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Full Length Research Paper

Age and growth of bullet tuna, *Auxis rochei* (Risso), from the Turkish Mediterranean coasts

Abdullah Ekrem Kahraman*, Didem Göktürk and F. Saadet Karakulak

Istanbul University, Faculty of Fisheries, Department of Fisheries Technology, Laleli-Istanbul, Turkey.

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The study aims to identify the age and growth parameters of bullet tuna (*Auxis rochei*) in Turkish waters. The fish were caught from the Turkish Mediterranean coasts between December 2008 and December 2009. A total of 186 dorsal fin spines obtained from the specimens were analyzed for ageing and growth studies. The fork length of the aged individuals ranged from 34 to 48 cm for males and from 35 to 46.5 cm for the females. Fish ages ranged 1 to 5 years old and the mean lengths by age were calculated for both sexes. Growth parameter estimates were calculated from 150 cut spine sections which provided readable growth annuli by sex. The growth parameters based on standard von bertalanffy growth function are the following: for males, $L\infty$ (asymptotic length) is equal to 60.417 cm; k (growth coefficient) is equal to 0.159; t_0 (age at zero length) is equal to – 4.311; for females, $L\infty$ is equal to 49.238 cm; k is equal to 0.312; t_0 is equal to –3.011; for both sexes, $L\infty$ is equal to 57.388 cm; k is equal to 0.181and t_0 is equal to –4.155, respectively. The length and weight relationship was calculated with W equal to 0.0542 $L^{2.68}$.

Key words: Bullet tuna, *Auxis rochei*, age determination, growth, the Mediterranean sea.

INTRODUCTION

The genus *Auxis* distributes worldwide in tropical and subtropical waters. Bullet tuna (*Auxis rochei*) is an epi and meso-pelagic fish that has a seasonal coastal distribution in temperate and tropical areas including the Mediterranean (Uchida, 1981; Collete, 1986; Valeiras and Abad, 2010). This species is abundant in the Strait of Gibraltar, north coast of Africa and Spanish Mediterranean coast (Postel, 1973).

Bullet tuna is exploited mainly by surface gears and artisanal fisheries as trolling lines, handlines, small-scale longlines, and a wide variety of nets, especially traps, gill or drift nets, ring nets, beach seines, otter trawls, and purse seines. In some of these fisheries, *Auxis* species are taken incidentally as by-catch as in purse seine fisheries for yellowfin and skipjack tuna (Valeiras and Abad, 2010). The bullet tuna is one of the most abundant small tuna species in Turkish waters where has been commercially exploited especially by purse seiners (Bök and Oray, 2001).

Several investigators (Rodriguez-Roda, 1983; Uchida, 1981; Grudtsev, 1992; Bök and Oray, 2001; Macias et al., 2005; Macias et al., 2006; Palandri et al., 2008; Valeiras et al., 2008; Kahraman et al., 2010) have studied 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 the schools have been investigated by (Yoshida and Nakamura, 1965; Ishida, 1971; Yesaki and Arce, 1994; Sabatés and Recasens, 2001; Oray et al., 2005; Oray and Karakulak, 2005).

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. Almost no recent information is available for bullet tuna from the Turkish Mediterranean coasts. Therefore, this study aimed to identify the age and growth parameters of this species.

*Corresponding author. E-mail: akahraman69@gmail.com.

Abbreviations: FL, Fork length; **TW,** total weight; **L∞,** asymptotic length; **k,** growth coefficient; **t_0,** age at zero length; **Φ',** growth performance index.

MATERIALS AND METHODS

A total of 186 dorsal fin spines were collected from 216 bullet tunas

Table 1. Length-weight relationships for bullet tuna ($W = a FL^b$) (N is the sample size; min. and max. are minimum and maximum fork lengths in cm; *a* and *b* are the parameters of the length-weight relationship; SE (*b*) is the standard error of the slope *b*; and r^2 is the coefficient of determination).

Sex	N	FL (cm)		TW (kg)		Parameters of the L-W relationship			
		Min.	Max.	Min.	Max.	*a*	*b*	S.E (*b*)	r^2
All samples	216	34	48	0.672	1.682	0.054	2.685	0.11	0.73
Females	106	35	46.5	0.704	1.574	0.026	2.885	0.19	0.70
Males	110	34	48	0.672	1.682	0.087	2.554	0.13	0.77

(110 males and 106 females) caught in Turkish waters, mostly by commercial purse seiners and trolling lines used by artisanal fishermen from December 2008 until December 2009. Sampling was done according to a random stratified design covering the length range of the species in the study area. For each specimen, fork length (FL) and total weight (TW) were determined, and then the sexes were recorded.

Methodology for spine analysis was based on Ortiz de Zárate et al. (2007). The first spine of the first dorsal fin was collected from each specimen. The spine was preserved in a dry state within a paper envelope and labeled. It was cut near to the base coinciding with the bulge in the spine (the part with the greatest diameter) and close to the ridge. Series of spines were encased in a matrix of plastic resin. A cross section of 0.5 mm thick was cut using an Isomed Low Speed Saw. Two consecutive cuts were made in order to choose the best one when taking the reading. The sections were washed in a 70% ethanol solution. They were later mounted onto labelled holders and embedded in Eukitt highly transparent mounting resin.

The two sections were examined using a Leica binocular microscope with transmitted light. Spine sections were read twice by one reader and unresolved differences in readings resulted in spine elimination. Alternative pairs of a translucent band and an opaque band were considered to be a year annuli. When presented, multiple annuli and disappearance of the first annulus in older fish were carefully considered to assess the age classes.

Age length keys were produced for males, females and for the two sexes combined, and their mean lengths at age and standard deviations calculated. Von Bertalanffy growth curves were fitted to the data applying the standard Von Bertalanffy growth function. Growth parameters were computed for females and males using non-linear least square estimation.

Theoretical growth in weight was obtained by converting length to weight using the length–weight relationship for bullet tuna. Linear regression was used to determine length–weight relationships. Differences between sexes were tested with tests of homogeneity of slopes and intercepts. The hypothesis of isometric growth (Ricker, 1975) was tested with a *t*-test.

Mean lengths at age were used to estimate the parameters of the von Bertalanffy growth curve:

$$Lt = L\infty\ (1\text{-}e^{-k(t\text{-}t0)})$$

Where, Lt, length at age t; $L\infty$, the asymptotic length; *k*, constant expressing the rate at which length reaches $L\infty$ and t_0, hypothetical age at which fish would have zero length.

The growth performance indexes (Φ') = lnk+2 ln $L\infty$, was computed (Sparre et al., 1989) to compare bullet tuna growth parameters of this study with those estimated in other studies from the Atlantic.

RESULTS

A total of 216 of bullet tuna 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 FL 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 female: male ratio was calculated as 1:1.04 F/M.

The relationship between FL (cm) and weight (kg), length and weight characteristics for bullet tuna are shown in Table 1. The *a* and *b* parameters in the length–weight relationship were calculated as 0.054 and 2.68, respectively. The relationships were highly significant ($p<0.001$). Negative allometric growth was observed for males and all individuals. Results from t-test indicated no significant differences ($p>0.05$) between the slopes (*b*) of the L-W relationship between females and males for bullet tuna. Isometric growth was observed for females. The values of *b* for males and both sexes were significantly different from 3 indicating negative allometric growth ($p<0.05$). The FL-W relationships are also represented in Figure 1.

Age estimations from 150 spine sections were obtained from 186 bullet tuna, ranging in fork length from 34 to 48 cm and from 672 to 1682 g in total weight. Only 36 spines that represent 19.36% of the sample were considered unreadable and rejected from the analysis. The obtained size-age key is presented in Table 2. Estimated ages ranged from 1^+ to 5^+ years. The age 2^+ and 3^+ were the most abundant in the sample. No specimens equal to or younger than 1 year old were observed. For females, the estimated ages ranged from 1^+ to 5^+ years, with 3^+ as the most abundant age; males ranged from 1^+ to 5^+ years, with 2^+ as the most abundant (Figure 2).

Mean back-calculated fork lengths-at-age showed rapid growth during the first year of life (Figure 3). The von Bertalanffy growth parameters were estimated as: L_∞ equal to 57.388 cm; *k*, 0.181 years^{-1}; t_o, –4.155 years for all individuals used for ageing; L_∞ equal to 49.238 cm; *k*, 0.312 years^{-1}; t_o, –3.011 years for females, and L_∞ equal to 60.417 cm; *k*, 0.159 years^{-1}; t_o, –4.311 years for males (Table 3). Back-calculated lengths-at-age were very close to predicted lengths.

DISCUSSION

In this study, age and growth of bullet tuna were estimated

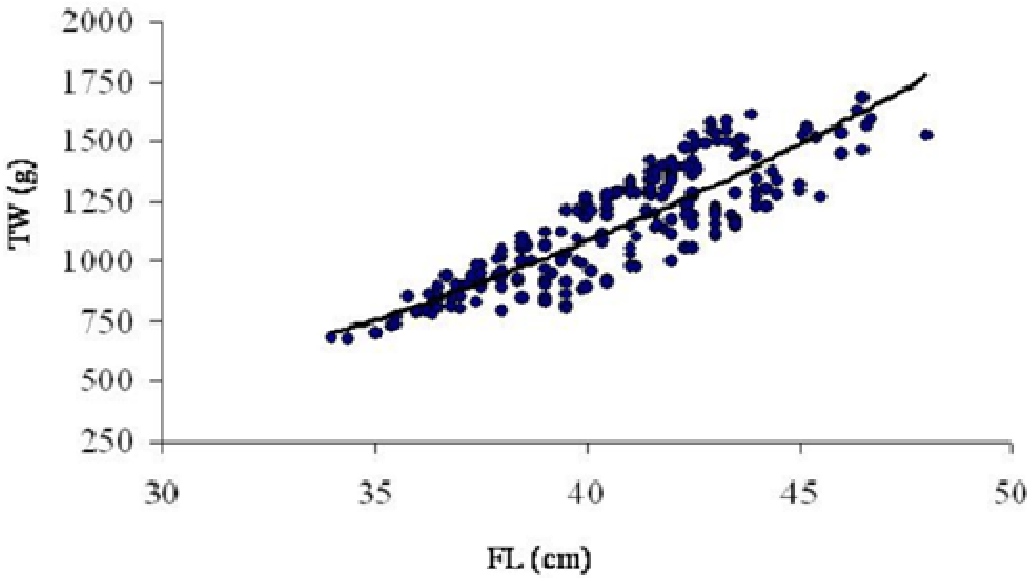

Figure 1. Length–weight relationship of *Auxis rochei* (N = 216, both sexes combined; TW = total weight; FL = fork length).

Table 2. Age-length key for all individuals of bullet tuna.

FL (cm)	1+	2+	3+	4+	5+	Total
34.0 - 34.9	2					2
35.0 - 35.9	3	2				5
36.0 - 36.9		12				12
37.0 - 37.9		8				8
38.0 - 38.9		9	1			10
39.0 - 39.9		15	2			17
40.0 - 40.9		7	9			16
41.0 - 41.9		3	19			22
42.0 - 42.9		2	23			25
43.0 - 43.9			13	5		18
44.0 - 44.9			2	4		6
45.0 - 45.9				3	1	4
46.0 - 46.9				1	3	4
47.0 - 47.9						0
48.0 - 48.9					1	1
Total	5	58	69	13	5	150

using spines of the first dorsal fin. In comparison with the use of the hard parts such as otoliths and vertebrae, spine sections as the structure to estimate age have the advantage of requiring easy sampling and easy reading (the growth rings stand out clearly), and samples are easily stored for future reexamination (Compean-Jimenez and Bard, 1983). Because of these advantages, spines of the first dorsal fin were widely used in the previous studies regarding age and growth determi-nations of the Scombrids (Sun et al., 2000; Stequert and Conand, 2004; Zaboukas and Megalofonou, 2007; Valeiras et al., 2008).

The size range of specimens studied was similar to those found in other studies, for example, Gibraltar Strait: 34-45 cm FL (Rodriguez-Roda, 1966); South Western Spanish Mediterranean: 33.4 – 47 cm FL (Macias et al., 2005)].

The fork length and total weight relationship of bullet tuna determined in various regions are given in Table 4. When compared with the other studies, *a* and *b* values estimated in this study are different. Such differences might be attributed to environmental characteristics and feeding capacity of the sampling areas. Furthermore, the

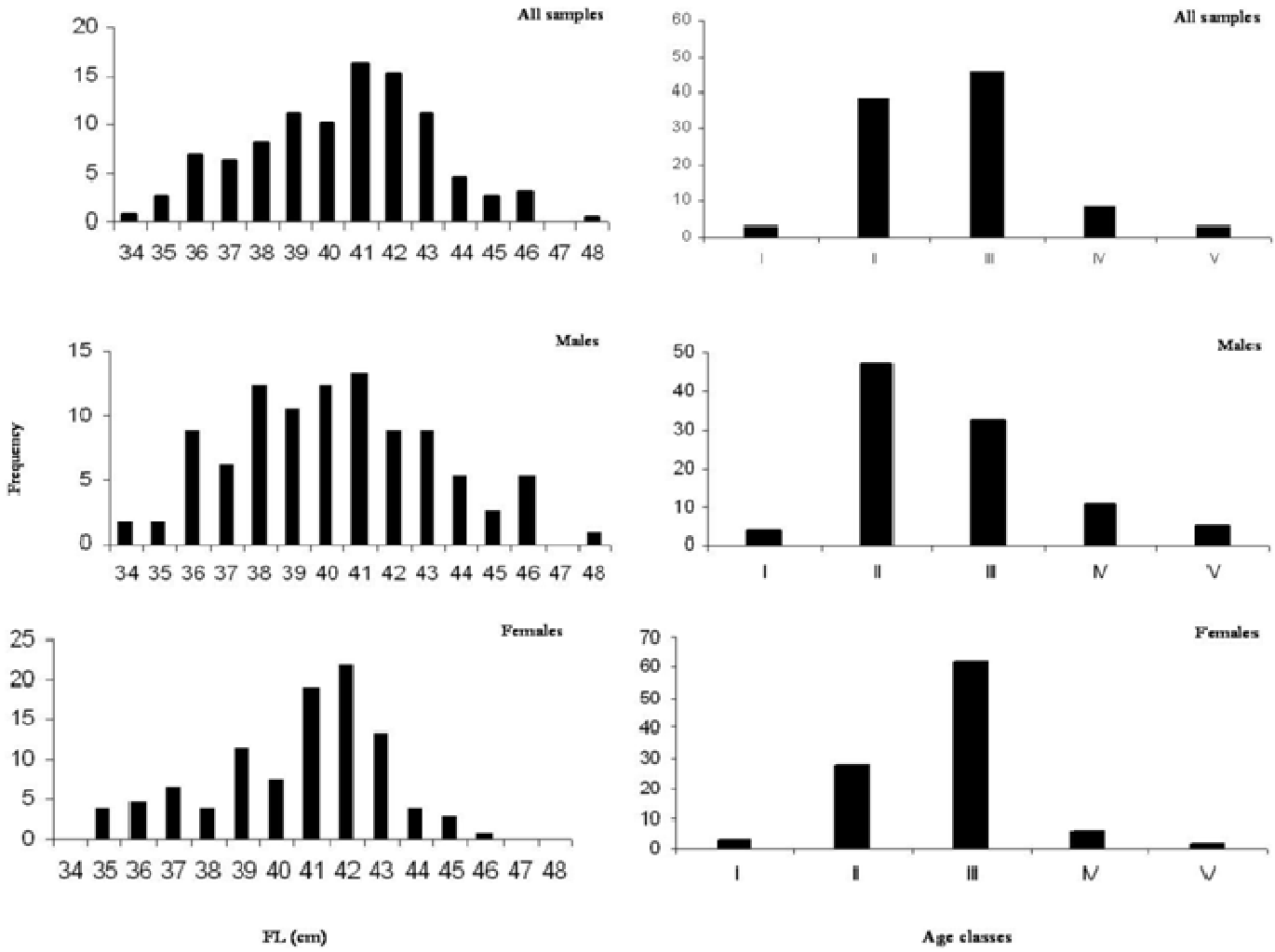

Figure 2. Fork length (FL) and age frequency distributions of bullet tuna sampled in the eastern mediterranean Sea from December 2008 to December 2009.

Figure 3. Von bertalanffy growth curve for bullet tuna sampled in the eastern Mediterranean sea.

Table 3. The von Bertalanffy growth parameters for bullet tuna.

Sex	N	k	t_o	L_∞	W_∞
All samples	150	0.181	–4.155	57.388	2.850
Females	69	0.312	–3.011	49.238	1.983
Males	81	0.159	–4.311	60.417	3.080

Table 4. *Auxis rochei*: comparison of fork length (FL, cm) and total weight (TW, g) relationship determined in various regions and the intercept for the respective equations (*a*, intercept of the relationship provided by source; *b*, slope of the relationship; *r*, correlation coefficient; n, number of specimens).

Reference	Regions	n	FL (cm)	*a*	*b*	r
Rodríguez- Roda (1966)	Gibraltar Strait	744	34.0 - 45.0	0.00001005	3.129	-
Bök and Oray (2001)	Turkish Medit. and Aegean Sea	936	28.5 - 44.5	0.0076	3.24	0.971
de la Serna et al. (2005)	Spanish Medit.	1064	31.0 - 44.0	0.002182	3.561	0.990
Machias et al. (2005)	S.Western Spanish Medit	177	33.4 - 47.0	$1.60943E^{-5}$	3.003	-
Macías et al. (2006)	Western Medit.	458	25.9 - 47.0	0.00559	3.29	0.860
Palandri et al. (2008)	Ligurian Sea	83	27.0 - 46.5	0.0014	3.675	0.980
Present study	Turkish Medit.	216	34.0 - 48.0	0.0542	2.685	0.733

Table 5. Von bertalanffy growth parameters and growth performance indexes (Φ') for bullet tuna from different regions ($L\infty$: asymptotic mean length; *k*: growth rate; t_o: hypothetic age at zero length).

Reference	Area	$L\infty$	*k*	t_o	Φ'
Grudstev (1992)	E. Atlantic	41.500	0.320	-0.830	6.312
de la Serna et al. (2005)	W.Mediterranean	73.200	0.447	-1.020	7.781
Valeiras et al. (2008)	W. Mediterranean	44.041	0.700	-0.139	7.214
Bök and Oray (2001)	E. Mediterranean	47.762	0.292	-2.365	6.501
Present study	E. Mediterranean	57.388	0.181	-4.155	6.390

length-weight relationship in fishes is affected by a number of factors such as gonad maturity, sex, diet and stomach fullness, health and preservation techniques (Tesch, 1971).

Rodriguez-Roda (1983) studied vertebrae of 27 bullet tuna from Atlantic area near Gibraltar strait and found four age groups (1 to 4). Valerias et al. (2008) studied by dorsal spines and found four age groups (2 to 5) for western Mediterranean Sea. Bök and Oray (2001) also studied age and growth of bullet tuna by otoliths and dorsal spines and found five age groups (0 to 4) for the Aegean Sea and the eastern Mediterranean. In this work, we estimated five age groups (1 to 5) by using spines of the first dorsal fin. We obtain similar results on growth parameters and mean lengths at age of bullet tuna in eastern Mediterranean compared to those of western Mediterranean Sea (Table 5).

Overall growth performance calculated from the length growth parameters applying the Φ' values implied that there was no significant differences (t-test; *P>0.05*, N=4) between bullet tuna from the NE Atlantic, West Mediterranean and East Mediterranean. However, the computed L_∞ value of bullet tuna from the Mediterranean seems to be higher than those from East Atlantic. The calculated values of Φ' is fairly similar (Table 5).

International Commission for conservation of Atlantic Tunas (ICCAT) is responsible for the management of tuna and tuna like species in the Mediterranean. There are no ICCAT regulations directly aimed at managing the Mediterranean bullet tuna stock. However, there is a closing season for bullet tuna (between 15 April and 31 August) in Turkish waters. In conclusion, it is necessary to apply the common fisheries management strategies for commonly shared resources in the Mediterranean Sea. In this respect, we hope that our results will contribute to the stock assessment studies on this species to be carried out in future.

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