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Growth parameters and mortality of bluefish (*Pomatomus saltatrix* Linnaeus, 1766) from Gallipoli peninsula and Dardanelles (northeastern Mediterranean, Turkey).

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ABSTRACT

In this study, the growth parameters of the bluefish, *Pomatomus* saltatrix (Linnaeus, 1766), were studied in Gallipoli Peninsula and Dardanelles (northeastern Mediterranean, Turkey) between November 2008 and October 2009. The length-weight relationship was calculated as $W=0.0082TL^{3.02}$ for females, $W=0.0081TL^{3.03}$ for males and $W=0.0081TL^{3.03}$ for all samples. Growth parameters of the populations were L_∞= 86.8 cm, k=0.15 year^{-1}, t_0=-1.40 for females; L_∞=89.1 cm, k=0.16 year^{-1}, t_0=-1.46 for males and L_∞=88.3 cm, k=0.15 year^{-1}, t_0=-1.43 for all samples. Total mortality rate (Z), natural mortality rate (M), fishing mortality rate (F) and exploitation rate (E) of the bluefish were 0.90 year^{-1}, 0.21 year^{-1}, 0.69 year^{-1} and 0.76 year^{-1}, respectively.

Introduction

Bluefish (*Pomatomus saltatrix* Linnaeus, 1766) is a migratory marine species with a large geographical distribution which extends throughout most of the world, with the exception of the northern and mid-Pacific Ocean, generally inhabiting temperate and warm continental shelf waters of all oceans (Wilk, 1977). This species is found all along Turkish coasts migrating via the Aegean Sea northwards from the Mediterranean in spring and returning south in early autumn (Ceyhan et al., 2007). It is one of the most important fish species of commercial fisheries in all Turkish seas and caught by the handlines, encircling nets, gillnets and purse-seiner. Total catches were averagely 4744 t in 2010 (TÜİK, 2011). The maximum recorded catch was 32.184 t in 1982.

Because of its worldwide commercial importance, there are different studies on age, growth, reproduction (Türgan, 1959; Lassiter, 1962; Wilk, 1977; Alpbaz and Kınacıgil, 1988; Krug and Haimovici, 1989; Barger, 1990; Lucena and O'Brien, 2001; Salerno et al., 2001; Dhieb et al., 2006; Ceyhan et al., 2007; Özdemir et al., 2009; Robillard et al., 2009), diet (Lucena et al., 2000; Harding and Mann, 2001), exploitation and mortalities (Akyol and Ceyhan, 2007), fishery (Ceyhan and Akyol, 2005; Sümer et al., 2010), heavy metal contaminaion (Türkmen et al., 2009), length-weight relationship (Torres, 1991; Bernardes and Rossi-Wongtschwski, 2000; Haimovici and Velasco, 2000; Harrison, 2001), otolith length (Ceyhan and Akyol, 2006; Cengiz et al., 2012), morphometric and meristic variation (Turan et al., 2006) and stock structure (Graves et al., 1992) of *P. saltatrix*.

The basic biological information is needed to undergird the sustainable management of the species. Hence, the objectives of the present study were to estimate age, growth, sex ratio, length distribution, length-weight relationship of the bluefish and to recommend precautions required for the sustainability of stock by comparing these results with previous studies.

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Material and methods

Bluefish samples were collected between November 2008 and October 2009 using handlines, encircling nets and gill nets from Gallipoli Peninsula and Dardanelles at depths ranging from 0 m to 40 m (Figure 1.).

Figure 1. Map of the study area.

Samples were measured to the nearest cm (total length), weighed to the nearest g (total weight). The length-weight relationship was calculated using the equation $W = aL^b$, where W is the weight, L is the total length and a and b are the parameters of the equation (Le Cren, 1951). The type of L-W relationship was identified by Student's t-test. The sex ratio (female: male) was calculated as the number of males divided by the number of females. The sex ratio was analyzed using the chi-square test (X^2). The differences in mean total lengths and total weights of the sexes were estimated by the Student's t-test. The reproductive period for bluefish began in early spring, peaked in July and extended until August in Marmara region (Ceyhan et al., 2007). Therefore, to compute the parameters of the von Bertalanffy growth equation, 1 July was chosen as the conventional birth day for all individuals.

The otoliths were used for age determination because they revealed much better between-reader agreement (92%) than scales (67%) or vertebrae (33%) (Barger, 1990; Sipe and Chittenden, 2002). Ages were determined with three independent readers by reading the sagittal otoliths. The otoliths were removed, wiped clean, and stored dry inside U-plates. The otoliths being placed in glycerol were examined under reflected light using a binocular microscope. The otoliths belonging to older fish were embedded in polyester molds, and two or three thin sections (0.1 mm) were cut along a transerve plane through the focus of the otolith by an Isomet lowspeed saw (Metin and Kınacıgil, 2001).

The von Bertalanffy growth equation was calculated according to $L_t = L_\infty [1 - e^{-k(t - to)}]$ for TL, where L_t is the fish length (cm) at age t, L_∞ is the asymptotic fish length (cm), t is the fish age (year), t_0 (year) is the hypothetical time at which the fish length is zero, k is the growth coefficient ($year^{-1}$) (Sparre and Venema, 1992). The growth performance index (Φ') was estimated in order to compare the values of the growth parameters obtained in the present paper with those reported by other authors for the same species. This index was calculated as follows:

$\Phi' = \log(k) + 2\log(L_\infty)$ (Pauly and Munro, 1984).

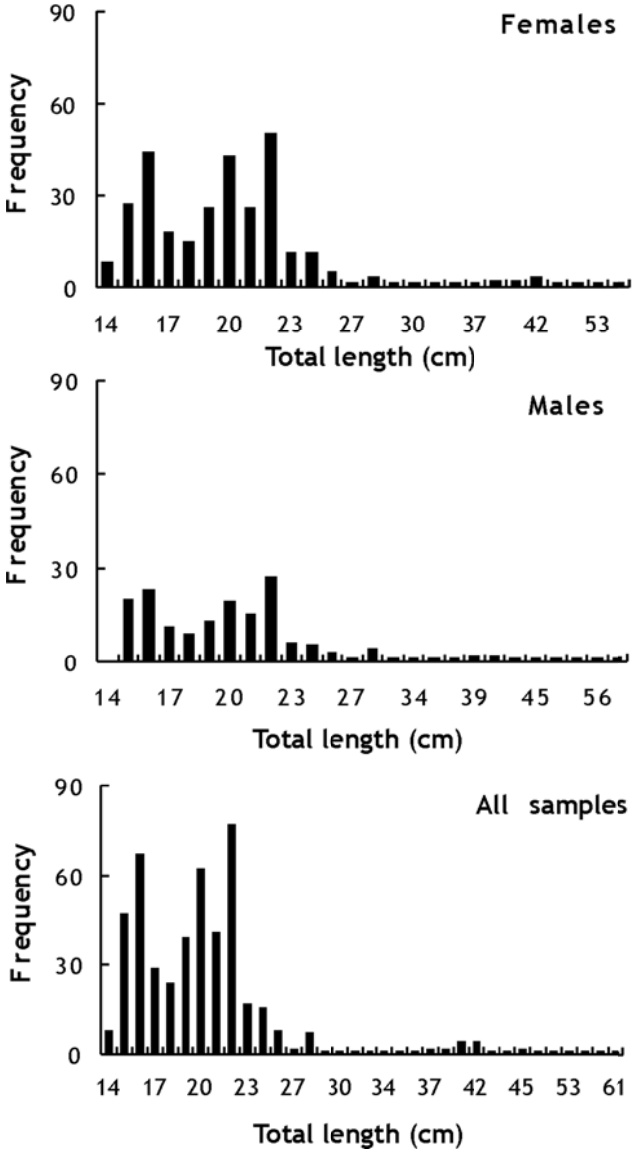

Figure 2. The length-frequency distributions for females, males and all samples of *P. saltatrix* from Gallipoli Peninsula and Dardanelles.

Total mortality rate (Z) was estimated from linearized catch curve based on age composition data (Sparre and Venema, 1992). Natural mortality rate (M) was computed from Pauly (1980)'s multiple regression formula:

M = 0.8*exp (-0.0152 -0.279 *ln L_∞ + 0.6543*ln K + 0.463*ln T), where L_∞ and K are the parameters obtained from the von Bertalanffy growth equation and T°C is the annual mean water temperature at the study locality. Fishing mortality rate (F) was estimated from F = Z - M, and the exploitation rate (E) from E = F / Z.

Results

In this study, a total of 673 specimen was collected between November 2008 and October 2009 using handlines, encircling nets and gill nets off Gallipoli Peninsula and Dardanelles at depths ranging from 0 m to 40 m. The otoliths of 645 individuals were successfully extracted and they were read for age determination by three independent readers. Agreement was achieved for 473 otoliths. The between readers or because the otoliths were impossible to read. For this reason, the other individuals were not further considered.

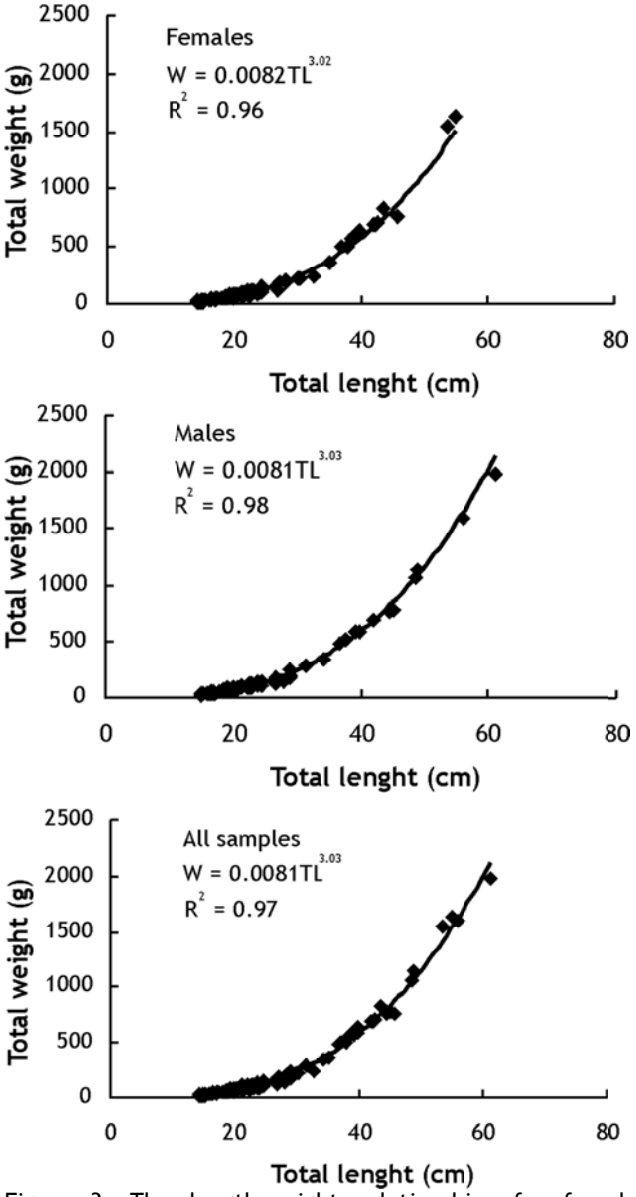

Figure 3. The length-weight relationships for females, males and all samples of *P. saltatrix* from Gallipoli Peninsula and Dardanelles.

Of the 473 specimens, 304 were females, 169 were males. Fish size ranged from 14.3 to 61.2 cm (TL) and weighed between 22,90 and 1980,00 g. The mean total length and total weight of all samples were calculated as 21.1 ± 0.30 (14.3 - 61.2) cm and 115.74 ± 9.09 (22.90 - 1980.00) g, respectively. The mean total lengths and total weights of the females and males were 20.8 ± 0.33 (14.3 - 55.1) cm, 104.81 ± 9.50 (23.01 - 1634.20) g and 21.7 ± 0.58 (15.0 - 61.2) cm, 135.41 ± 18.80 (22.90 - 1980.00) g, respectively (Figure 2). No significant difference was statistically found between mean total lengths and total weights of sexes ($P > 0.05$; $P = 0.170$). The sex ratio was calculated as 1:0.56 (F:M). The chi-squared test showed that there was significant difference in the sex ratio ($P < 0.05$).

It was calculated the length-weight relationships for females, males and all samples, separately, as $W = 0.0082TL^{3.02}$ ($r^2 = 0.96$), $W = 0.0081TL^{3.03}$ ($r^2 = 0.98$) and $W = 0.0081TL^{3.03}$ ($r^2 = 0.97$) (Figure 3.). The *b*-values and *t*-test results indicated isometric growth for females, males and all samples. The *b*-values showed no significant difference from 'value 3' for females, males and all samples ($P > 0.05$).

Age distribution ranged from 0 to VI years. Year class 0 (67.0%) was dominant, followed by year classes I (27.1%), II (3.0%) and III (1.7%) and IV, V and VI (0.4%) (Table 1).

The von Bertalanffy growth equations were computed as L_∞=86.8 cm, k=0.15 year^{-1}, t_0=-1.40 year for females; L_∞=89.1 cm, k=0.16 year^{-1}, t_0 =-1.46 year for males and L_∞=88.3 cm, k=0.15 year^{-1}, t_0 =-1.42 year for all samples. The growth performance index (Φ') was calculated as 3.05, 3.10 and 3.07 for females, males and all samples, respectively (Figure 4).

Total mortality rate (Z) for all samples was 0.90 year^{-1} (Figure 5). The annual mean water temperature at the study locality was 12.7°C. Thus, natural mortality rate (M) was estimated as 0.21 year^{-1}. Fishing mortality rate (F) was found to be 0.69 year^{-1}. The exploitation rate (E) was calculated as 0.76 year^{-1}.

Discussion

In this study, the length range of the bluefish population varied from 14.3 to 61.2 cm (TL). The maximum fork lengths was observed by Lassiter (1962) as 81.2 cm, Wilk (1977) as 86.0 cm, Robillard et al. (2009) as 87.0 cm,

Table 1. Mean total lengths at ages for females, males and all samples of *P. saltatrix*

Age	Females			Males			All samples		
	N	%	Mean Length ± S.E Min. - Max.	N	%	Mean Length ± S.E Min. - Max.	N	%	Mean Length ± S.E Min. - Max.
0	209	68.8	18.3 ± 0.16 14.3 - 22.7	108	63.9	18.1 ± 0.22 15.0 - 22.7	317	67.0	18.2 ± 0.13 14.3 - 22.7
I	80	26.3	23.5 ± 0.20 21.2 - 29.9	48	28.3	28.9 ± 0.31 21.4 - 28.9	128	27.1	23.6 ± 0,17 21.2 - 29.9
II	8	2.6	36.3 ± 1.21 30.2 - 39.9	6	3.6	36.5 ± 1.32 31.3 - 39.8	14	3.0	36.4 ± 0.86 30.2 - 39.9
III	5	1.6	43.3 ± 0.68 42.0 - 45.8	3	1.8	44.0 ± 0.95 42.1 - 45.2	8	1.7	43.5 ± 0.53 42.0 - 45.8
IV	-	-	-	2	1.2	48.8 ± 0.20 48.6 - 49.0	2	0.4	48.8 ± 0.20 48.6 - 49.0
V	2	0.7	54.4 ± 0.75 53.6 - 55.1	-	-	-	2	0.4	54.4 ± 0.75 53.6 - 55.1
VI	-	-	-	2	1.2	58.6 ± 2.60 56.0 - 61.2	2	0.4	58.6 ± 2.60 56.0 - 61.2
	304	100	20.8 ± 0.33 14.3 - 55.1	169	100	21.7 ± 0.58 15.0 - 61.2	473	100	21.1 ± 0.30 14.3 - 61.2

S.E=Standard Error; Min=Minimum; Max=Maximum.

Salerno et al. (2001) as 88.0 cm. Furthermore, Lucena and O'Brien (2001) determined maximum length of the bluefish as 77.0 cm in gill net samples from southern Brazil. The likely reasons for these differences could be different sampling instruments, different locations and depths of sampling (Soykan et al., 2010).

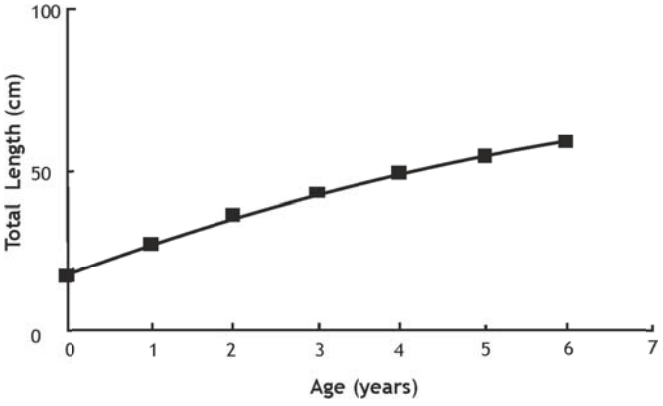

Figure 4. The von Bertalanffy growth curve for all samples of *P. saltatrix* from Gallipoli Peninsula and Dardanelles.

The length-weight relationships could be influenced by various factors such as area, gonad maturity, habitat, degree of stomach fullness, season, length range, sex, health, preservation techniques (Baganel and Tesch, 1978), number of specimens analyzed, area/season effects, and sampling duration (Moutopoulos and Stergiou, 2002),different fishing gear used (Kapiris and Klaoudaos, 2011) and size selectivity of the sampling gear (İşmen et al., 2007). Hence, the possible reasons for differences in length-weight relationships between others to this study could be related to one and more factors given above. Some of previous studies on length-weight relationship and length range for *Pomatomus saltatrix* from different locations are represented in Table 2.

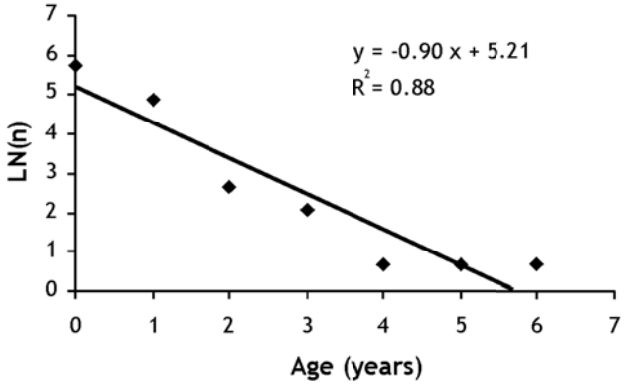

Figure 5. Age structured catch curve for estimation of total mortality (Z) for *P. saltatrix* from Gallipoli Peninsula and Dardanelles.

In present study, the age range (0-VI) is within the longevity limits observed by Krug and Haimovici (1989), except other studies. Comparable maximum ages in previous studies include age 12 (Salerno et al., 2001), age 13 (Robillard et al., 2009) and age 14 (Wilk, 1977; Türgan, 1959). Gibson (2005) underlined that maximum ages can vary widely between populations within species, specially, those that have wide distributions. In this respect, the growth of fish could be affected by environmental conditions and fishing efforts (Weatherley and Gill, 1987). The mean lengths at age for *Pomatomus saltatrix* given by various authors are showed in Table 3.

Table 2. Some of the previous studies on length-weight relationship and length range for *P. saltatrix* from different locations

References	Locality	Sex	LT	N	L_{min}	L_{max}	a	b	r^2
Alpbaz and Kınacigil (1988)	İzmir Bay	Σ	TL	400	15.0	40.5	0.0202	2.96	-
Barger (1990)	Atlantic Ocean	Σ	FL	588	-	-	0.0020	2.80	-
Barger (1990)	Gulf of Mexico	Σ	FL	611	-	-	0.0002	2.17	-
Torres (1991)	South Africa	Σ	-	-	-	-	0.0131	2.93	-
Bernardes and Rossi-Wongtschowski (2000)	Southeast Brazilian	Σ	TL	92	24.0	48.0	6.0E-0.6	3.05	0.91
Haimovici and Velasco* (2000)	Southern Brazil	Σ	TL	1771	25.1	67.6	1.712E-0.5	2.90	0.98
Haimovici and Velasco** (2000)	Southern Brazil	Σ	TL	275	8.6	25.0	6.796E-0.6	3.05	0.99
Harrison (2001)	South African	Σ	SL	85	2.6	41.2	1.105E-0.5	3.09	0.99
Lucena and O' Brien (2001)	Southern Brazil	Σ	TL	580	-	-	0.8E-0.5	3.05	0.99
Dhieb et al.(2006)	Gulf of Gabes, Tunisia	Σ	TL	-	-	-	0.0110	2.95	0.99
This study	Gallipoli Peninsula and Dardanelles	Σ	TL	473	14.3	61.2	0.0081	3.03	0.97
		♀+♂	TL	304	14.3	55.1	0.0082	3.02	0.96
			TL	169	15.0	61.2	0.0081	3.03	0.98

*Adult; **Juvenile; LT=Length Type; Min and Max=Minimum and Maksimum; N=Sample size; *a* and *b* are the parameters of the relationships: r^2 is the coefficient of determination. Σ: All samples; ♀ Females; ♂ Males.

Table 3. Mean lengths at age for *P. saltatrix* given by various authors

References	Locality	N	LT	Age Group														
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Türgan (1959)*	Marmara Sea, Turkey	2297	FL	-	16.0	30.7	41.7	52.4	52.4	57.0	72.0	76.0	78.0	80.0	82.0	83.0	85.0	86.0
Lassiter[a] (1962)	Coast of North Caroline	290	FL	-	26.6	37.6	48.4	53.5	61.2	68.2	74.1	79.2	-	-	-	-	-	-
Lassiter[b] (1962)	Coast of North Caroline	154	FL	-	14.8	30.3	41.9	48.4	-	-	-	-	-	-	-	-	-	-
Wilk (1977)*	Florida - Rhode Island	7425	FL	-	21.0	35.0	46.0	55.0	62.0	66.0	-	-	-	-	-	-	-	-
Champagnat (1983)*	Senagal	8271	FL	-	20.9	37.5	50.0	60.4	68.9	75.8	91.3	85.8	89.3	-	-	-	-	-
Alpbaz and Kınacıgil (1988)*	İzmir Bay, Turkey	400	TL	-	19.1	29.6	37.0	-	-	-	-	-	-	-	-	-	-	-
Krug and Haimovici (1989)	Southern Brazil	306	TL	19.6	35.6	43.8	50.6	56.2	60.0	61.8	-	-	-	-	-	-	-	-
Barger (1990)*	Atlantic Ocean	842	FL	-	29.0	36.1	41.5	47.3	-	-	-	-	-	-	-	-	-	-
Barger (1990)*	Gulf of Mexico	1190	FL	-	30.8	41.3	50.9	57.6	62.7	67.5	71.5	76.6	-	-	-	-	-	-
Lucena and O' Brein (2001)*	Southern Brazil	1159	TL	-	21.4	35.1	45.1	50.6	55.4	61.5	64.7	-	-	-	-	-	-	-
Ceyhan et al. (2007)	Marmara Sea, Turkey	1114	FL	14.4	19.5	27.5	33.3	-	-	-	-	-	-	-	-	-	-	-
This study	Gallipoli Peninsula and Dardanelles	473	TL	18.2	23.8	36.8	43.5	48.8	54.4	58.6	-	-	-	-	-	-	-	-

[a]Spring spawned; [b]Summer spawned; LT=Length Type; TL=Total Length; FL=Fork Length; * from Ceyhan (2005).

Table 4. Comparision of growth parameters and growth performance indices obtained from previous studies for *P. saltatrix*

References	Locality	Method	L_∞	k	t_0	Φ'
Lassiter[a] (1962)	Coast of North Caroline	Scales	67.5	0.34	-0.25	3.19
Lassiter[b] (1962)	Coast of North Caroline	Scales	128.5	0.10	-1.37	3.22
Wilk (1977)	Florida - Rhode Island	Scales	87.9	0.24	-0.11	3.27
Champagnat (1983)	Northwest Africa	-	104.4	0.18	-0.52	3.29
Krug and Haimovici (1989)	Southern Brazil	Scales	66.2	0.39	-0.32	3.23
Barger (1990)	Atlantic Ocean	Otoliths	101.9	0.10	-2.49	3.02
Barger (1990)	Gulf of Mexico	Otoliths	94.4	0.18	-1.03	3.21
Lucena and O' Brein (2001)	Southern Brazil	Scales	75.4	0.26	-0.15	3.17
Salerno et al. (2001)	Northeast coast of United State	Scales	87.2	0.26	-0.93	3.30
Dhieb et al. (2006)	Gulf of Gabes. Tunisia	Scales	48.3	0.20	-0.99	2.67
Ceyhan et al. (2007)	Marmara Sea, Turkey	Otoliths	51.0	0.23	-1.26	2.78
Özdemir et al. (2009)	Black Sea, Turkey	Length frequency	30.9	0.21	-	2.30
Robillard et al.(2009)	East coast of United State	Otoliths	82.1	0.28	-0.74	3.28
This study	Gallipoli Peninsula and Dardanelles	Otoliths	88.3	0.15	-1.42	3.07

[a]Spring spawned; [b]Summer spawned

In general, the differences in length at age and growth parameters between different areas can probably be attributed to a combination of sample characteristics (sample sizes and range of sizes), geographical differences, ageing methodology used (Monterio et al., 2006), incorrect age interpretation (Matić-Skoko et al., 2007). Champagnat (1983) suggested that differences in length at first maturity could lead to differences in growth parameters. The size, quantity and quality of food and water temperature affect the growth parameters of a population (Santic et al., 2002). Furthermore, the gear selectivity can influence the estimates of growth parameters (Ricker, 1969). The *t*-test showed no significant differences between the growth performance indices from other areas ($P > 0.05$). The comparison of growth parameters and growth performance indices obtained from previous studies for *Pomatomus saltatrix* are given in Table 4.

Table 5. Some of earlier studies concerning mortality rates of *P. saltatrix* from different localities.

References	Locality	Z	M	F	E
Wilk (1977)*	Florida - Rhode Island	-	0.36	-	-
Champagnat (1983)*	Senegal	-	0.37	-	-
Salerno et al. (2001)*	Northeast coast of United State	-	0.30	-	-
Akyol and Ceyhan (2007)	Marmara Sea, Turkey	0.96	0.36	0.60	0.62
Özdemir et al. (2009)	Black Sea, Turkey	1.35	0.52	0.83	0.62
This study	Gallipoli Peninsula and Dardanelles	0.90	0.21	0.69	0.76

Z=Total mortality rate; M=Natural mortality rate; F=Fishing mortality rate; E=Exploitation rate
* from Özdemir et al. (2009)

The discrepancies between the mortality rates from different localities can probably be attributed to various factors such as different ecological conditions and intensive fishing activities between the localities and unequal precision of employed various methods (Joksimović et al., 2009). Some of earlier studies concerning mortality rates of bluefish from different localities are represented in Table 5.

As a result, this work reached new findings on the length-weight relationship, age, growth, sex ratio, length distribution of the bluefish. Akyol and Ceyhan (2007) stated that younger individuals from the landings were the evidence of heavy fishing pressure on bluefish in the Sea of Marmara. Similarly, our findings indicated that younger individuals were existed and exposed to heavy fishing pressure. The minimum landing size (MLS) for *P. saltatrix*. is 20.0 cm in the Turkish Fishery Regulations. In the light of these results and assessments, if minimum harvest size remains as current, overfishing continues by this rate and some regulations are not implemented (higher minimum landing size, selectivity studies of the gears, fishing effort of the fleets, efficacious monitoring and surveillance systems, etc), the sustainability of stock will go under threat in the process of time. Nevertheless, although this study updated the knowledge on the biology of bluefish, further research is required on subjects where information is lacking, such as fecundity, feeding and stock structure of species for Turkish waters.

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