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THE STOCK PARAMETER OF ANCHOVY (*Engraulis encrasicolus*) POPULATION ON THE COASTS OF THE EASTERN BLACK SEA: REASON AND IMPLICATIONS IN DECLINING OF ANCHOVY POPULATION DURING THE 2004-2005 AND 2005-2006 FISHING SEASONS

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ABSTRACT

Some basic characteristics of anchovy (*Engraulis encrasicolus)* population in the Eastern Black Sea coasts were estimated in order to explain the differences seen in the catch of anchovy during the fishing seasons of 2004-2005 and 2005-2006. The samplings were carried out from October to April in both fishing seasons on board of commercial fishing vessels. A total of 1499 and 1485 individuals were examined during 2004-2005 and 2005-2006 fishing seasons, respectively. Weight- length relationship and von Bertalanffy growth equations were calculated as $W = 0.0101\ L^{2.7948}$ and $L_t = 16.114\ (1 - e^{-0.2919\ (t + 2.56262)})$ and $W = 0.0055\ L^{3.0425}$ and $L_t = 15.272\ (1 - e^{-0.284\ (t + 3.530)})$ for the 2004-2005 and 2005-2006 fishing seasons, respectively. Total (Z), natural (M) and fishing mortality rates (F) of 2004-2005 fishing season were calculated as Z = 0.99 year^{-1}, M = 0.45 year^{-1}, and F = 0.54 year^{-1}, respectively. Corresponding rates for 2005-2006 season, on the other hand, were calculated as Z =1.56 year^{-1}, M =0.54 year^{-1} and F =1.02 year^{-1}. There were remarkable differences in some growth parameters including weight (9.27 vs. 6.80), length (11.36 vs. 10.05), percentage of fish having a length less than 9 cm (4.39 vs. 34.08), percentage of immature individuals (4 vs. 16) and condition factor (1.02 vs. 0.49) between 2004-2005 and 2005-2006 fishing season, respectively. The changes in these parameters suggested that environmental or biological factors could not be suitable for anchovy especially during the 2005-2006 fishing season. The results of higher natural mortality rate, lower weight, length, and condition factor for the 2005-2006 fishing season and higher catches of bonito during this fishing season (12 times greater than previous season) suggested that bonito, one of the natural enemies of anchovy, could affect anchovy through predation or by preventing anchovy to freely forage in feeding areas (i.e., anti-predator behavior). In addition to the effect due to presence of bonito, extreme changes in the other biological and physical conditions could have operated together with bonito causing population parameters of anchovy to decline during the 2005-2006 fishing season.

KEYWORDS: *Engraulis encrasicolus,* Black Sea, population, mortality, *Sarda sarda*.

INTRODUCTION

Black sea, one of the world's productive ecosystems, has an important contribution to the total fishery production for Turkey and other surrounding countries. Its importance in fishery production is largely due to high abundance of anchovy (*Engraulis encrasicolus,* L., 1758), which makes up almost 70 % of the total marine fish production in the Black Sea [1]. The problems associated with stocks of this valuable fish species have always been greater and initiated many studies aiming to determine its population parameters in the Black Sea.

The total fishery production obtained from the Black Sea has shown a fluctuating pattern over the last 30 years. The fishery production including *Engraulis encrasicolus* and other commercial species had been gradually increased until 1988. But, the total fishery production of the Black Sea followed a sudden declining trend from 1989 to 1992 (Fig. 1). This trend was not only common for Turkish fisheries but also for fisheries of other surrounding countries [2, 3]. Declining in the total fishery production during this time period was frequently linked to eutrophication, over-fishing and *Minemiopsis leidyi* invasion [3, 4]. In addition to these factors, increases in the number of fishing fleets and high-tech equipment used in fishing were also claimed to be other important factors accelerating the decline in the total fishery production. Having taken some measures of conserving Black Sea ecological conditions, the total fishery production, mainly anchovy, in Turkey started to increase up to 387.000 t in 1995 [5] (Fig.1). The anchovy is not an important contributor to the total fishery production for Turkey, but also is major food source for other commercially important fishes such as Atlantic bonito (*Sarda sarda*), bluefish (*Pomatomus saltatrix)* and tuna (*Thunnus spp.)* in the Black Sea [6, 7].

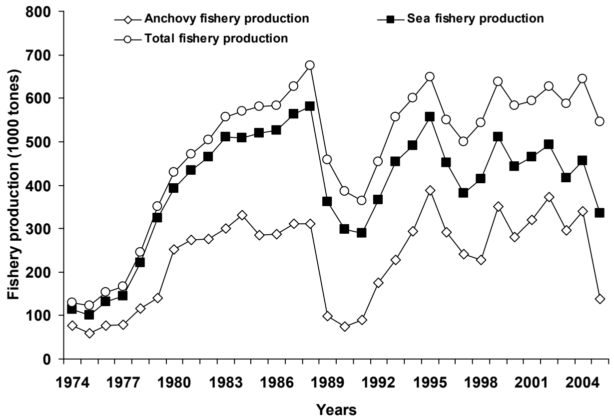

FIGURE 1 - Total fish production (catch) of Turkey between 1974 and 2003 [1].

The recent studies have reported that anchovy population is being continuously recovered although some annual fluctuations are common [8-11]. Despite its importance, its stock size, maximum sustainable yield, and the fishing effort, which are the parameters needed to determine the size of the stock to be harvested, have not been fully determined yet. Although the previously performed studies and our study aimed to determine some population parameters, there was slight difference between our study and previous ones. In this study, we aimed to compare some population parameters (length, age composition, condition factor, growth, and death rate etc.) of the 2004-2005 fishing season (thereafter "the first fishing season") and 2005-2006 (thereafter "the second fishing season") and discuss and understand the factors behind the large differences between the total anchovy production of both seasons. We specially focused on changes in biotic and abiotic factors encountered during the both fishing seasons and related those changes to changes seen in anchovy total production. We directly focused on the bonito population, one of the natural predators of anchovy, and related the increase in the total bonito production of the second fishing season to the reduction seen in anchovy total production of this season.

MATERIALS AND METHODS

The samples of anchovy were taken from commercial catches at three landing stations located in the cities of Trabzon, Rize and Hopa (Fig. 2). The fish were generally collected at night by commercial fishing boats of various lengths ranging from 12 m to 60 m using purse-seine (400-2000 m length and 60-200 m deep) at the depths ranging from 20 to 200 meters along the Turkish coasts of the Black Sea (Trabzon, Rize and Hopa) (Fig. 2). Three sub-samples were randomly taken from different parts of fish biomass found on the deck of carrier boats at the landing stations during November-March and October-March of both fishing seasons. This study primarily examines the seasonal variations (month and year) in the parameters of anchovy population rather than spatial variations. Therefore, sub-samples taken in a given month at three landing stations were aggregated to represent the sample of that month. Fresh anchovy samples were then transported to a laboratory located at the Rize University, Faculty of Fisheries for further analysis. In the laboratory, a total of 1499 (2004-2005) and 1485 (2005-2006) individuals of fish species were measured (TL to nearest 1 mm) and weighed (nearest to 0.001g). We used capital otolith pairs for age determination. Otoliths were removed and dried in the laboratory and stored in labeled envelopes. Age was determined by a stereoscopic microscope [12] and recorded as 0, 1, 2 and 3 group. Sex was determined by examination of gonads. The length-weight relationship was determined by using Guland's equation [13]:

$$W = a\,L^{b} \qquad (1)$$

where W is the body weight (g), L is the total length (cm) a and b are regression constants.

The growth parameters in the von Bertalanffy growth equations were determined according to Pauly [14] and Avşar [15]. The equations of von Bertalanffy growth:

$$L_t = L\infty\,[1 - e^{-k\,(t - to)}] \text{ and } W_t = W\infty\,[1 - e^{-k\,(t - to)}]^{b} \qquad (2)$$

where L_t and W_t are total length (cm) and weight (g) at age t, respectively, $L\infty$ and $W\infty$ are asymptotic length and weight, k is the growth coefficient, t_0 is the time (age) at which length and weight equal to zero and b is the exponent of the length – weight relationship.

We used following equation to determine the monthly condition factors. The equation [16, 17]:

$$CF = (W/L^{b})*\,100 \qquad (3)$$

where W is weight (g), L is total length (cm), and b is the exponent of the length – weight relationship for overall.

The natural mortality coefficient (M) was estimated by using Ursin's equation [15]:

$$M = \overline{W}^{\,-(1/b)} \qquad (4)$$

where b is the exponent of the length – weight relationship for overall.

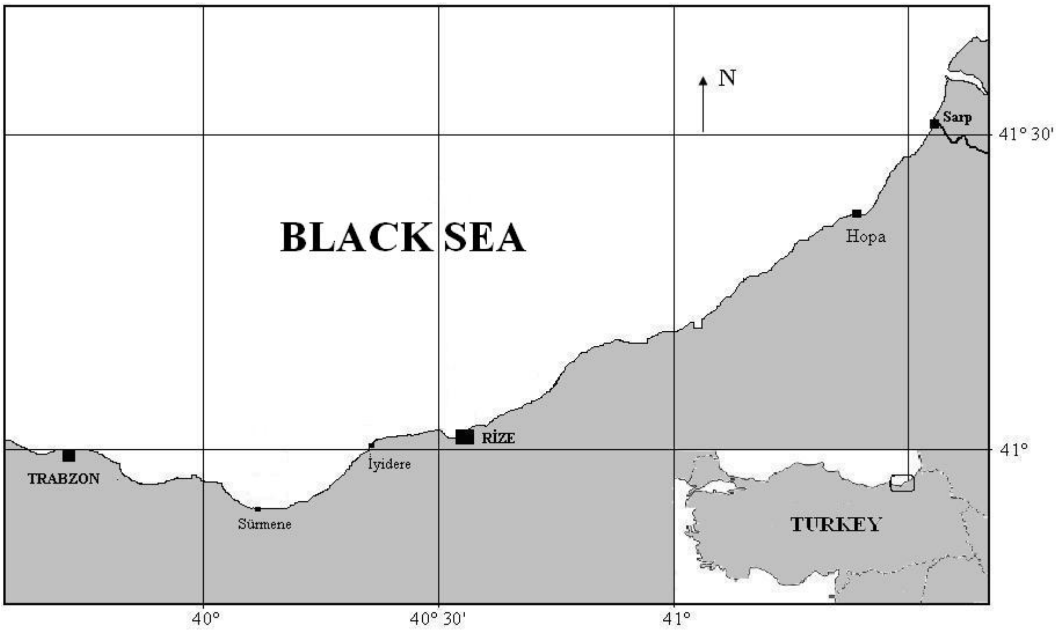

FIGURE 2 - The map of landing stations at which samples of individuals were taken.

Instantaneous mortality rate (Z) was estimated using the equation:

Z=-Ln (S) (5)

where S is the survival rate.

Fishing mortality (F) was calculated using the equation of following [15-18]:

F=Z-M (6)

One-way ANOVA was used to test differences in fish length and weight among months and seasons. Prior to the analysis of variance, all variables were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Levene test). This study also aimed to investigate the relationship between anchovy and bonito total production. Since the studies investigating different aspects of bonito in the region of our study are scarce, we only had data on the total production of bonito recorded by Turkish National Statistics Institute. We, therefore, used this data to investigate the relationship between anchovy and bonito through ordinary linear regression analysis performed between total production of anchovy and bonito of both seasons.

RESULTS

Size composition

The size (Total Length) of analyzed individuals ranged from 6 to 15 cm and 4 to 15 cm during the first and second fishing seasons, respectively. When the frequency of length class was taken into consideration, the percent frequency of individuals that had total length less than 9 cm, which is the minimum size allowed for harvesting in the Black Sea, was calculated as 4.39% and 34.08% for the first and second fishing seasons, respectively (Table 1).

The monthly length of the analyzed individuals exhibited distinct distribution pattern at each season. The monthly mean length of individuals followed a decreasing trend starting from October to February during the second fishing season. The monthly mean length of individuals captured during the first fishing season, on the other hand, showed a slightly increasing trend with some exceptions. Although mean length of individuals obtained in October 2005, which is the month at which anchovy fishing season starts, was 13.04 cm (S.D.±0.64 cm), the mean length, contrary to expected pattern of increase, progressively decreased to the lowest value (8.94 cm, S.D.±2.14 cm) in February 2006 (Table 2, Fig. 3). This pattern of change in monthly mean length was significant ($F_{5,\ 1479}$=131.67, P< 0.0001). The mean length of October and February 2005 were significantly higher and lower than those of remaining months, respectively. The mean length of January and March did not reveal significant difference. The differences among the monthly mean length were also significant during the first fishing season ($F_{5,\ 1493}$=48.73, P<0.0001). In this fishing season mean length of individuals reached the highest value in February 2005 (12.19 cm S.D. ±1.40 cm) and lowest one in January (10.73 cm, S.D. ±1.09). The mean length of February was significantly higher than those of other months except March. The mean size of individuals captured in January, on the other hand, was significantly lower than those of other months except December. Overall, the mean length of 2004-2005 population (11.36 cm,

TABLE 1 - The length-frequency distribution of *E. encrasicolus* for two fishing seasons.

Length class (cm)	Number (2004-2005)	Percentage (2004-2005)	Number (2005-2006)	Percentage (2004-2005)
	Fishing Seasons			
4.00	0	0	5	0.34
5.00	0	0	18	1.21
6.00	8	0.53	26	1.75
7.00	31	2.00	103	6.94
8.00	28	1.86	354	23.84
9.00	35	2.15	294	19.80
10.00	329	22.00	172	11.58
11.00	717	48.00	167	11.25
12.00	208	14.00	278	18.72
13.00	115	7.60	62	4.18
14.00	27	1.80	5	0.34
15.00	1	0.06	1	0.07
	1499	100.00	1485	100.00

TABLE 2 - The monthly variations of condition factor of *E. encrasicolus* population. (N: Number, CF: Condition Factor). SD: Standard Deviation.

	Fishing Seasons							
	2004-2005				2005-2006			
Months	**N**	**Mean Length ± SD (cm)**	**Mean Weight ± SD (g)**	**CF**	**N**	**Mean Length± SD (cm)**	**Mean Weight ± SD (g)**	**CF**
October	0	0	0	0	38	13.04±0.64	13.51±2.04	0.48±0.002
November	120	11.34±0.76	10.15±1.79	1.14±0.076	263	11.82±1.26	10.59±2.82	0.50±0.057
December	518	11.14±1.18	9.24±2.42	1.07±0.076	432	9.88±1.45	6.41±3.00	0.51±0.077
January	233	10.73±1.09	8.30±2.03	1.06±0.083	511	9.43±1.42	5.40±2.62	0.49±0.078
February	275	12.19±1.40	10.72±3.50	0.95±0.102	181	8.94±2.14	4.84±3.54	0.47±0.050
March	155	11.45±0.74	8.88±1.62	0.97±0.070	60	10.20±2.50	6.61±3.80	0.41±0.062
April	198	11.41±0.97	8.26±1.95	0.90±0.081	0	0	0	0
Tot/Mean	**1499**	**11.36±1.21**	**9.27±2.60**	**1.02**±0.110	**1485**	**10.05±1.86**	**6.80±3.67**	**0.49**±0.072

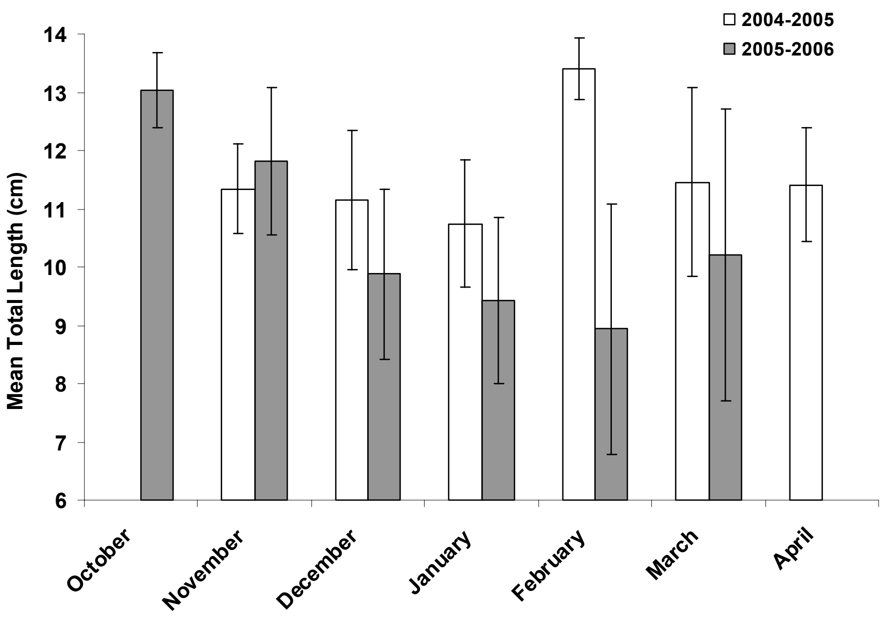

FIGURE 3 - Monthly values of total length for two fishing seasons. ± bars for standard deviation.

TABLE 3 - Age composition and mean length and weight, including standard error, of the *E. encrasicolus* population in the Black Sea in 2004-2005 and 2005-2006 (I: Immature, F: Female, M: Male). SD: Standard Deviation.

Age Groups	Sex	2004-2005 N	2004-2005 Mean Length ± SD (cm)	2004-2005 Mean Weight ± SD (g)	2005-2006 N	2005-2006 Mean Length ± SD (cm)	2005-2006 Mean Weight ± SD (g)
	I	53	7.53±0.56	2.70±0.85	236	7.56±0.96	2.69±1.01
0	F	30	8.79±0.67	6.57±1.14	189	8.90±0.52	4.34±0.96
	M	42	8.56±0.65	5.70±1.28	217	8.85±0.50	4.31±0.93
	I+F+M	**125**	**8.82±1.08**	**4.64±1.78**	**642**	**8.39±0.95**	**3.72±1.24**
	F	496	11.08±0.38	8.65±1.09	348	10.15±0.95	6.55±2.24
I	M	314	11.01±0.42	8.67±1.20	287	10.04±0.81	6.28±1.87
	F+M	**810**	**11.06±0.39**	**8.66±1.14**	**635**	**10.10±0.89**	**6.43±2.08**
	F	228	11.90±0.53	11.00±1.69	124	12.15±0.74	11.01±1.99
II	M	115	11.80±0.38	10.90±1.37	52	11.97±0.98	10.64±2.47
	F+M	**343**	**11.80±0.50**	**10.95±1.61**	**176**	**12.11±0.83**	**10.90±2.15**
	F	101	13.23±0.64	13.28±2.14	23	12.80±0.61	12.95±1.63
III	M	120	12.99±0.63	12.99±2.05	9	12.71±0.95	12.34±2.55
	F+M	**221**	**13.10±0.64**	**13.12±2.11**	**32**	**12.78±0.79**	**12.55±2.54**
Total/ Mean	**I+F+M**	**1499**	**11.36±1.21**	**9.27±2.58**	**1485**	**10.05±1.86**	**6.80±3.67**

S.D.±1.21 cm) was greater than that of the 2005-2006 population (10.05 cm, S.D.±1.86cm) (Fig. 3). The difference in mean length between two consecutive fishing seasons was significant ($F_{1,\ 2982}$=518.96, P<0.0001)

Age and sex composition

Age specific mean length and weight is presented in Table 3 for both fishing season. The population of anchovy in the Black Sea consisted of four age classes which were 0, I, II, and III. More than half of the population consisted of one year old individuals (54.03 %) during the first season; whereas population was mainly dominated by individuals belonging to zero age class (43.23 %) during the second season. Female individuals dominated the population during both fishing season. The percentages of female, male and immature individuals during the first fishing season were 57 % and 39 %, 4 %, respectively. On the other hand, the percentages of female, male and immature individuals during the second fishing season were 50 %, 34 % and 16 %, respectively. An increase in the percentage of immature individuals during the second fishing season compared to previous season is remarkable (Table 2).

Growth rate

Sex dependent growth parameters were calculated using the age specific mean length (L_t) and weight (W_t) for both fishing seasons (Table 2). The results of these calculations were presented in Table 4. The relationships between age-length and age-weight are depicted in Fig. 4. The weight of individuals ranged from 1.18 g to 22.43 g for the first and from 0.45 g to 20.46 g for the second fishing season. Mean weight was 9.27 g (S.D.±2.60g) and 6.80g, (S.D.±3.67g) during the first and second fishing seasons, respectively. The difference in the mean weight of both fishing season was highly significant ($F_{1,\ 2982}$=456.04, P< 0.0001).

Length - Weight relationship

Since the length and weight are the sex dependent traits of fish, the relationship were calculated for male and female individuals together and separately. These relationships are presented in Table 5. The corresponding curves for these equations are shown in Fig. 5. From these figures, one can easily conclude that anchovy grew allometrically and isometrically during the first and second fishing season, respectively.

Condition factors

Condition factors (CF) were calculated for both fishing seasons using the regression coefficient ***b*** obtained from the length-weight relationships presented in Fig. 5. There were remarkable differences between condition factors of both fishing season (Table 2). The mean condition factor was twice as high for the second fishing (Mean=1.02 (S.D. ± 0.11)) compared to the first fishing season (Mean= 0.49, S.D.±0.07). There were also considerable variations in the monthly mean of the condition factors of both fishing season. The monthly condition factor ranged from 0.95 to 1.14 and 0.41 to 0.51 for the first and second fishing season, respectively. The individuals of the first fishing season had higher condition factor in the periods of October–January and compared to February–April. The fish captured during the second fishing season had also similar pattern of variation with the highest and lowest mean values obtained during the first and second three months of the season, respectively (Table 2).

Mortality ratio

Instantaneous mortality (Z) rate was calculated using survival rate. The survival (S), Z, natural mortality (M), and fishing mortality (F) rates were estimated as 0.39, 0.93, and 0.45 and 0.54 during the first fishing season. These rates, on the other hand, were S = 0.24, Z = 1.40, M = 0.54 and F=1.02 during the second fishing season.

TABLE 4 - The von Bertalanffy growth equations for each sex.

	Fishing Seasons	
	2004-2005	**2005-2006**
Male	$L_t = 15.103\,[1 - e^{-0.307\,(t + 2.096)}]$ $W = 21.328\,[1 - e^{-0.307\,(t + 2.096)}]^{2.9709}$	$L_t = 15.152\,[1 - e^{-0.35\,(t + 2.429)}]$ $W = 22.481\,[1 - e^{-0.351\,(t + 2.429)}]^{3.1585}$
Female	$L_t = 16.036\,[1 - e^{-0.312\,(t + 2.334)}]$ $W = 23.830[1 - e^{-0.312\,(t + 2.334)}]^{2.8445}$	$L_t = 14.756\,[1 - e^{-0.409\,(t + 2.232)}]$ $W = 19.903\,[1 - e^{-0.409\,(t + 2.232)}]^{3.1187}$
Male+ Female	$L_t = 16.114\,[1 - e^{-0.291(t + 2.562)}]$ $W = 23.889\,[1 - e^{-0.291(t + 2.562)}]^{2.7948}$	$L_t = 15.272\,[1 - e^{-0.284(t + 3.530)}]$ $W = 21.996\,[1 - e^{-0.284(t + 3.530)}]^{3.0425}$

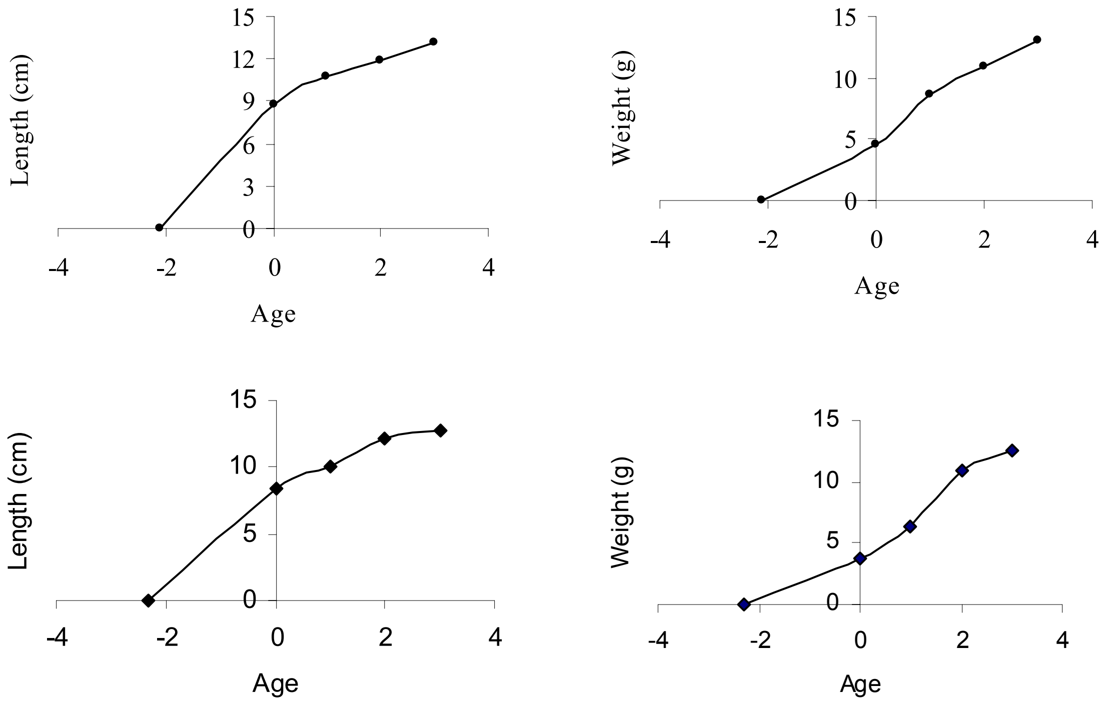

FIGURE 4 - Age-length and age-weight relationships for 2004-2005 (upper panels) and 2005-2006 (lower panels) fishing seasons.

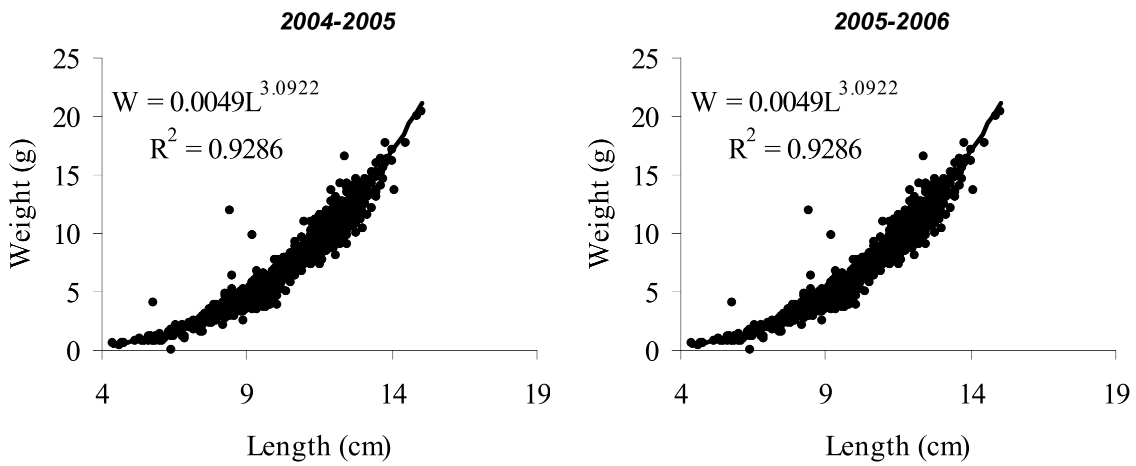

FIGURE 5 - Length-weight relationships for 2004-2005 and 2005-2006 fishing seasons.

TABLE 5 - The length-weight relationship of *E. encrasicolus* in two fishing seasons.

Sex	2004-2005	2005-2006
Male	$W = 0.0067\ L^{2.9709}$	$W = 0.0042\ L^{3.1585}$
Female	$W = 0.0089\ L^{2.8445}$	$W = 0.0045\ L^{3.1187}$
Male+Female	$W = 0.0101\ L^{2.7948}$	$W = 0.0055\ L^{3.0425}$

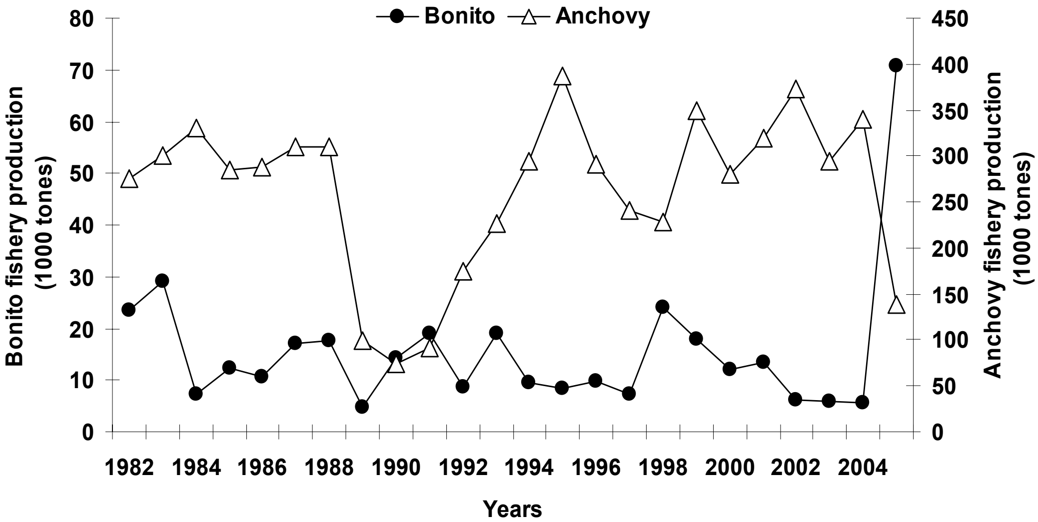

FIGURE 6 - Total catches of anchovy and Atlantic bonito captured in Turkey during the last 24 years. Data were taken from National Statistics Institute of Turkey [1].

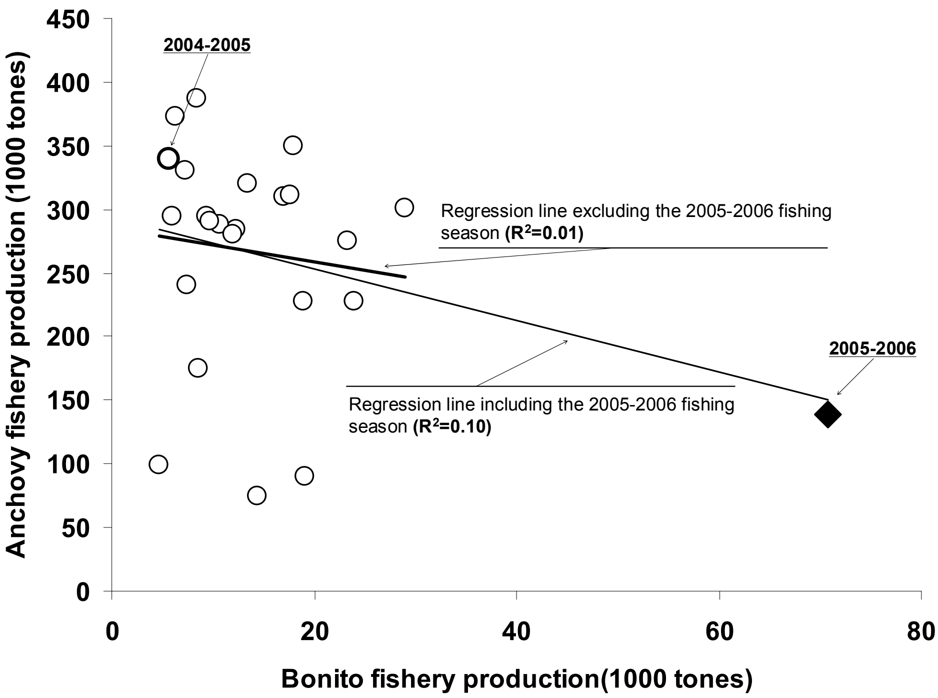

FIGURE 7 - The relationships between the catches of anchovy and bonito during the last 24 four years. The data were taken from the National Statistics Institute of Turkey [1]. The closed circle and open diamond are for 2004-2005 and 2005-2006 fishing season, respectively.

TABLE 6 - Some growth parameters of anchovy population obtained in previous studies and current study (bolded) [10].

Sex ratio		Growth parameters				Percentages of Survivor and Death				Study date
Female	Male	L_∞	W_∞	k	t_0	S (%)	Z	F	M	
61.00	39.00	16.77	34.71	0.33	-2.27	55.45	0.59	0.09	0.50	1985/86
46.00	54.00	16.85	34.48	0.32	-1.99	35.16	1.05	0.52	0.53	1986/87
49.15	50.85	14.14	20.04	0.92	-0.32	24.76	1.40	0.83	0.57	1987/88
64.07	35.93	15.73	23.32	0.32	-2.19	41.83	0.87	0.37	0.50	1988/89
-	-	23.50	78.69	0.14	-3.08	26.42	1.30	0.72	0.61	1989/90
52.90	47.10	15.01	22.51	0.61	-0.07	6.70	2.70	2.05	0.65	1990/91
59.38	40.62	18.30	37.70	0.25	-2.14	20.30	1.60	1.01	0.58	1991/92
59.31	40.69	16.72	24.76	0.50	-0.35	59.13	0.53	0.12	0.58	1992/93
59.58	40.42	15.82	23.07	0.34	-2.14	20.00	1.61	1.08	0.53	1993/94
57.40	42.60	16.83	29.47	0.31	-2.21	29.00	1.25	0.78	0.47	1994/95
60.43	39.57	16.65	26.12	0.30	-2.49	35.46	1.04	0.52	0.51	1995/96
60.78	39.22	17.00	27.23	0.31	-2.16	21.00	1.67	1.10	0.56	1996/97
62.09	37.91	15.57	22.42	0.42	-1.83	19.00	2.07	1.40	0.67	1997/98
67.00	33.00	15.66	22.28	0.33	-2.52	24.00	1.44	0.95	0.49	1998/99
45.00	55.00	17.07	30.04	0.28	-2.10	20.00	1.60	1.14	0.46	1999/2000
51.17	48.83	15.30	21.02	0.39	-2.11	32.00	1.14	0.57	0.57	2002/03
53.60	**46.40**	**16.11**	**23.88**	**0.291**	**-2.56**	**39.18**	**0.99**	**0.54**	**0.45**	**2004/05**
60.20	**39.80**	**15.27**	**21.99**	**0.284**	**-3.53**	**24.67**	**1.56**	**1.02**	**0.54**	**2005/06**

Relationship between bonito and anchovy

Bonito total production (catch) ranged from 6000 to 71000 tones with a mean 15.5 tones over the last 24 years (Fig. 6). The maximum production (71000 tones) of the last 24 years was obtained during the 2005-2006 fishing season. The regression analysis between bonito and anchovy production using the data belonging to last 24 years revealed non significant association (R^2 = 0.1). When excluding the data belonging to the second fishing season at which the maximum and minimum catch was obtained for bonito and anchovy, respectively, the association between catches of both species became weaker (R^2= 0.01), suggesting that bonito seemed to have direct effect on anchovy through predation or indirect effect through preventing anchovy to forage effectively (i.e., anti-predator behavior of anchovy) (Fig. 7).

DISCUSSION

The anchovy is both ecologically and economically the most important fish species for the Black Sea ecosystem. In this study, we aimed to determine some basic population parameters of this valuable fish species in order to understand the fluctuation seen in anchovy population during the 2005-2006 fishing season. We compared our results of the 2005-2006 season with the results of previous fishing one (2004-2005) in order to evaluate the reason behind the fluctuation seen in anchovy population during 2005-2006 fishing season.

It is obvious from the length data that the anchovy stocks did not grow well during the last fishing season compared to the first season. During this season the anchovy population was mainly dominated by the individuals whose lengths were less than 9 cm, which is the minimum harvestable length allowed in the Black Sea. The percentage of individuals having length less than 9 cm was 34 % during the second fishing season, whereas the percentage was only 4.53 % during the first fishing season, a result pointing out some environmental and/or biological factors (predation, chlorophyll a, competition, food availability etc.) that could inhibit the growth. A study showed that anchovy growth is primarily affected by primary production and temperature [19]. Compared to the first fishing season, temperature and primary production did not vary much during the second fishing season. On the other hand, considerable difference occurred in the second fishing season was an increase in the bonito catch. Bonito, which is the one of the predators of anchovy, stayed longer during the second fishing season. It is well known that predators not only affect the prey directly by consuming it, but also prevent the prey reaching or using nursery habitats or feeding grounds. Since both anchovy and bonito are pelagic species, it seems that anchovy showed an anti-predator behavior at which bonito prevented it to reach or freely use of foraging habitats. The fact that the bonito inhibited the anchovy growth through the anti-predator behavior could, however, be resolved by performing more detailed feeding habits studies of both species occurring at the same place and time.

In addition to higher percentage of individuals having length less than 9 cm during the second fishing season, the mean length and weight of individuals also provided information that the anchovy did not grow well during this season. The mean length and weight of individuals were 10.05 cm (S.D.± 1.86 g) cm and 6.80 (S.D.± 3.67g) during the second, whereas these averaged at 11.36 cm (S.D.± 1.21 cm) and 9.27 g (S.D.± 2.60g) for the first fishing season (Tables 1 and 2). The significant difference seen in the mean length and weight of individuals between two fishing season implied that one or multiple factors including natural and fishing mortality might have affected the anchovy stocks adversely. The differences seen in length and weight of individuals presented above could be a result of differences in ecological conditions of the Black Sea. As stated above the difference in the ecological conditions between two fishing season was the longer stay of bonito in the Black Sea. During the second fishing season, the landing value of bonito reached its maxima (70.797 and 5.701 tones for the second and the first fishing season, respectively) and this fish species stayed longer (six months) than normal (two months) in the Black Sea [1]. It is well known that anchovy serves as main prey item for many fish species including dolphins, bonito, and sharks. Among these, bonito seemed to be the reason of obtaining smaller sized anchovy in the second fishing season. The lower weight and length of individuals during the second fishing season compared to previous season provides further evidence that predators (mainly bonito) could be the main factor affecting the anchovy population during the second fishing season. Bonito and other predators probably consumed larger individuals in order to maximize energy acquisition while minimizing the energetic cost of food uptake by targeting the most abundant, profitable and easily captured prey (i.e., optimal foraging) [20]. The fact that predators often maximize energy assimilation by targeting the largest prey that also carry lowest relative costs in terms of searching, capture, and handling [21] supports the view of optimal foraging.

Condition factor is used as an indicator of “condition”, “well-being”, “plumpness” of an individual of fish [22] and a fish stock [23]. Variation in a fish condition factor is primarily attributed to state of sexual maturity, degree of nourishment, fish age, and sex in some species [24]. Condition factor of the anchovy in the Black Sea showed a considerable variation between the first (1.02) and second (0.49) fishing season. The previous studies showed that condition factor of anchovy is closely related to food availability (chlorophyll a) [25, 26], temperature [26]. The fact that chlorophyll a concentration and temperature did not vary considerable between two fishing seasons and considerable increase in the bonito catch and longer stay of bonito obtained during the second fishing season may suggest that bonito seemed to be the primary agent influencing the foraging activity and habitat selection of anchovy (anti-predator behavior). Fish as prey, in the presence of predators, may modify their behavior in a way that reduces the risk of being eaten. This behavior involves trade-off with other behaviors including habitat selection, foraging time and intensity. If the habitats in which the prey finds it more profitable to forage are also places in which they may be under the greater risk from predators, the prey may have to balance the profitability against risk. A fish that has its foraging success restricted by the presence of predators will have a reduced growth rate [27].

Natural mortality rate was greater during the second than the first fishing season. Comparing the total catches of both seasons, one can see that fishing efforts were lower but total catches were higher during the first, and vise versa for the second fishing season. The results of obtaining higher catch with lower fishing efforts during the first season could be linked to prevalence of normal conditions of Black Sea, which yielded the expected catches although the efforts remains as the same compared to previous years. But, anchovy during the second fishing season could be affected by two main factors. The first is that fishing season for bonito continued longer than normal (ends before start of anchovy fishing). That is to say bonito stayed longer in the Black Sea and continued predation on anchovy. The second reason is that more fishing pressure applied on the anchovy stocks which were also under the effect of bonito in order to reach yearly expected catch. Heavy fishing pressure applied those exploited stocks by predation resulted in lower catch compared to previous fishing seasons.

The causes of natural mortality of a given species could be related to abiotic (water temperature, salinity etc.) and biotic component (competition, predation etc.) of ecosystems where species live. Aside from all other potential biotic factors including competition, food shortage etc., an increase in the total catches of bonito, an unusual biological event occurred in the Black Sea during the second fishing season and cited one of the predators of anchovy, and greater mortality rates (0.39 vs. 0.59) during the second fishing season also made bonito strong candidate causing decline in anchovy catches.

It is naturally expected that mean weight and length of fish show an increasing trend with time. Contrary to this expected trend, however, anchovy mean weight and length especially during the second fishing season did not follow this general expected trend. The length of individuals of fish sampled gradually declined starting from October, which is the first month of anchovy fishing season, until February. This unexpected results could be attributed to the fact that anchovy migrates from the west to the east during the fishing season, which might have caused stocks to mix up with another immigrating stocks, resulting in changes in the length distribution. Another reason could be, as stated in somewhere else, the predation by the fish. A stated previously, predators maximize acquisition while minimizing the energetic cost of food uptake by targeting the most abundant, profitable and easily captured prey (i.e., optimal foraging) [20]. Thus, predators, mainly bonito, seemed to harvest the most suitable individuals of anchovy in order to maximize the energy acquisition and minimizing the energetic costs by targeting the largest individuals.

The occurrence of huge fluctuations in anchovy stocks between 1989 and 1992 caused a serious crisis in fishing industry. The crisis initiated many studies aimed to understand the factors affecting anchovy stocks adversely. The studies have been centered on population structure, size of the stocks, and its ecological habitats [3, 7, 10, 11, 28, 29].

It has been clearly seen from Fig.1 that following an extraordinary decline in anchovy production during 1989 and 1992, the anchovy production increased starting from 1993 to 1995 and stabilized thereafter with taking serious measures (fishing anchovy smaller than 9 cm was banned, determination of net size as 6 mm, and reducing the number of fishing fleets) for conserving the stocks. Although these measures could not be fully implemented (C. Sahin Personal observation), the stocks showed a recovery trend since 1992. These measures, however, seemed not to be enough securing sustainable management of anchovy stocks, a result supported by the fishing catch obtained during the second fishing season when stocks showed a huge fluctuation compared to the last 15 years. In this study, we compared the population parameters including growth parameters, mortality rates, and yearly total catches obtained during the second and the previous fishing seasons. Sudden declines were observed in the mean length, weight, and growth parameters, and an increase in the rates of fishing mortality and natural mortality rates, reflecting an increase the number of natural enemy. Both an increase in the fishing and natural mortality rates indicated that anchovy stocks were under the effects of fishermen and the predators especially bonito which gave the highest catch in the Black Sea.

Decline in the anchovy is not only directly dependent on bonito but also other factors including uncontrolled fishing effort, eutrophication, effects of an exotic invader (*Minemiopsis leidyi* [5]), and increase in the Black Sea dolphin population [30]. The effects of three factors (uncontrolled fisheries, eutrophication, invader of *Minemiopsis leidyi*) on anchovy and other fish stocks are beyond doubt, however, the effects of increase in the number of top predatory species (dolphins and sharks and bonito) on anchovies and other fish species could also be important contributors responsible for decline in fish stocks. For example, a dolphin consumes prey equaling to 2-4 percent of its body weight. It was estimated that there were 500,000 dolphins in the Black Sea in 1988 [31]. Based on an estimate that 13,000 individuals are recruiting to dolphin population each year [30], the total number of dolphins is expected to reach approximately 750,000 in the Black Sea. Ünsal [30] concluded that new recruits consume daily 50 tones of prey, totaling 18,000-20,000 tones of fish in a year. He suggested a certain number of dolphins (13,000) from the population should carefully be removed each year. Fishermen of the region, who frequently have been viewed as the major factor causing the collapse of anchovy and other fish stocks, like Ünsal [30], pointed to dolphins as the cause of this collapse. Dolphins as well as other top predatory species could, as claimed by Ünsal, cause the decline in fish stocks. Determining the magnitude of their effects on fish stocks, however, requires detailed studied food web structure of which fisheries management requires a conceptual understanding [32]. In this study we demonstrated that an increase in the bonito catch during the second fishing season could be responsible for decline in the anchovy stocks. We aware that the presented data solely based on population parameters of anchovy and increase in the catch of bonito could not provide strong evidence for blaming the bonito for causing anchovy stocks to decline. But here we pointed out predatory species as potential candidate responsible for decline in anchovy stocks. We are also aware that the effects of predatory species on anchovy population, on the other hand, could be documented in detail by performing food webs studies which identify who eats whom and what amount of prey is consumed by each predatory species.

In addition to predatory species, there are still problems with the heavy or uncontrolled fishing pressure on anchovy stocks. As indicated somewhere in the text, some measures have already been taken to protect stocks. But these measures remain to be insufficient for stocks of unknown size. In order to ensure sustainable anchovy fisheries, the following measures should also be taken by the countries situated along the coasts of Black Sea. Turkey should employ and take new strategies and measures as many developed countries do. In order to conserve anchovy stocks and maintain sustainable fisheries, standardization of number of fishing fleets and fishing equipment should be done immediately. In addition to these two measures, determination of stock size should be done. To perform meaningful determination of stock size, the total catch should be recorded. With the aid of these records, healthy estimation of stocks size could become possible. Quota system should be employed with taking consideration of size of fishing fleets and stocks. Lastly, the way of taking and recording fishing statistics should be re-structured ensuring continuity.

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