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PRELIMINARY ESTIMATES OF THE POPULATION PARAMETERS OF FOUR SPECIES IN THE BULGARIAN BLACK SEA COAST

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Abstract- Sex ratio, morphometric characteristics, age and growth for four fish species from Bulgarian Black Sea were examined. A total of 2013 individuals from 4 families, were caught between May 2006 and December 2010. Female: male sex ratio varied from 1:0.3 in Trachurus mediterraneus ponticus to 1:1.9 in Sarda sarda. According to the age readings, distribution varied from I to VI year. The von Bertalanffy equation and growth performance index were determined by FiSAT II software in Alosa imaculata, Engraulis encrasicolus, Trachurus mediterraneus ponticus and Sarda sarda. Asymptotic values for total length (L_∞) ranged from 82.97 cm for S. sarda to 14.60 cm for E. encrasicolus. Growth rates (k) varied from 0.4794 $year^{-1}$ for E. encrasicolus to 0.1044 $year^{-1}$ for T. mediterraneus. The data sets were limited in most cases, thus this study provides preliminary population parameters only, but for species for which information is scarce.

Keywords: Age, growth, morphometric characteristics, sex ratio

I. INTRODUCTION

Population parameters of bonito, anchovy and pontic shad are not frequently reported from species and populations along the Bulgarian coast. Such data are useful for various purposes. Examination of age and growth is very important in ichthyologic investigations, because fish growth is one of the four main factors (recruitment, natural mortality coefficient and fishing mortality coefficient) determining stock condition (Mikhailov and Prodanov, 1983). In this study report data for four species obtained by trawl fisheries in the Black Sea (Bulgarian territorial waters), where there is little or no data available in the scientific literature.

The general biology and population dynamics of the anchovy have been well researched in various countries (Özdamar, 1991; Düzgüneş and Karaçam, 1989; Erkoyuncu and Özdamar, 1989; Ünsal, 1989; Karaçam and Düzgüneş, 1990; Özdamar *et al*., 1994; Özdamar *et al*., 1995; Cihangir and Uslu, 1992; Kayalı, 1998; Avşar *et al*., 1999; Lee and Lee, 1996; Gordina *et al*., 1997; Kideys *et al*., 1999; Bellido *et al*., 2000; Mullon *et al*., 2002; Gücü, 2002, Samsun *et al*., 2004).

Scientific concern about the sustainability of horse mackerel populations have lead to several studies of the population biology and distribution of *T. mediterraneus* in Black Sea waters (Şahin *et al*. 1997; Prodanov *et al*. 1997; Yankova, 2009; Yankova and Raykov, 2009; Yankova, 2010 a; 2011; 2013 a, b,c ; Yankova *et al*. 2010 a, b; Yankova *et al*. 2013).

Regarding pontic shad (*Alosa immaculata*) many histological studies on the territory of Bulgaria have been carried out (Kolarov, 1958a; 1958b; 1960a, 1960b; 1961; 1963; 1964; 1965; 1978; 1980; 1982; 1983; 1985; 1989; Ivanov and Kolarov, 1979 and Prodanov and Kolarov, 1983) but in the recent years the studies are rare (Ciolac and

Patriche, 2004; Yankova *et al*. 2013; Rozdina *et al*. 2013). The species is vulnerable according to IUCN and Bulgarian Red Data Book (http://e-ecodb.bas.bg/rdb/bg/ vol2/ Alpontic. html; http://www. iucnredlist.org/apps/redlist/ details/907/0. It is also included in Annex 2 and 4 of the Bulgarian Biodiversity   Act   (http://www.biodiversity. bg/files/File/zak_bg_biodiv.pdf).

A better understanding of the life and growth parameters of the individual species is crucial for management of these marine fishes (Musick, 1999).

Recent papers on length–weight relationship (LWR) for bonito of Bulgarian Black Sea waters include only Yankova, *et al*. (2013). Information on morphometric characteristics, sex ratio, age and growth of bonito fish species in this area is still absent. The present contribution aims to compensate for this lack of information.

II. MATERIALS AND METHODS

The investigated area includes the Bulgarian Black Sea waters in front of Cape Kaliakra, Varna, Cape Emine, Bourgas, and Sozopol (Figure 1), and the study was conducted from May 2006 to December 2010. A total of 2013 specimens from 4 fish species were collected by different fishing techniques (gill net with mesh size 2a=400 mm; trawl net with an "effective" part of the mouth of 16 m, vertical opening of 4 m, mesh size of the cod end of 6.5 mm; and trap nets). The samples were transported to the research laboratory in polythene bags containing ice blocks to prevent spoilage and were then stored in a deep freezer (-30 °C) to avert deterioration. The total length of each fish (measured to the nearest 0.1 cm) was taken from the tip of the snout to the extended tip of the caudal fin using a measuring board. Body weight was measured to the nearest gram using a balance. Sex of individuals was determined by macroscopic

observation of gonads. After omission of juvenile fish, mature fish were used to calculate female: male (F:M) sex ratio. Chi-square (χ^2) test was used to test deviations from the expected sex ratio (1:1). One-way ANOVA was used to determine difference in length (TL) and body weight between sexes. Growth was determined by fitting the von Bertalanffy growth function to length-at-age data using FiSAT II (version 1.2.2) software (Gayanilo *et al.*, 2005). This allowed a non-linear estimation of growth parameters L_∞ and k where L_∞ is the asymptotic length and k is the growth coefficient.
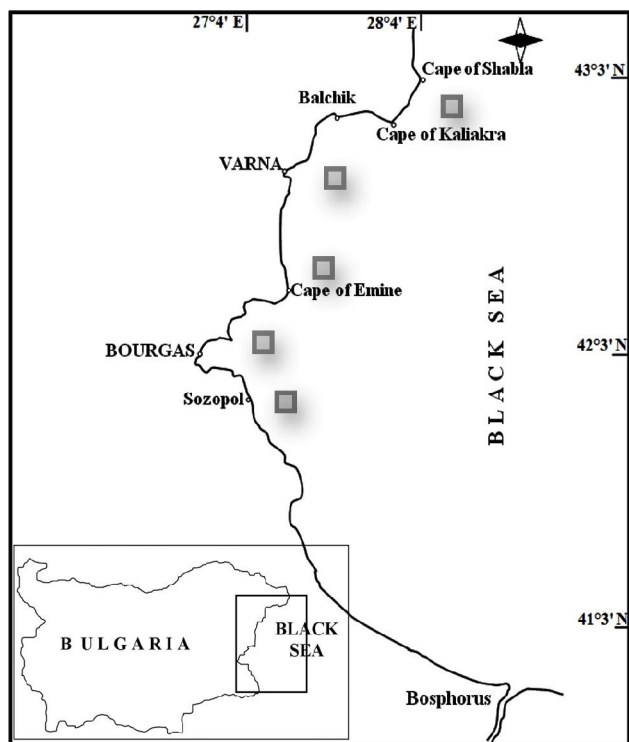

Figure 1. Sampling area.

The hypothetical time at which the length equals zero (t_0) was subsequently calculated from the known length-at-age data and estimated L_∞ and k according to the von Bertalanffy plot based on linear regression (Sparre and Venema, 1998):

$$-\ln (1\text{-Lt} /L_\infty) = - K*t_0 + K*t$$

where $-\ln (1\text{-Lt}/L_\infty)$ is the dependent variable and age (t) is the independent variable.

The growth performance index (ø') was calculated using FiSAT II (version 1.2.2) software according to the equation (Sparre and Venema, 1998):

$$ø' = \log_{10} (K) + 2 \log 10 (L_\infty)$$

where K is the growth coefficient and L_∞ is the asymptotic length.

The present study used otoliths to determine age (for *E.encrasicolus*, *T.mediterraneus, A. imaculata* and *S.sarda*) which was determined from otolith rings. Otoliths removed from the fish were stored dry in paper envelopes, and were then examined in glycerin under a digital microscope (Microbiotest, Ltd.). Two independent observations of each sample were performed with reflected lights and unreadable otoliths were eliminated from age determination.

III. RESULTS

Mean ± S.E. values for total length, body weight and sex ratio in investigated fish species are presented in Table 1. One-way ANOVA showed that differences in total length and body weight between sexes were statistically significant in *S.sarda* (P=0.019, P=0.022, respectively). Chi-square (χ^2) analysis showed that female: male sex ratio was significantly different from the expected sex ratio (1:1) in *S. sarda* (χ^2 =8.2, P<0.05). According to the age readings, distribution varied from first year to six year (Table 2). The most dominant age groups for *A. imaculata* and *S.sarda* -II and V, for *E.encrasicolus*-II and III and for *T.mediterraneus* I and IV, respectively). The estimated growth parameters (L_∞, k) and the growth performance index (ø') are given in Table 3. The maximum estimate of asymptotic length L_∞ was observed for *S.sarda* (82.97cm), and the minimum for *E. encrasicolus* (14.60 cm). On the whole, the studied species in the Bulgarian Black Sea waters we received low values of growth rates k (<0.60 $year^{-1}$). The smallest k values were found for *T.mediterraneus* (k = 0.1044 $year^{-1}$) and *A. imaculata* (k = 0.2738 $year^{-1}$). The *S. sarda* and *E. encrasicolus* presented the growth rates k = 0.3298 and 0.4794 $year^{-1}$, respectively. The maximum growth performance (ø') estimated was 3.3565 for *S.sarda* and the minimum value was 1.6160 for *E. encrasicolus*. Fitted von Bertalanffy curves in Pontic shad, Anchovy and Bonito are presented in Figure 2.

Table 1. Length and weight (mean±S.E.) by sex and female: male (F: M) sex ratio in fish species from the Bulgarian Black Sea coast.

Species	Sex	N	BW	TL	Sex ratio
Clupeidae					
A. imaculata	♀	260	318.66±6.041	27.4±3.45	1:0.8
	♂	218	291.10±1.95	28.24±4.12	
	Total	478	302.75±2.34	26.17±5.70	
Engraulidae					
E.encrasicolus	♀	348	13.94±0.83	13.39±1.32	1:0.82
	♂	296	14.03±1.49	12.47±1.79	
	Total	644	13.58±1.63	12.13±1.17	
Carangidae					
T.mediterraneus	♀	356	22.40±2.12	14.78±3.18	1:0.3
	♂	271	27.16±1.92	12.92±2.42	
	Total	627	24.09±1.51	13.97±2.13	
Cybiidae					
S.sarda	♀	137	920±10.35	30.14±2.52	1:1.9*
	♂	264	965±6.75	39.14±1.66	
	Total	264	880±7.41	33.35±1.57	

*N - number of individuals, BW - body weight, TL - total length, * statistical significance P<0.05

Table 2. Length and weight (mean±S.E.) by age categories in fish species from the from the Bulgarian Black Sea coast.

Species		Age					
		I	II	III	IV	V	VI
Clupeidae							
A. imaculata	N	51	112	78	89	95	53
	BW	134.72±4.9	157.65±7.12	194.29±6.92	290.68±12.52	382.74±15.61	465.16±16.08
	TL	12.95±1.49	20.02±1.35	23.61±3±1.05	27.39±1.63	30.86±2.75	33.12±0.17
Engraulidae							
E.encrasicolus	N	152	181	174	137		
	BW	8.26±2.31	12.97±3.42	14.81±3.97	16.56±5.32		
	TL	10.3±1.42	11.98±0.76	12.86±0.56	13.6±1.14		
Carangidae							
T.mediterraneus	N	211	119	79	150	50	18
	BW	8.63±3.75	12.44±5.36	15.37±4.45	22.75±6.04	28.33±3.71	35.59±1.05
	TL	9.83±1.33	11.7±0.90	12.72±0.30	14.2±0.58	15.26±0.57	16.52±0.81
Cybiidae							
S.sarda	N	50	80	49	24	61	
	BW	531.25±17.72	585.64±12.39	630±19.44	715±15.41	821.43±20.86	
	TL	37.15±6.02	52.12±2.83	57.10±2.65	63.1±3.20	72±0.56	

*N – number of individuals, BW – body weight, TL – total length

Table 3. Growth parameters in the most abundant fish species from the Bulgarian Black Sea coast.

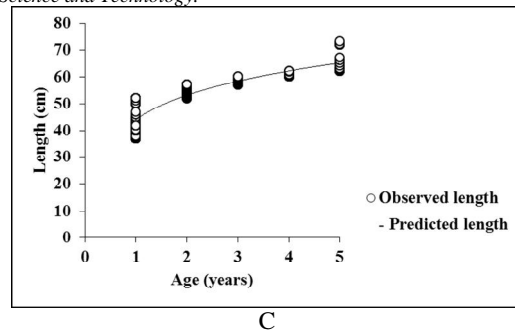| Species	L_∞ (cm)	k (year^{-1})	t_0	ø'
A. imaculata	39.82	0.2738	-0.41121	2.64
E. encrasicolus	14.60	0.4794	-1.54417	2.01
T.mediterraneus	25.97	0.1044		1.85
S.sarda	82.97	0.3298	-1.75967	3.36

*L_∞ - asymptotic length (cm), k- growth coefficient (year^{-1}), t_0- hypotethical time at which length equals zero (year), ø'- growth performance index.
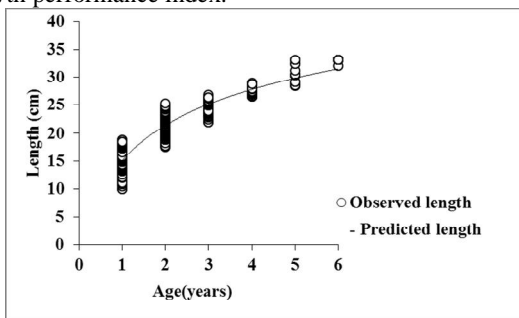
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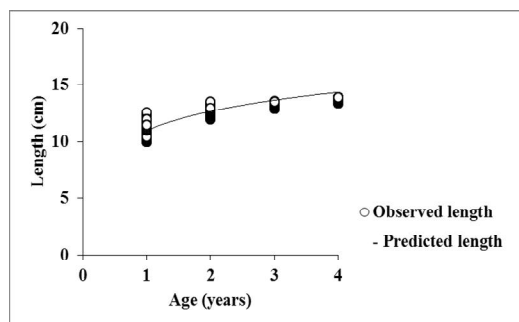
B

C

Figure 2. Fitted von Bertalanffy growth curve for: (A) Black Sea shad; (B) anchovy; (C) bonito.

Table 4. Von Bertalanffy's growth model (VBGM) parameters: L_∞ (cm), k (year^{-1}), t_0 (year).

Species	Water body and autor	L_∞ (cm)	K (year^{-1})	t_0 (year)
Pontic shad (*A. immaculata*)	Danube River (Rozdina *et al.* 2013)	35.75(cm)	0.4932	-0.3411
Pontic shad (*A. immaculata*)	Danube River (Kolarov, 1980)	57.38(cm)	0.1067	-1.727
Pontic shad (*A. immaculata*)	Danube River, Black sea (Kolarov, 1983)	40.43(cm)	0.2705	-0.218
Pontic shad (*A. immaculata*)	Black sea (Prodanov, Kolarov, 1983)	40.43(cm)	0.27	-0.218
Horse mackerel (*T. mediterraneus*)	Turkish Black Sea (Şahin *et al.* 1997)	18.35(cm)	0.4271	-0.5986
Horse mackerel (*T. mediterraneus*)	Black sea (Prodanov *et al.* 1997)	19.25(cm)	0.3481	-0.5914
Horse mackerel (*T. mediterraneus*)	Bulgarian Black Sea (Yankova & Raykov, 2006)	19.99(cm)	0.3066	-0.4912
Horse mackerel (*T. mediterraneus*)	Bulgarian Black Sea Sea (Yankova & Raykov, 2009)	17.55(cm)	0.45	-0.82
Horse mackerel (*T. mediterraneus*)	Bulgarian Black Sea (Yankova *et al.* 2011)	19.60(cm)	0.2964	-0.8768
Horse mackerel (*T. mediterraneus*)	Bulgarian Black Sea (Yankova, 2013b)	19.95(cm)	0.64	-0.55
Anchovy (*E.encrasicolus*)	Black Sea (Ozdamar *et al.* 1991)	16.77(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Karaçam & Düzgüneş 1990)	16.85(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Düzgüneş & Karaçam, 1989)	14.14(cm)	-	-
Anchovy (*E. encrasicolus*)	Turkish Black Sea (Unsal 1989)	15.73(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Ozdamar *et al.* 1994)	17.99(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Bingel *et al.* 1996)	16.16(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea(Ozdamar *et al.* 1995)	16.83(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Kayalı 1998)	17.42(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Gözler and Çiloğlu 1998)	16.97(cm)	-	-
Anchovy (*E.encrasicolus*)	Turkish Black Sea (Samsun *et al.* 2004)	15.66(cm)	-	-
Anchovy (*E. encrasicolus*)	Turkish Black Sea (Samsun *et al.* 2006)	17.07(cm)	-	-
Bonito (*S.sarda*)	Black Sea and Eastern Mediterranean (Zusser, 1954)	103	0.132	-1.8
Bonito (*S.sarda*)	Black Sea and Eastern Mediterranean (Tkacheva, 1958)	67.8	0.795	-
Bonito (*S.sarda*)	Black Sea and Eastern Mediterranean (Mayorova and Tkacheva, 1959)	81.5	0.525	-
Bonito (*S.sarda*)	Black Sea and Eastern Mediterranean (Demir, 1963)	64	0.86	-
Bonito (*S.sarda*)	Black Sea and Eastern Mediterranean (Kutaygil, 1967)	95.6	0.237	-1.24
Bonito (*S.sarda*)	Gibraltar Strait (Rey *et al.* 1986)	80.87	0.352	-1.7
Bonito (*S.sarda*)	Mediterranean, Ionian Sea (Santamaria *et al* 1998)	80.6	0.36	-1.37
Bonito (*S.sarda*)	West Mediterranean (Valeiras *et al.* 2008)	62.5	0.719	-1.21
Bonito (*S.sarda*)	Black Sea and Sea of Marmara (Ateş *et al.* 2008)	68.0	0.82	-0.39
Bonito (*S.sarda*)	Northern Aegean Sea (Cengiz, 2013)	69.8	0.76	-0.44

IV DISCUSSION

Morphometric data of horse mackerel did show differences when compared to previous research (Yankova, 2009; 2010a; 2011; 2013a, b, c) of this investigated area. Lower values in total length and body weight were observed in horse mackerel. These differences are mainly caused by differences in age categories, where less intividuals of higher age groups (V and VI) and more individuals of the lower age groups (I and IV) were caught in the present study. Total length of the horse mackerel samples ranged from 9.83 cm to 16.52 cm. This range differs from those reported by Şahin *et al.* (1997) and Genç *et al.* (1999) for horse mackerel populations of the Turkish Black Sea coast (7.4-14.5 cm) and the Eastern Black Sea (6.5-19 cm), respectively. There were however,

differences in mean length values between the investigations. Higher variability in length was observed in fish from the Turkish Black Sea coast (Şahin *et al*., 1997). According to Ozaydin *et al*. (2000), such differences may be attributed to the sampling strategy used, such as the sampling period, as well as to variations in temperature and probable differences between the trophic potential of various localities.

Kolarov (1978) has established 19 size classes for Pontic shad in the area of Silistra and Svishtov. The most abundant were 21–22 and 23–34 size classes for the both area. Other authors describe smaller number of size classes (Pavlov, 1953; Kolarov, 1964; 1980). Rozdina *et al.* (2013) reported that the biggest individual was male with length 37 cm, and weight 225 g. The specimen with the highest weight (W = 351 g) was two years old male with a length of 29 cm.

The average length and weight increases with increasing the fish age. Similar results were obtained for other populations of *A. immaculata* (Kolarov, 1960a; 1964; 1965; 1978; 1980; 1983; 1985; Ciolac and Patriche, 2004 and Ergüden *et al*., 2007).

Mean lengths of anchovy stated in our study (13.39 cm for females and 12.47 cm for males) were slightly greater than those found in other studies carried out in the Turkish Black Sea waters (Özdamar *et al*., 1991); Karaçam and Düzgüneş, 1990; Düzgüneş and Karaçam, 1989; Ünsal 1989; Özdamar *et al*., 1994; Bingel *et al*., 1996; Özdamar *et al*., 1995; Kayalı 1998; Gözler and Çiloğlu 1998; Samsun *et al*., 2004). The mean values of anchovy in our study is similar to the values recorded by Samsun *et al*. (2006), which confirmed that the females are larger than males.

The length and weight value for *S. sarda*, calculated in the present study could not be compared with those of previous studies due to the absence of available data.

The average weight increases with increasing the fish age. Similar results were obtained for other populations of *A. immaculata* (Kolarov, 1960a; 1964; 1965; 1978; 1980; 1983; 1985; Ciolac and Patriche, 2004) and of *T.meditteraneus* (Yankova, 2009; 2010a; 2010b; 2011; 2013a).

Sex ratio is an important characteristic of fish populations, given that this relationship depends on reproduction, growth or stagnation of certain species (Budakov *et al*., 1983). When comparing present sex ratio data of horse mackerel with results of Yankova *et al.* (2010 c), significant differences are observed. These differences are most likely caused by sampling periods. Mentioned authors conducted researches during spawning periods while the current research was conducted outside the spawning period and therefore there were no significant differences in sex ratio in horse mackerel. Values of growth parameter L_∞ observed in *E. encrasicolus* were slightly smaller when compared to research conducted by Özdamar *et al*., (1991); Karaçam and Düzgüneş, (1990); Ünsal (1989); Özdamar *et al*., (1994); Bingel *et al*., (1996); Özdamar *et al*., (1995); Kayalı (1998); Gözler and Çiloğlu (1998); Samsun *et al*., 2004 and Samsun *et al*., (2006). These differences in growth might be caused by differences in food supplies, competition for food between species, differences in water temperature, length, age and other (Ricker , 1975, cited from Okgerman *et al*., 2010). In this work our results on

asymptotic length (L_∞) for anchovy are more similar to estimates by Düzgüneş and Karaçam, (1989).

The asymptotic length (L_∞) values calculated of *S.sarda* for the Black Sea and Eastern Mediterranean (Zusser, 1954) and values of the studies by Kutaygil (1967) are higher than those of other studies as well as that of our study. In addition, the table shows that the L_∞ values of the studies by Tkacheva (1958), Demir (1963), Valeiras *et al*. (2008), Ateş *et al*. (2008) and Cengiz (2013) are lower than those of 10 other studies. Comparing the temp of growth with the coefficient k from the von Bertalanffy's equation the population studied by us shows the lowest growth rates (Table. 3). Fastest temp of linear growth had the population studied by (Tkacheva, 1958; Mayorova & Tkacheva, 1959; Demir, 1963; Valeiras *et al*. 2008; Cengiz, 2013; Ateş *et al*. 2008) and lowest growth rates had the population studied by (Zusser, 1954; Kutaygil, 1967).

L_∞ values of horse mackerel in the present study was 25.97 cm. Prodanov *et al*. (1997) calculated an L_∞ value of 19.25 cm for horse mackerel. Yankova and Raykov (2006) estimated the L_∞ value to be 17.55 cm. The L_∞ value given by Şahin *et al*. (1997) for the Turkish Black Sea Coast is 18.36 cm. Raykova-Petrova and Zivkov (1987) reported that the interrelationship between the growth rate and asymptotic length is inversely proportional, as in the present investigation. Zivkov *et al*. (1999) identified the biological reasons for the unsuitability of growth parameters and indices in comparing growth rates, including the absence of biological significance at such high levels of L_∞, as well as growth self-regulation and compensation. The growth coefficient k= 0.1044 year^{-1} of horse mackerel is lower than the k reported in previous studies (Yankova & Raykov, 2006; Yankova *et al*. 2011, Table 4). Şahin *et al*. (1997) determined that the growth coefficient k is a characteristic that is at least partly genetically determined and that L_∞ is phonotypical. According to Ricker (1975) this variation may be due to different stages in ontogenetic development, as well as differences in environmental conditions, length, age, sex, and gonad development. The size, quantity and quality of food, as well as water temperature are closely linked to the growth parameters of a population (Santic *et al*., 2002).

The range of L_∞ values (39.82 cm) in our study is almost similar to the values (40.43 cm) recorded by Kolarov (1983), which studied the parameters of *A. imaculata* in the Danube River of Black sea. It is also similar to the L_∞ values (40.43 cm) obtained in Prodanov, Kolarov (1983) which studied the fish species in Black Sea. Other studies have described different values of L_∞ for Pontic shad (Kolarov, 1980; Rozdina *et al*., 2013). Reasons for the differences in growth among the waters in our study are not known, but may be due to the availability of food resources. Comparing the temp of growth with the coefficient k from the von Bertalanffy's equation the population studied by us shows the lowest growth rates (Table. 3). Fastest temp of linear growth had the population studied by Rozdina *et al*. (2013) in Danube River.

Almost similar values of ø' can be observed for species such as *A. imaculata* (2.64 in this study and 2.80 in Danube River by Rozdina *et al*. (2013) and *T.mediterraneus* (1.85 in this study and calculated by Raykov and Yankova (2005) in the Bulgarian Black Sea (1.74). Among investigated species,

E. encrasicolus in the present study provided the biggest growth performance (2.01) as compared to reported by Samsun *et al.* 2004 (1.87) for the same species in Turkish waters by. For *S.sarda*, the computed value of ø' (3.36) was in the range of those reported by Tkacheva, 1958 in Black Sea (3.56).

Population parameters for *E. encrasicolus* and *S.sarda* were not yet available in the Bulgarian Black Sea and hence these results contribute to our knowledge of this species.

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