tuna catch during recent years (2000–2008). The Indian Ocean Tuna Commission (IOTC) estimated that spawning stock biomass has decreased markedly over the last decade (IOTC, 2010). The IOTC recommended that catches of yellowfin tuna should not exceed 300,000 tonnes per year in order to increase the biomass to levels that will sustain catches at levels of Maximum Sustainable Yield (MSY) in the long term (IOTC, 2010). During the last decade the IOTC has recommended and encouraged research on the reproductive biology of yellowfin in order to acquire updated information to be used in the assessment and management process of the population (Somvanshi, 2002; Zhu et al., 2008). A proper estimation of the reproductive potential of the stock would contribute to better and sound management advice for this species in the area.

In the Indian Ocean, yellowfin tuna spawning seems to occur mainly in the equatorial area (0–10°S), with the main spawning ground west of 75°E (IOTC, 2003). Different spawning periods have been described for yellowfin tuna in the Indian Ocean, extending from December to March (IOTC, 2003), and from January to June (Zhu et al., 2008). Also Stéquert et al. (2001) described two reproductive seasons that are related to the north monsoon (main spawning period) and the south monsoon (less reproductive activity). Yellowfin tuna is considered a batch spawner (Joseph, 1963; McPherson, 1991; Orange, 1961; Schaefer, 1998), with a protracted spawning season (Itano, 2000; Schaefer, 1998, 2001b). The pattern of oocyte development is defined as asynchronous (Schaefer, 1998, 2001a), the ovary presenting different oocyte development stages with no clear dominant oocyte stage (Wallace and Selman,

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1981), and fecundity was assumed to be indeterminate (Schaefer, 1996, 1998). However, these findings were only based on indirect evidence such as the absence of the gap between the diameter of oocytes in primary and secondary growth stages (i.e. asynchronous oocyte development) and/or based on the spawning pattern (i.e. batch fecundity). Nevertheless, evidence of these two reproductive characteristics does not necessarily confirm an indeterminate oocyte recruitment type as noted in other studies (Greer Walker et al., 1994; Alonso-Fernández et al., 2008). Therefore, in addition to the spawning pattern (i.e. batch fecundity) and the oocyte development pattern (i.e. asynchronous), other key characteristics need to be applied to test the oocyte recruitment type of a species (Murua and Saborido-Rey, 2003; Kjesbu, 2009). For example, knowledge of the seasonal variation in the percentage and number of different oocyte stages, seasonal variation in the mean diameter of the tertiary vitellogenic oocytes, and the incidence of atresia through the spawning season, are necessary (Murua and Saborido-Rey, 2003) to ascertain accurately the oocyte recruitment type of a species.

Fecundity regulation is related to the manner in which individuals of a species recruit and develop oocytes until they are ovulated (Murua and Motos, 2006). Fecundity pattern can be classified according to the time lag between oocyte recruitment and spawning, and generally two types are defined: determinate and indeterminate (Hunter et al., 1992; Murua and Saborido-Rey, 2003). In fishes with determinate fecundity, oocyte recruitment is completed before onset of spawning and hence the number of advanced oocytes in the ovary corresponds to the potential annual fecundity. In contrast, in fishes displaying indeterminate fecundity, oocyte recruitment and spawning period overlaps, i.e. potential fecundity is not fixed before commencement of spawning. Thus, annual fecundity in fishes with indeterminate fecundity should be estimated multiplying the number of oocytes spawned per batch, the percentage of females spawning per day (i.e. spawning fraction), and the duration of the spawning season (Hunter and Macewicz, 1985a). Therefore, knowledge of oocyte recruitment and development pattern is essential for appropriate fecundity estimation, as the selected method to estimate fecundity is based on the reproductive strategy (Armstrong and Witthames, 2012; Hunter et al., 1992; Kjesbu, 2009; Korta, 2010; Murua and Saborido-Rey, 2003). Moreover, appraisal and acquiring knowledge of the fecundity type is necessary before applying any Egg Production Methods (EPM) (Armstrong and Witthames, 2012; Bernal et al., 2012). For example, the daily egg production method (DEPM) (Lasker, 1985; Parker, 1980) in principle is suitable to be applied to all batch spawner species with indeterminate and determinate fecundity, while the annual egg production method (AEPM) and daily fecundity reduction method (DFRM) are suitable for species with determinate fecundity (Armstrong and Witthames, 2012). Any possible successful application of the egg production survey method would help in the estimation of spawning potential of this specie providing a fishery independent alternative to catch based assessments (Stratoudakis et al., 2006).

The main objective of this research is to determine whether yellowfin tuna exhibits indeterminate or determine fecundity. For that purpose and based on previous studies on fish reproductive strategies (Greer Walker et al., 1994; Hunter et al., 1989; Murua and Saborido-Rey, 2003), we investigated, for the first time, four principal factors related to oocyte development and recruitment in yellowfin tuna. These are: (a) phase-specific and month-specific variation of oocyte size–frequency distribution; (b) seasonal variation in the percentage and number of different oocyte stages during spawning season, (c) seasonal variation in the mean diameter of the tertiary vitellogenic oocytes; and (d) seasonal incidence of atresia through the spawning season.

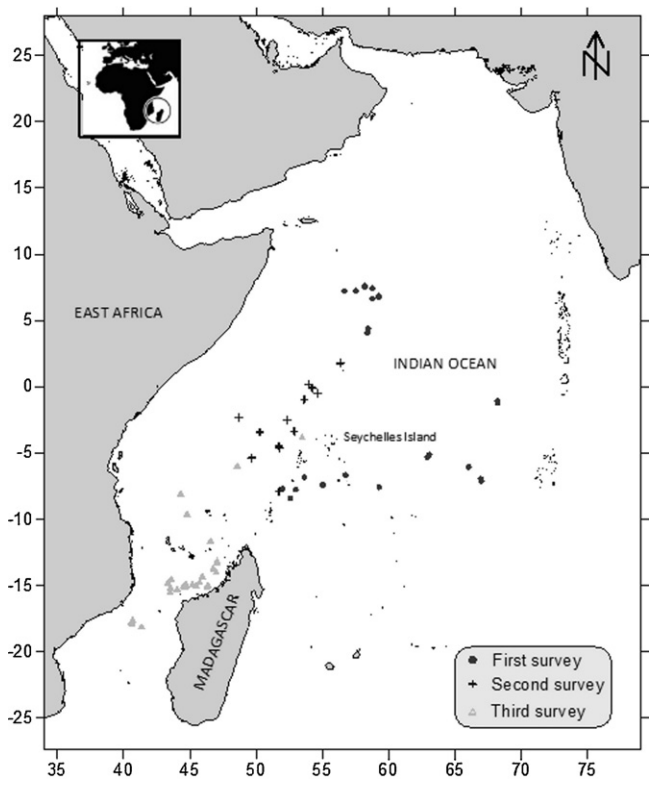

Fig. 1. Location of yellowfin tuna sample collection in the Western Indian Ocean during 2009 and 2010.

2. Material and methods

2.1. Field sampling

Sampling was carried out by scientific observers during three surveys onboard a commercial purse seiner in the Western Indian Ocean during 2009 (2 surveys) and 2010 (1 survey). The first survey was performed from 21st January to 23rd March 2009, the second survey was conducted between 5th June and 25th July 2009, and the third survey from 3rd April to 21st May 2010. The sampling sets were distributed throughout the areas of Somalia, South East Seychelles, North West Seychelles, Chagos and the Mozambique Channel (Fig. 1). In addition to sampling at sea, ovaries were collected at Seychelles cannery from the purse seiner fleet operating in the Western Indian Ocean during the same period.

A total of 319 female yellowfin tuna were sampled onboard a purse seiner, ranging in size from 48 cm to 153 cm fork length, and 500 female yellowfin tuna were collected from the cannery, ranging between 61 and 147 cm fork length (Table 1). Each fish was measured (fork length) to the nearest cm and weighed to the nearest 0.1 kg. Gutted weight, maturity and sex were also recorded. Ovaries were removed from all specimens and weighed to the nearest g, and a 4–5 cm cross-section of the gonad was taken from the middle to end part of the right or left lobe and preserved in 4% buffered formaldehyde immediately after the sampling until they were processed in the laboratory.

2.2. Description of oocyte development stages and atresia

A cross-section (approximately 1 cm) from the preserved portion of the ovary was embedded in resin sectioned at 3–5 μm and stained with H&E. The yellowfin tuna ovaries were classified histologically following the criteria of Wallace and Selman (1981) and modified by Schaefer (1996, 1998). In the present work, the