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Full Length Research Paper

Some reproductive aspects of female bullet tuna, *Auxis rochei* (Risso), from the Turkish Mediterranean coasts

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The study aims to investigate some reproductive properties of bullet tuna (*Auxis rochei*) in Turkish waters. A total of 216 bullet tunas, 110 males (50.93%) and 106 females (49.07%), from the Turkish Mediterranean coasts were sampled monthly between December 2008 and December 2009. The sex ratio was 1:1.04. A total of 106 ovaries were obtained from the females, and these ovaries were histologically examined to determine the reproductive conditions and developmental stages of oocytes. The gonado-somatic index (GSI) values calculated for females indicated that spawning generally occurred between May and September. The most intensive spawning period was observed between June and August. A total of 40 females collected between May and September were sexually mature.

Key words: Bullet tuna, *Auxis rochei*, reproduction, spawning, Mediterranean Sea.

INTRODUCTION

The bullet tuna (*Auxis rochei* Risso, 1810) is a commercially important Scombrid widely distributed in tropical and subtropical waters around the world (Sabatés and Recasens, 2001). It is an epi or meso-pelagic fish that chooses a seasonal coastal distribution in temperate and tropical waters, including the Mediterranean (Uchida, 1981; Collete, 1986). In Turkey, this species is mostly caught in the Aegean and Mediterranean Seas (Bök and Oray, 2001). Several authors (Rodriguez-Roda, 1980; 1983; Uchida, 1981; Grudtsev, 1992; Macias et al., 2005; Macias et al., 2006 a,b; Palandri et al., 2008; Valeiras et al., 2008) have investigated the age determination, length at first maturity, gonado-somatic index, sex ratio, and the spawning period. Furthermore, the studies concerning the fisheries, spawning areas, and the behavior patterns of schools have been investigated by Yoshida and Nakamura (1965), Ishida (1971), Yesaki and Arce (1994), Sabatés and Recasens (2001).

The species is a multiple spawner with asynchronous oocyte development that carried out several spawning steps by reproductive season (Niiya, 2001; Macias et al., 2005). The spawning period for *A. rochei* lasts from June to September in the Mediterranean Sea (Ehrenbaum, 1924; Uchida, 1981; Piccinetti et al., 1996; Alemany, 1997). Those studies have shown that *A. rochei* larvae are abundant in different regions in both the Western and Eastern Mediterranean basins (Ehrenbaum, 1924; Duclerc et al., 1974; Dicenta, 1975; Dicenta et al., 1983; Piccinetti and Piccinetti, 1994; Piccinetti et al., 1996). The first maturity size has been stated in 35 cm (FL) when the fish is two years old (Rodriguez-Roda, 1983). Some of these studies are fairly old and mostly from other regional observations. Modern conservation and management strategies for tuna stocks require updating and area-specific information on the reproduction biology to ascertain that the north-eastern Mediterranean Sea is a

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Abbreviations: GSI, Gonado-somatic index; **FL,** fork length; **TW,** total weight.

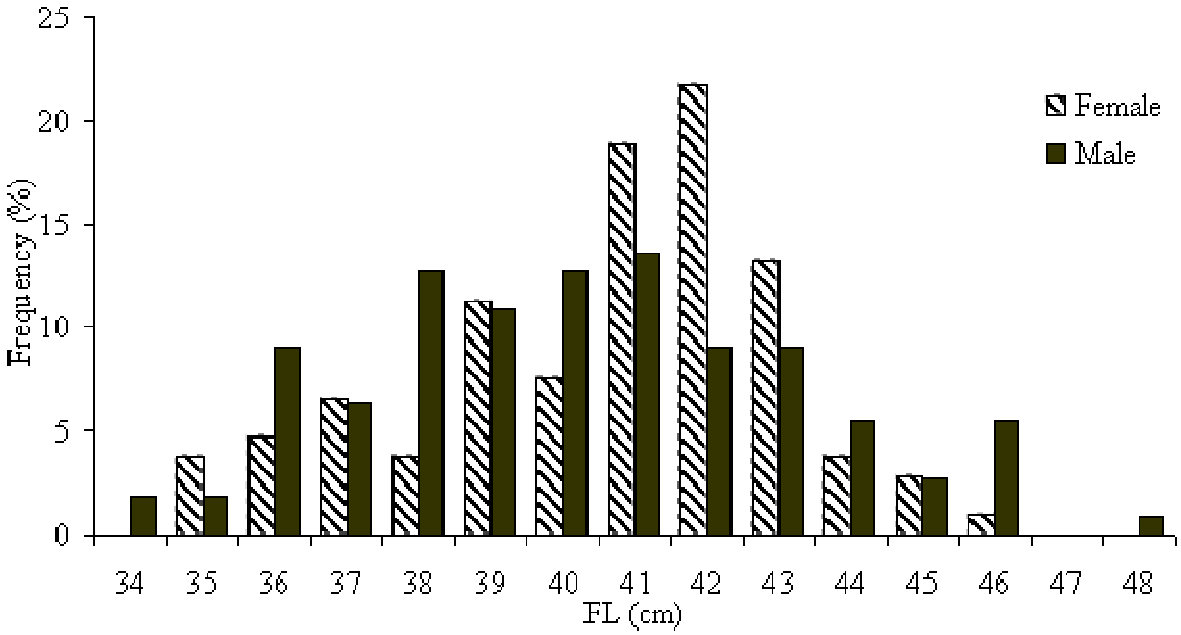

Figure 1. Length-frequency distribution of bullet tuna, *Auxis rochei* (n = 216, both sexes combined).

spawning area. There is no information regarding the reproductive biology of bullet tuna in Turkish waters; the investigation therefore aimed to determine the developmental stages of oocytes together with the seasonal cycle of sexual maturity based on the determination of the gonado-somatic index.

MATERIALS AND METHODS

Between December 2008 and December 2009, a total of 216 bullet tunas (110 males and 106 females) were caught in Turkish waters, mostly by commercial purse-seiners and trolling lines used by artisanal fishermen. For each specimen, fork length (FL) and total weight (TW) were determined. Each pair of gonads were removed and identified macroscopically as male or female and weighed (± 0.01 g), then a section of 0.5 cm width from the central part of only one single gonad was taken and preserved in 10% buffered formalin and stored. A portion of each section preserved was washed in buffer solution, dehydrated in ethanol and n-butanol series, and embedded in paraffin. The samples were sectioned at approximately 5 µm with a microtome, and mounted on slides. Then, the preparations were stained with haematoxylin-eosin and examined in a light microscope. Furthermore, the diameters of the oocytes were measured. Maturity stages were classified according to Tyler and Sumpter (1996), Coward and Bromage (1998), and Susca et al. (2001). Finally, to identify the spawning period, the gonado-somatic index, GSI = [Gonad weight (GW) /(Total weight (TW) – Gonad weight (GW))]*100 (Gibson and Ezzi, 1980), and the condition factor, K = [(Total weight (TW) – Gonad weight (GW))/Fork length $(FL)^3$]*100 (Htun-Han, 1978) were calculated for female specimens. Independent samples t-test was used to test for possible significant difference in mean length between males and females, and the overall sex ratio was assessed using Chi-square test (Zar, 1996). Statistical analyses were performed with SPSS 11.0 software package and a significance level of 0.05 was adopted.

RESULTS

A total of 216 bullet tunas were collected during the study period. The fork length of all individuals ranged from 34 to 48 cm (average length 40.78 ± 0.19 cm); the total weight was from 0.672 to 1.682 kg (average weight 1.160 ± 0.016 kg). Females ranged from 35 to 46.5 cm (average length 40.95 ± 0.24 cm) and males from 34 to 48 cm (average length 40.61 ± 0.29 cm). The results of independent samples t-test indicated there were no significant differences ($p > 0.05$) in mean length between males and females (Figure 1).

In this study, it was determined that 106 specimens (49.07%) were female, 110 specimens (50.92%) were male, and the sex ratio was 1:1.04, and there was no significant relation in the sex ratio according to the Chi-square test ($p > 0.05$). GSI values were calculated monthly for females (Figure 2), and peaked in June and August. In general, these values increased remarkably in the summer, during intensive reproductive activities. The condition factor (K) values calculated monthly for females were given in Figure 3.

As seen in these figures, it was found that the GSI values increased, while the condition factor showed a tendency to decrease notably in June, July, and August. Thus, there was an inverse correlation between condition factor and ovarian development.

It was also observed that an increase occured in the condition factor in September, when the reproduction activity ended. It was determined that the ovaries presented four different development stages of oocytes (Figure 4).

Of all 106 female specimens, it was found that 50

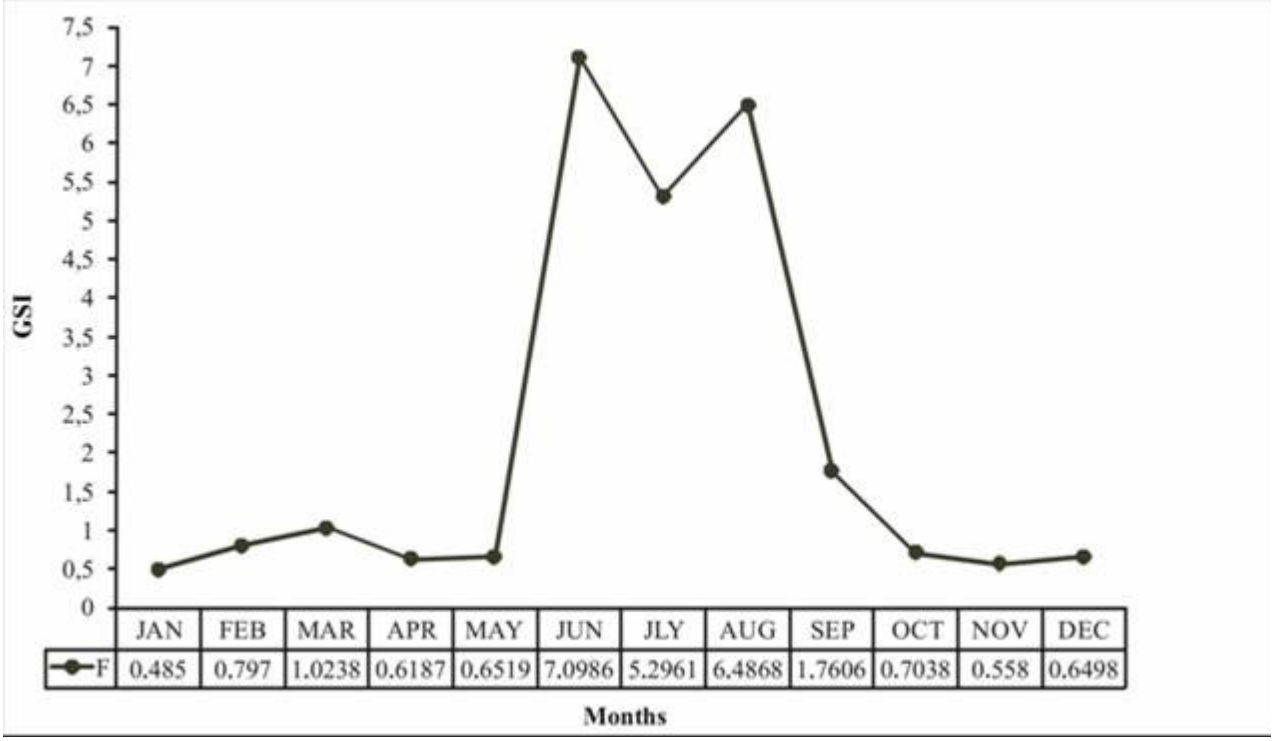

Figure 2. Monthly changes in the mean gonado-somatic index (GSI) for female bullet tuna.

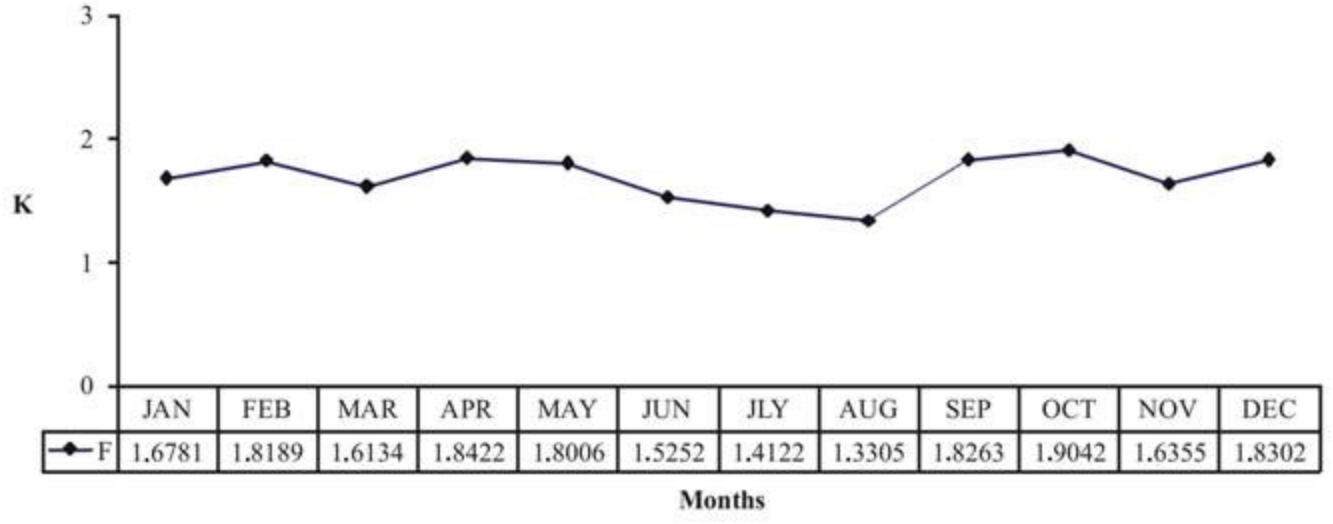

Figure 3. Monthly changes in the mean condition factor (K) for female specimens.

specimens were in stage a, 16 in stage b, 34 in stage c, and 6 in stage d. A total of 40 sexually mature females collected between May and September were in stage c and d, and were over 35 cm FL (Table 1).

Ovaries from immature fish showing only perinucleolar stage oocytes (stage a) were found remarkably in the winter, in the period between September and May. In contrast, the existence of vitellogenic oocytes (stages b and c) mostly observed between May and September showed that the reproductive activity of bullet tuna occured especially in the summer. The spawning specimens with post-ovulatory follicles (stage d) were first observed in July and August. The average GSI values increased starting in May and peaked in June, thus leading to the conclusion that these specimens reached complete sexual maturity in June.

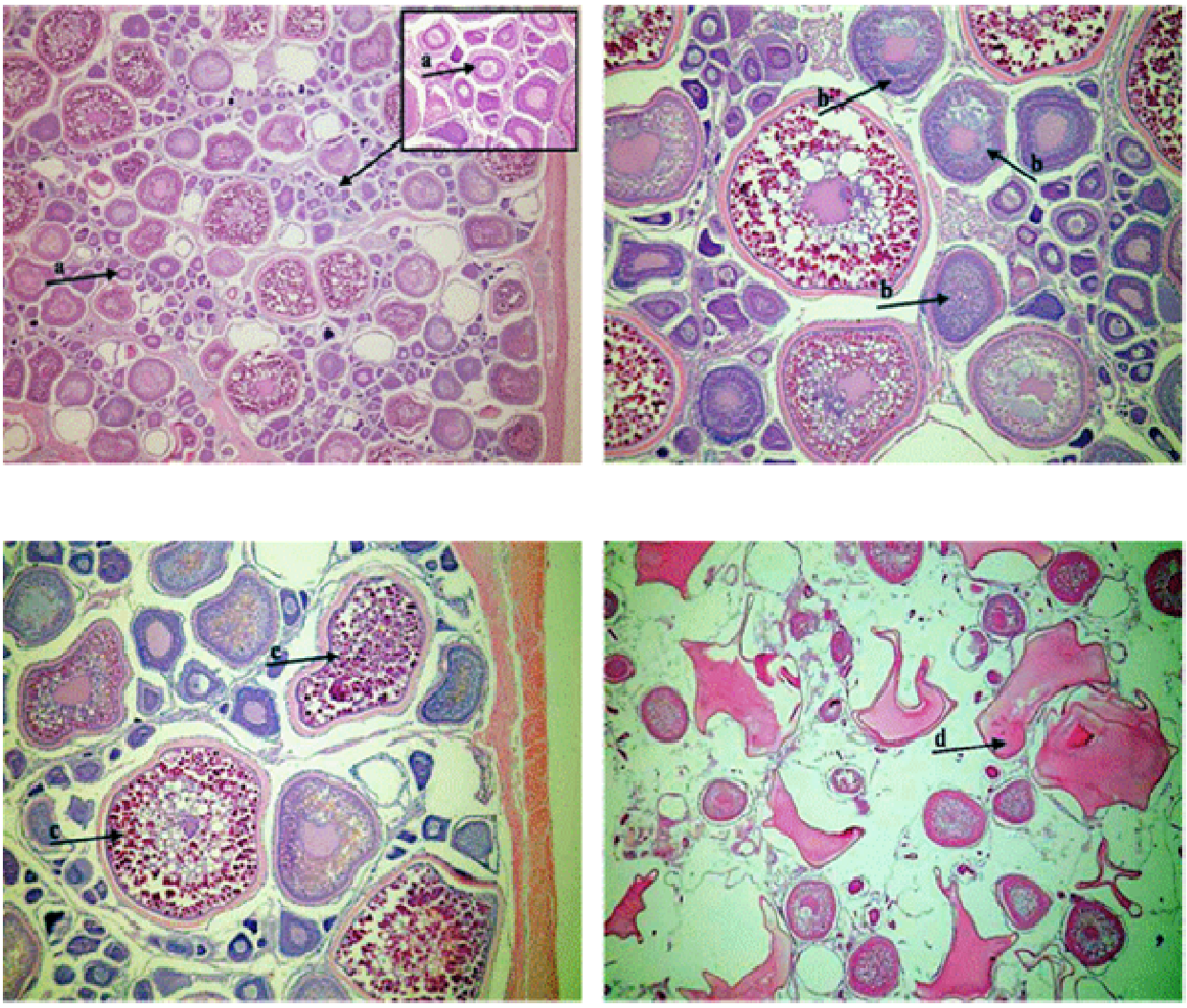

Figure 4. Micrographs from gonad cross-sections of immature stage. (a): Ovary from an immature fish showing only perinucleolar stage oocytes, oocyte diameter: 115 – 354 μm (original magnification, ×100); non-spawning mature stage (b): ovary from an active non-spawning specimen with vitellogenic oocytes with yolk granules, oocyte diameter: 223 – 495 μm ×200); spawning stage (c): ovary from spawning individual with vitellogenic oocytes with enlarged yolk granules, oocyte diameter: 388 – 683 μm (×200); postovulatory stage (d): ovary from a spawning individual with post-ovulatory follicles (×40).

DISCUSSION

This study represents the first attempt at a histological identification of oocyte developmental stages of bullet tuna caught in the Turkish Mediterranean coasts, and also deals with some other reproductive aspects of this species.

The length range of specimens in this study was similar to those found in other studies [Gibraltar Strait: 34-45 cm (Rodriguez-Roda, 1966); Turkish waters: 28.5 - 44.5 cm (Bök and Oray, 2001); South Western Spanish Mediterranean: 33.4–47 cm (Macias et al., 2005); Western Mediterranean: 25.9–47 cm (Macias et al., 2006b); Ligurian sea: 27-46.5 cm (Palandri et al., 2008); the Turkish Mediterranean coasts (present study): 34–48 cm)]. We conclude that our sampling captured a representative size distribution that is similarly reflected in most of the previous studies.

The spawning period in the Mediterranean has been reported to occur from June to September (Ehrenbaum, 1924; Piccinetti et al., 1996; Alemany, 1997; Sabatés and Recasens, 2001). According to Palandri et al. (2008), the reproductive period of bullet tuna in the Ligurian Sea occurs from May to September. Similarly, this period has been presented by Santamaria et al. (1996) for the Ionian Sea. In Turkish waters, the spawning period of bullet tuna seems to be in between May and September, but can already be significant in June, July, and August. This species is a multiple spawner with asynchronous oocyte development that carries out several spawning steps by reproductive season (Niiya, 2001; Macias et al., 2006 a). As seen in the micrographs from gonad cross-sections

Table 1. Oocyte developmental stages related to fork length (FL, cm) in immature and mature females of *Auxis rochei* as identified by histological sections.

Months	N	Oocyte developmental stages and numbers of exhibiting these stages				
		FL (cm)	Stage a	Stage b	Stage c	Stage d
January	6	34 – 41	6	-	-	-
February	10	37.5 – 42.5	10	-	-	-
March	8	41.6 – 46.7	8	-	-	-
April	9	38 – 43.5	2	7	-	-
May	6	35.8 – 39.4	1	4	1	-
June	10	35.4 – 43.5	-	2	8	-
July	12	38 – 44	-	-	8	4
August	16	37 – 48	-	-	14	2
September	11	39.4 – 43.7	5	3	3	-
October	11	39.8 – 43.9	11	-	-	-
November	3	34.4 – 38.7	3	-	-	-
December	4	36.2 – 42	4	-	-	-

FL = Fork length.

(Figure 4), the oocyte development observed in this study is an asynchronous type. Thus, it can be safely concluded that bullet tuna is a multiple spawner species.

The first maturity size has been stated as 35 cm (FL), when the fish is two years old (Rodriguez-Roda, 1983). In this study, it was determined that sexually mature specimens were always well over 35 cm FL.

Certain areas in the Mediterranean have been suggested as possible spawning sites of *Auxis* sp: Greece and Gulf of Catania (Belloc, 1954), Balearic Islands (Duclerc et al., 1974), Tunisian and Algerian waters (Postel, 1964) and off East Spanish Mediterranean coasts (Macias et al., 2005). Furthermore, the larvae of bullet tuna were found in June within the Turkish Mediterranean coasts (Oray and Karakulak, 2005). It can be inferred from the mature ovaries as well as the spawned specimens in this study that the Turkish Mediterranean coasts are the spawning sites for bullet tuna.

The oocyte development observed in micrographs from gonad cross-sections is an asynchronous type, thus it is obvious that this species is a multiple spawner. Furthermore, our results show a similar trend compared to the previous studies. In conclusion, we expect that these results will contribute to future studies, particularly in relation to the stock assessment of this species.

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