

Age, Growth, and Mortality Rates of the European Anchovy (*Engraulis encrasicolus* L. 1758) off the Turkish Black Sea Coast

Osman SAMSUN*, Necati SAMSUN, Atilla Cem KARAMOLLAOĞLU
Faculty of Fisheries, Ondokuz Mayıs University, 57000 Aklıman, Sinop - TURKEY

Received: 07.04.2003

Abstract: This study was conducted during the *Engraulis encrasicolus* fishing seasons of 1998-1999 and 1999-2000, and some basic characteristics of this population off the Turkish coast of the Black Sea were examined. Weight-length relationships and von Bertalanffy growth equations were estimated as $W = 0.0083 L^{2.872}$ and $L_t = 15.66[1 - e^{-0.3368(t+2.526)}]$ and $W = 0.0076 L^{2.919}$ and $L_t = 17.07[1 - e^{-0.2836(t+2.1047)}]$ for the 1998-1999 and 1999-2000 fishing seasons, respectively. For the 1998-1999 fishing season total (Z), natural (M), and fishing (F) mortality rates were $Z = 1.44 \text{ year}^{-1}$, $M = 0.49 \text{ year}^{-1}$ and $F = 0.95 \text{ year}^{-1}$ and for the 1999-2000 season they were $Z = 1.60 \text{ year}^{-1}$, $M = 0.46 \text{ year}^{-1}$ and $F = 1.44 \text{ year}^{-1}$, respectively. The exploitation rates (E) of 0.66 and 0.71 for each season indicate that the population is being heavily exploited.

Key Words: Anchovy, *Engraulis encrasicolus*, Black Sea, age, growth and mortality rates

Türkiye'nin Karadeniz Sahillerindeki Hamsi Balığının (*Engraulis encrasicolus* L. 1758) Yaş, Büyüme ve Ölüm Oranları

Özet: Bu çalışma Karadeniz'in Türkiye sahilinde 1998-1999 ve 1999-2000 av sezonlarında avlanan hamsi balığının bazı temel özelliklerini incelemek için yürütülmüştür. Uzunluk-ağırlık ilişkisi ve von Bertalanffy büyüme parametreleri 1998-1999 ve 1999-2000 av sezonunda $W = 0.0083 L^{2.872}$, $L_t = 15.66[1 - e^{-0.3368(t+2.526)}]$ ve $W = 0.0076 L^{2.919}$, $L_t = 17.07[1 - e^{-0.2836(t+2.1047)}]$ olarak hesaplanmıştır. Toplam (Z), doğal (M) ve avcılık (F) ölümleri sırasıyla, 1998-1999 av sezonu için $Z = 1,44 \text{ yıl}^{-1}$, $M = 0,49 \text{ yıl}^{-1}$, $F = 0,95 \text{ yıl}^{-1}$ ve 1999-2000 sezonu için $Z = 1,60 \text{ yıl}^{-1}$, $M = 0,46 \text{ yıl}^{-1}$, $F = 1,44 \text{ yıl}^{-1}$ olarak hesaplanmıştır. Her iki sezon için sırasıyla 0,66 ve 0,71 olarak hesaplanan stoktan yararlanma oranı (E), popülasyonun yoğun bir şekilde av baskısı altında olduğunu göstermektedir.

Anahtar Sözcükler: Hamsi, *Engraulis encrasicolus*, Karadeniz, yaş, büyüme ve ölüm oranları

Introduction

The European anchovy (*Engraulis encrasicolus*) is the most abundant fish species in the Black Sea, and is represented by 2 species, *E. encrasicolus ponticus* and *E. encrasicolus maeoticus*. The first is of commercial interest for all Black Sea countries (1). Most *E. encrasicolus* have been caught by Turkey and former USSR countries in the eastern part of the Black Sea. Fishing is carried out from October to April, but mostly (96.03%) from December to March (2). The fishing of *E. encrasicolus* from 1938 to 1960 was less than one quarter of the total catch in the

Azov-Black Sea and Sea of Marmara; in the 1970s it accounted for more than half, and even as much as two-thirds, of the total (3). Since 1981, the highest annual fish catches among all the Mediterranean and Black Sea countries has been achieved by Turkey. Black Sea has an important place in Turkish fisheries. *E. encrasicolus* is the major fish production of the Black Sea (69% of the total in 2001) (4).

Until recently, there had been a gradual increase in the catches of *E. encrasicolus* and other plankton-feeding pelagic fishes. However, there has been a sudden

* E-mail: osamsun@yahoo.com

decrease in *E. encrasicolus* landings since 1988: from 295,000 t in 1988 to 97,000 t in 1989 and to 66,000 t 1990 (5). In the last few years, dramatic reductions have been reported not only for Turkish Black Sea fisheries, but also in the fisheries of other riparian countries (6). However, some increase is seen due to largely new fishing technology and also some important factors such as increased nutrients, particularly on the north-western shelf (7). However, eutrophication (particularly in the shallow north-western region) in combination with overfishing and the recent appearance of the competing invader *Mnemiopsis leidyi* (Ctenophora) appears to be the reason for an abrupt decrease to 60,000 t in *E. encrasicolus* catches at the end of the 1980s (6). After the sudden decline in *Mnemiopsis leidyi* (Ctenophora), the *E. encrasicolus* fishing in Turkey has again consistently increased to a maximum of 374,000 t in 1995 (8) (Figure 1). *E. encrasicolus* is the most important commercial fish in Turkey, constituting 77% of the total sea fish catch. *E. encrasicolus* constituted 24-70% of the total sea fisheries production between 1988 and 2001 in Turkey (5) (Figure 1). *E. encrasicolus* is not only an important species for commercial fishing; it is also a major food source for other economically important fishes such as bonito, bluefish and tuna in the Black Sea (9). Therefore, studies on *E. encrasicolus* are increasing year by year in Turkey (9-20).

Since *E. encrasicolus* is being caught and consumed in large amounts in the Black Sea the monitoring of anchovy stocks by year is essential for Turkey as well as other countries around the Black Sea. The objective of the current study was to examine the biological characteristics of *E. encrasicolus* to obtain basic information necessary for the introduction of an appropriate management system for *E. encrasicolus* populations in the Black Sea.

Materials and Methods

Monthly samples of *E. encrasicolus* were collected by purse-seine fishing boats from November to March (1998-1999 and 1999-2000) during its fishing seasons along the Turkish coast (Sinop) in the Black Sea (Figure 2). From the fresh samples, total length (Lt) and body weight (W) were measured to the nearest 0.1 cm and 0.01 g, respectively.

Otoliths were removed and dried in the laboratory and stored in labeled envelopes. Age was determined by stereoscopic microscope (21) and recorded as group 0, 1, 2 and 3. Sex was determined by gonad examination. The length-weight relationship was determined according to Gulland's equation (22): $W = a L^b$, where W = body weight (g), L = total length (cm) and a and b are constants. The von Bertalanffy growth equations were determined (23):

$L_t = L_\infty [1 - e^{-k(t-t_0)}]$ and $W_t = W_\infty [1 - e^{-k(t-t_0)}]^b$ where L_t and W_t = total length (cm) and weight (g) at age t, L_∞ and W_∞ = asymptotic length and weight, k = the growth coefficient, t_0 = time (age) at which length and weight equal zero and b = the exponent of the length-weight relationship.

Condition factors were computed for each sex as follows: $CF = (W/L^3) * 100$, and $CF = (W/L^b) * 100$ were calculated for each sex, where W is weight (g), L is total length (cm), and b is the exponent of the length-weight relationship for females, males, and overall. According to Ricker (24) the rate of growth was calculated by mean total length and weight at age. The index of growth performance was calculated according to Sparre and Venema (25) as follows: $\emptyset = \ln k + 2 \ln L_\infty$ where k and L_∞ are von Bertalanffy growth equation parameters.

The natural mortality coefficient (M) was estimated using Pauly's equation (26):

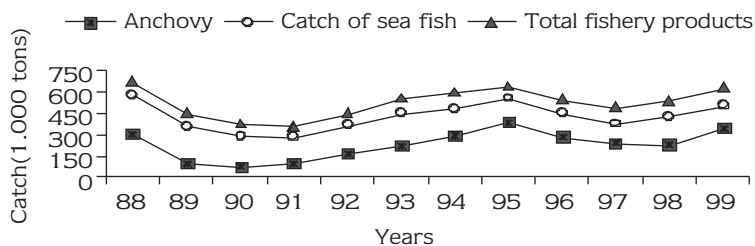


Figure1. Fishery production of Turkey 1988-1999.

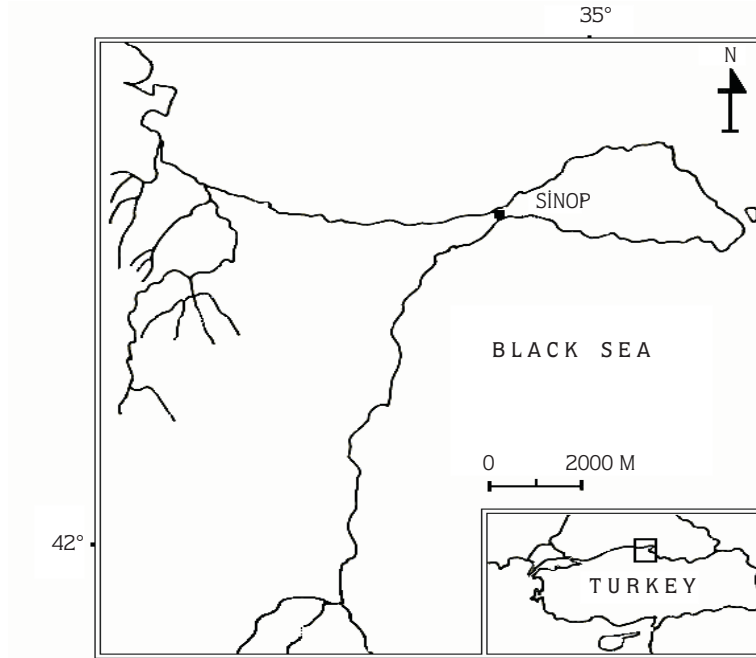


Figure 2. Geographical location of the sampling station.

$M = 0.8 [10^{(-0.0066 - 0.279 \log L_{\infty} + 0.6543 \log k + 0.4634 \log T)}]$ where T is the mean annual water temperature (10 °C in this study). L_{∞} and k are the parameters of the von Bertalanffy growth equation. The last method was (27) $M = (\ln x_d - \ln x_m) / (x_d - x_m)$ where x_m is the age at sexual maturity and x_d is the life span, taken as 1 and 4 years, respectively. The total mortality coefficients were estimated by 4 different methods in order to compare the confidence of the estimation. The first method for the length-converted catch curve was applied as follows (26): $\ln(N/\Delta t) = a + bt$ where N is the number of fish in a sample versus respective length class, a and b are constants of the regression equation, Δt is the time needed to grow from the lower (t_1) to the upper (t_2) limit of a given length class and t is the relative age corresponding to the mid-range of the length class in question. The total mortality coefficient (Z) is defined as equal to “-b” in the regression line. The second method for estimating the mortality coefficient was (28) $Z = k(L_{\infty} - \bar{L}) / (\bar{L} - L')$ where K and L_{∞} are the growth coefficient and asymptotic length (cm), respectively. \bar{L} is the mean length of all fish $\geq L'$ and L' is the smallest length at full recruitment based on the other methods (29,30).

The fishing mortality coefficient (F) and the exploitation ratio (E) were calculated (31,32) in order to judge whether the stock is over fished or not. Annual survival rate (S), mortality rate (A), natural mortality rate (v), and fishing mortality rate (u) were estimated (24): $F = Z - M$, $E = F/Z$, $S = e^{-Z}$, $A = 1 - S$, $v = (M * A)/Z$, $u = (F * A)/Z$.

Observed differences (mean \pm SE) were evaluated statistically using ANOVA and Student's t-test.

Results

Age and sex composition

The mean length and weight of each age group are presented for the 2 fishing seasons (Table 1). The *E. encrasicolus* population in the Black Sea consisted of 4 different age groups (0, 1, 2 and 3). Age 0 indicates fish younger than 1 year old. The results show that age group 1 was the most abundant at 58.52% and 69.07% and age group 3 was the least abundant at 3.56% and 3.18%, respectively, in the 2 fishing seasons (1998-1999 and 1999-2000) (Table 1). The sex distributions were 67% and 55% female in the 1998-1999 and

1999-2000 fishing seasons, respectively. Females were dominant in each age group.

Size composition

It was found that 81.21% and 85.8%, respectively, of fish were between 8 cm and 12 cm in the 2 fishing seasons (Table 2). The mean total length values for the

first and second seasons and the average of the 2 were 10.82 ± 0.03 cm, 10.53 ± 0.04 cm and 10.70 ± 0.03 cm, respectively. There were significant differences between female and male *E. encrasicolus* in terms of length and weight for each fishing season ($P < 0.05$). Mean total length was reduced throughout the end of both fishing seasons (Figure 3).

Table 1. Age composition and mean length and weight, including standard error, of the *E. encrasicolus* population in the Black Sea in 1998-1999 and 1999-2000.

Fishing Seasons	Age groups	N % total	% Female	Mean Length \pm SE (cm)	Mean Length \pm SE (g)
1998-1999	0	20.39	13.1	8.97 ± 0.03	4.49 ± 0.06
1999-2000		10.49	4.56	8.19 ± 0.04	3.42 ± 0.06
1998-1999	1	58.52	38.28	10.91 ± 0.02	8.11 ± 0.06
1999-2000		69.07	36.55	10.40 ± 0.03	7.32 ± 0.06
1998-1999	2	17.53	12.13	12.20 ± 0.02	10.74 ± 0.07
1999-2000		17.27	11.02	12.02 ± 0.03	10.74 ± 0.10
1998-1999	3	3.56	3.51	13.23 ± 0.06	13.45 ± 0.30
1999-2000		3.18	2.97	13.29 ± 0.09	13.33 ± 0.30

Table 2. The length-frequency distribution of *E. encrasicolus* for 2 fishing seasons.

Length class limits (cm)			Fishing Season			
Lower	Upper	Mid-point (cm) N	1998-1999 %	1998-1999 N	1999-2000 %	1999-2000 N
6.05	6.55	6.3	1	0.07	0	0.00
6.55	7.05	6.8	0	0.00	2	0.21
7.05	7.55	7.3	3	0.21	7	0.74
7.55	8.05	7.8	14	0.98	24	2.54
8.05	8.55	8.3	30	2.09	46	4.87
8.55	9.05	8.8	107	7.47	60	6.36
9.05	9.55	9.3	132	9.22	66	6.99
9.55	10.05	9.8	128	8.94	103	10.91
10.05	10.55	10.3	110	7.68	139	14.72
10.55	11.05	10.8	182	12.71	162	17.16
11.05	11.55	11.3	287	20.04	151	16.00
11.55	12.05	11.8	187	13.06	83	8.79
12.05	12.55	12.3	166	11.59	55	5.83
12.55	13.05	12.8	52	3.63	26	2.75
13.05	13.55	13.3	22	1.54	10	1.06
13.55	14.05	13.8	9	0.63	8	0.85
14.05	14.55	14.3	2	0.14	2	0.21
			1432	944		

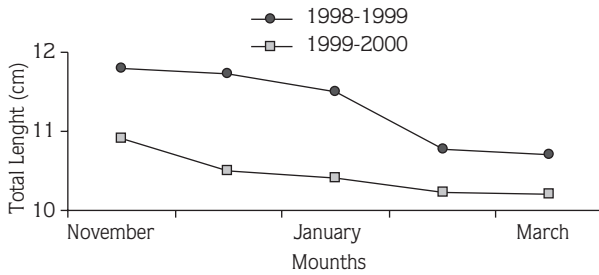


Figure 3. Monthly values of total length for 2 fishing seasons.

Growth rate

The von Bertalanffy growth equations and growth performances were estimated using mean length and weight at different ages for each sex in 2 seasons.

1998-1999 fishing season

Female

$$L_t = 21.31 [1 - e^{-0.1375(t+3.5746)}]$$

$$W = 53.40 [1 - e^{-0.1375(t+3.5746)}]^{2.8156}$$

$$\text{Growth performance } (\emptyset) = 4.13$$

Male

$$L_t = 17.88 [1 - e^{-0.2456(t+2.4747)}]$$

$$W = 37.50 [1 - e^{-0.2456(t+2.4547)}]^{3.0549}$$

$$\text{Growth performance } (\emptyset) = 4.36$$

Female and Male

$$L_t = 15.66 [1 - e^{-0.3368(t+2.526)}]$$

$$W = 22.28 [1 - e^{-0.3368(t+2.526)}]^{2.872}$$

$$\text{Growth performance } (\emptyset) = 4.41$$

1999-2000 fishing season

Female

$$L_t = 22.93 [1 - e^{-0.1505(t+3.066)}]$$

$$W = 65.63 [1 - e^{-0.2675(t+2.4729)}]^{2.8156}$$

$$\text{Growth performance } (\emptyset) = 4.38$$

Male

$$L_t = 19.03 [1 - e^{-0.2203(t+2.5347)}]$$

$$W = 45.37 [1 - e^{-0.2203(t+2.5347)}]^{3.0549}$$

$$\text{Growth performance } (\emptyset) = 4.37$$

Female and Male

$$L_t = 17.07 [1 - e^{-0.2836(t+2.1047)}]$$

$$W_t = 30.04 [1 - e^{-0.2836(t+2.1047)}]^{2.919}$$

$$\text{Growth performance } (\emptyset) = 4.41$$

The weight of *E. encrasicolus* varied between 1.2 g and 22.3 g in the 1998-2000 fishing season. Mean weight was 8.02 ± 0.07 g, 7.69 ± 0.09 and 7.89 ± 0.05 g in the 1998-1999, 1999-2000 and 1998-2000 fishing seasons, respectively. There were significant differences between length and weight in 2 fishing seasons.

There was no significant difference between the measured and estimated lengths and weights.

Weight-length relationship and condition factors

Since there are important differences between females and males in terms of length and weight, it was considered that the length-weight relationships could be calculated from their sexual conditions (Table 3).

Table 3. The length-weight relationships of *E. encrasicolus* in 2 fishing seasons.

	Fishing seasons	
	1998-1999	1999-2000
Female	$W = 0.0317 L^{2.3042}$	$W = 0.0097 L^{2.8156}$
Male	$W = 0.0088 L^{2.8404}$	$W = 0.0056 L^{3.0549}$
Female + Male	$W = 0.0083 L^{2.872}$	$W = 0.0076 L^{2.919}$

In the 1998-1999 fishing season it was observed that female growth was allometric and male growth isometric. However in 1999-2000 the growth of both sexes was close to isometric.

As shown in Table 4, Fulton's condition factor varied significantly with the b factor ($P < 0.05$). Generally b is assumed to be 3 for calculating the condition factor. However b values varied between male and female fish. Therefore, it was thought convenient to use calculated b values instead of the constant 3 for condition factor calculations. In the first season, the condition of the females and males according to Fulton, a and b were 0.64 ± 0.04 and 3.38 ± 0.19 for females and 0.61 ± 0.002 and 0.88 ± 0.003 for males. In the second season these values were, in the same order, 0.63 ± 0.003 and 0.97 ± 0.005 for females and 0.64 ± 0.004 and $0.56 \pm$

Table 4. The monthly variation of condition factor parameters in the *E. encrasicolus* population.

Months	Fishing seasons					
	Sample Size	1998-1999		1999-2000		
		CF ± SE (Fulton)	CF ± SE (constant b)	Sample Size	CF ± SE (Fulton)	CF ± SE (constant b)
November	308	0.6252 ± 0.004	2.8254 ± 0.006	196	0.6812 ± 0.006	0.8118 ± 0.009
December	366	0.6154 ± 0.003	2.4253 ± 0.007	127	0.6713 ± 0.007	0.7941 ± 0.005
January	298	0.5950 ± 0.004	2.2360 ± 0.005	218	0.6572 ± 0.006	0.7498 ± 0.006
February	276	0.6114 ± 0.003	2.2157 ± 0.009	205	0.6483 ± 0.005	0.7374 ± 0.004
March	184	0.5912 ± 0.003	2.1400 ± 0.001	198	0.6245 ± 0.006	0.7252 ± 0.005

0.003 for males. The mean condition factors were reduced throughout the end of both fishing seasons (Figure 4).

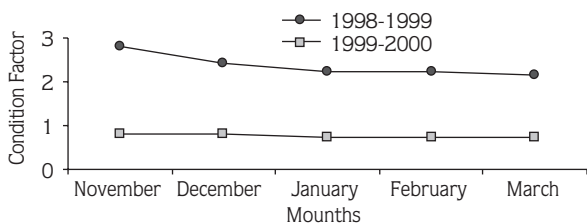


Figure 4. Monthly values of condition factors for 2 fishing seasons.

Mortality parameters

The values of mean Z, M, and F were calculated as $Z = 1.44 \text{ year}^{-1}$ (1.86, 1.8, 0.8 and 1.31 according to references 25-29, respectively) $M = 0.49 \text{ year}^{-1}$ (0.52 and 0.46 according to references 25, 26, respectively), $F = 0.95 \text{ year}^{-1}$ in the 1998-1999 fishing season and $Z = 1.60 \text{ year}^{-1}$ (1.9, 2.0, 1.02 and 1.42 according to references 25-29, respectively), $M = 0.46 \text{ year}^{-1}$ (0.46 according to references 25, 26, respectively) and $F = 1.14 \text{ year}^{-1}$ in the 1999-2000 fishing season, respectively. Annual survival rates (S) were (24%) and (20%) for each season. The exploitation rate (E) was higher (0.71) in 1999-2000 than that (0.66) in 1998-1999. Fishing mortality rate (u) increased from 50% in 1998-1999 to 57% in the 1999-2000. Due to increased fishing mortality rates, the natural mortality rate (v) decreased from 26% in 1998-1999 to 23% in 1999-2000.

Discussion

The results of mean length, mean weight, condition factors, von Bertalanffy growth values and weight-length relationship values of *E. encrasicolus* off the Turkish coast of the Black Sea are shown in Table 5. Although the female and male ratios determined in this study are similar to those reported previously, the female ratio of 67% was the highest value observed during the 1998-1999 fishing season. The female ratio decreased to 55% in 1999-2000. As shown in Table 5 results of length and weight values previously reported are similar to this study. Statistical differences between weight and length of the female and male *E. encrasicolus* were observed ($P < 0.05$). The females were larger than the males in many species of the order *Mugilidae* (33), Pacific whiting (34), whiting *Merlangius merlangus euxinus* (35) and *Psettodidae* (36), as well as *Engraulis* spp. The mathematical models emphasize that these correlations are the result of evolutionary adjustments due to the trade-off between reproduction, growth and survival (37-40).

There was an increase in stock of *E. encrasicolus* in comparison with previous values (Figure 1). There are 2 possible reasons for this: first the ctenophore, *Beroe ovata*, which arrived in the Black Sea in the late 1990s, seemed to be a very effective predator of *Mnemiopsis*. When the *Mnemiopsis* population crashed, it led to increases in nongelatinous zooplankton, *E. encrasicolus* landings and egg density of *E. encrasicolus* (41); and second, dust storms from the Sahara desert come during the day with rain and increase the amounts of the alga

Table 5. Some study results for *E. encrasicolus* off the Turkish Black Sea coast.

Studies	Fishing Season	Parameters									
		Female (%)	Lt (cm)	W (g)	§CF	a	b	L _∞ (cm)	K l/year	To (year)	Ø
(9)	85-86	61	11.33	10.53	0.6275	0.0023	3.4128	16.77	0.3235	-2.2705	4.51 *
(13)	86-87	46	10.83	8.65	0.6128	0.0025	3.3832	16.85	0.3241	-1.9882	4.52 *
(10)	87-88	49	9.34	6.62	0.6488	0.0025	3.3868	14.14	0.9180	-0.3200	5.21 *
(12)	88-89	64	-	-	0.61	0.0064	2.9743	15.73	0.3166	-2.1966	4.36 *
(15)	87-89	52	10.06	6.75	-	0.0047	3.1002	17.51	0.2773	-2.937	4.44 *
(16)	94-95	57	9.02	4.79	0.5839	0.0047	3.0975	16.83	0.3102	-2.2093	4.48 *
(18)	96-97	66	9.6	7.20	0.88	0.0057	3.117	17.42	0.284	-2.108	4.46*
(20)	98-99	73	11.22	8.67	0.59	0.0057	3.015	16.97	0.260	-6.145	4.32*
This study	98-99	67	10.82	8.02	0.61	0.0083	2.872	15.66	0.3368	-2.526	4.41
This study	99-00	45	10.53	7.69	0.66	0.0076	2.919	17.07	0.2836	-2.1047	4.41

Emilialina huxleyi (Ehux) (42-44). It is also pointed out that, *E. encrasicolus* larvae emerge from the eggs during this time and they feed on this alga and this increases their survival rate significantly (44). In particular, during the summer of 1998, in the Black Sea, there was an explosion of Ehux, which increased levels of *E. encrasicolus* fishing to 350,000 t in 1999.

The age composition of 0- and 1-year-old fish was about 80% in those years, indicating that the *E. encrasicolus* stock in the Black Sea was becoming younger compared to previous reports in Turkey (10, 11, 13). Ivanov and Beverton (1) reported that there had been 4-year-old *E. encrasicolus* until 1975, based on Soviet research data, and 4-5-year-old *E. encrasicolus* had been found until 1979 according the Bulgarian research data in the Black Sea. Due to increases in the number of fishing vessels, fishing capacity and technology since 1970, overfishing has given the fish no chance to grow for more than 3 years. As a result, the *E. encrasicolus* stock mainly consists of age groups of 0 and 1. In general, the percentage of fish in age group 3 was very low in other studies, as well as in the present study (3%). (9-11,13-16). Age group 1 was dominant during the 2 fishing seasons. This was considered to indicate a high level of spawning in summer 1997 and 1998. There were differences in the sexual conditions and length-weight relationship of *E. encrasicolus* according to year. The length-weight relationship, von Bertalanffy, and condition factor results found in this study are similar to those reported previously (Table 5). The growth differences in

E. encrasicolus during the 2 seasons had a great impact on their conditions. There were differences between the female and male condition factors and the females were in better condition than the males. The condition of *E. encrasicolus* in the 1998-1999 fishing season was better than that in the next fishing season. The "b" value, which shows the growth of fish, varies based on the season, age, stomach contents and spawning conditions (45). The functional regression "b" value represents the body form, and it is directly related to the weight affected by ecological factors such as temperature, food supply, spawning conditions and other factors, such as sex, age, fishing time and area, and fishing vessels (24). Throughout the fishing season, the total length and condition factors decreased. The reason is thought to be a decrease in feeding activity due to low water temperature and an increase in young fish from December to March, which is also mentioned by Özdamar et al. (9). Although the intensive spawning season of *E. encrasicolus* in the Black Sea is between June and August (46), it is considered that 6-9-month-old fish are recruited into the vulnerable stock after December. The migration of fish schools of age 0 occurs in the southern part of the Black Sea from the end of December to February (15). Figure 3 shows that the mean length of *E. encrasicolus* decreased at the end of the fishing season (March).

Although the natural mortality coefficient (M) in the present study was similar to that reported by Özdamar et al. (16), the total mortality coefficient, fishing mortality

coefficient, exploitation rate and annual mortality rate were higher than those reported by other authors (15,18). The same species may have different natural mortality rates in different areas depending on the density of predators and competitors, and whose abundance is affected by fishing pressures (25). Fishing mortality increased from 0.50 year⁻¹ for the 1998-1999 season to and 0.57 year⁻¹ for the following season. The exploitation rate was estimated as 0.66 year⁻¹ for the 1998-1999 fishing season and 0.71 year⁻¹ for the following season. It has been cited by Leonardos (47) that Patterson (48) reported an exploitation rate of about 0.4 to be safe for the stock and may be used as a guideline for the appropriate exploitation of small pelagic species (48). Our results imply that the present stock is being heavily exploited in the fishing season. Although the exploitation rate was estimated during 1976-1980 (1) as 0.25-0.36 year⁻¹, it increased sharply to 0.57-0.63 year⁻¹ for the 1987-1989 season (14), 0.62 year⁻¹ for the 1994-1995 season (15), and 0.66-0.71 year⁻¹ for the 1998-2000 season in the present study. This increase in the exploitation rate appears to be due to the increasing total fishing effort with an increased number of fishing boats, total capacity and transportation capability since the 1970s.

Over the last two decades, an important reduction has been observed for Turkish Black Sea fisheries and other riparian countries (Russia, Romania and Bulgaria). Since, anchovy fishing is important sources of income and protein for people especially inhabiting the Turkey Black Sea coast, collapsing of this will have an adverse effect on protein consumption and economical situation of these people (6).

The reasons for the decrease in the *E. encrasicolus* stock in the Black Sea are extensive fishing, uncontrolled

development, and pollution of the ecological system. In particular over the past 20 years there have been remarkable increases in the number of fishing boats and their capacity. It is also pointed out that the number of fishing boats in the Black Sea increased by 100% and the catch capacity became about 6 million tons during 1982-1986 (49). In addition fishing boats build from 1976 to 1980 were only 17.99 ± 0.24 m in length and had a 240 ± 7 hp engine, whereas those build from 1986 to 1990 have increased to 21.64 ± 0.40 m in length and with a 423 ± 21 hp engine. Unfortunately, Turkish fishing boats, due to improper planning and rules and unnecessary competition among fisherman, are not economically efficient (50). The uncontrollable increase in the number of fishing boats is most remarkable in the field of *E. encrasicolus* fishing. In recent years, although there have been some improvements in fish numbers, the impact of overfishing is still present in this study of the mortality rate of this fish (Table 5).

Appropriate fishery management, including the restriction of fishing, by limiting all the fishing grounds, especially nursery grounds and rules for fish size should be applied for *E. encrasicolus*. The females of *E. encrasicolus* reach sexual maturity at a length of 9.3 cm (18). In the fishing regulations in Turkey, the minimum legal length for catching this species is 9 cm. It has been pointed out that this limit needs to be enforced by extensive controls.

In order to avoid decreases in *E. encrasicolus* stocks, which occurred in the 1980s overfishing should be avoided. Collaboration between Black Sea countries is essential and it is necessary to determine and control the fishing quotas of each country. There is an additional factor to consider: pollution caused by the Danube, Dniester and Dnieper rivers.

References

- Ivanov, L., Beverton, R.J.H.: The fisheries resources of the Mediterranean, part two: Black Sea. *FAO Stud. Rev.*, 1985; 60: 37-54.
- Prodonov, K., Mikhailov, K., Dasklov, G., Maxim, C., Chashchin, A., Arkhipov, A., Shlyakhov, V., Özdamar, E.: Environmental management of fish resources in the Black Sea and their rational exploitation. *FAO Stud. Rev.* 1997; 68: 39-53.
- Rass, T.S.: Changes in the fish resources of the Black Sea. *Oceanology*, 1992; 32:197-203.
- Devlet İstatistik Enstitüsü: 2001 yılı Su Ürünleri İstatistikleri, DİE, Ankara, 2003.
- Devlet İstatistik Enstitüsü: Su Ürünleri İstatistikleri 1988-2001. DİE, Ankara, 1989-2003.
- Kideys, A. E.: Recent dramatic changes in the Black Sea ecosystem: The reason for the sharp decline in Turkish anchovy fisheries. *J. Marine Syst.*, 1994, 5: 171-181.
- Zaitsev, Yu. P.: Recent changes in the tropic structure of the Black Sea. *Fish Ocean*, 1992; 1: 180-189.

8. Kideys, A. E., Gordina, A. D., Bingel, F., Nierman, U.: The effect of environmental conditions on the distribution of eggs and larvae of anchovy (*Engraulis encrasicolus* L.) in the Black Sea. ICES J. Marine Sci., 1999; 56 (suppl): 58-64.
9. Özdamar, E., Khiara, K., Erkoyuncu, İ.: Some biological characteristic of European anchovy *Engraulis encrasicolus* L in the Black Sea. J. Tokyo Univ. Fisher., 1991; 78: 57-64.
10. Düzgüneş, E., Karaçam, H.: Karadeniz'deki hamsi (*Engraulis encrasicolus* L., 1758) balıklarında bazı popülasyon parametreleri ve büyüme özelliklerinin incelenmesi. Doğa Zooloji, 1989; 13: 77-83.
11. Erkoyuncu, İ., Özdamar, E.: Estimation of the age, size and sex composition and growth parameters of Anchovy *Engraulis encrasicolus* (L) in the Black Sea. Fisher. Res., 1989; 7: 241-247.
12. Ünsal, N.: Karadeniz'deki hamsi balığı *Engraulis encrasicolus* (L., 1758)'nın yaş-boy-ağırlık ilişkisi ve en küçük av büyüklüğünün saptanması üzerine bir araştırma. İstanbul Üniv. Su Ürün. Derg., 1989; 3: 17-28.
13. Karacam, H., Düzgüneş, E.: Age, growth and meat yield of European Anchovy (*Engraulis encrasicolus* L., 1758) in the Black Sea. Fisher. Res., 1990; 9: 181-186.
14. Özdamar, E., Erkoyuncu, İ., Erdem, M.: Research on recent variations of European Anchovy (*Engraulis Encrasicolus* L., 1758) stock in The Black Sea as viewpoint of population dynamics. Proceedings of the Black Sea Symposium Ecological Problems and Economical Prospects; 1994: 197-203.
15. Özdamar, E., Khiara, K., Sakuramoto, K., Erkoyuncu, İ.: Variation in the population structure of European anchovy, *Engraulis encrasicolus* L. in The Black Sea. J. Tokyo Univ. Fisher., 1994; 81: 123-134.
16. Özdamar, E., Samsun, O., Erkoyuncu, İ.: Karadeniz' de (Türkiye) 1994-1995 av sezonunda hamsi (*Engraulis engrasicolus* L.) balığına ilişkin popülasyon parametreleri tahmini. Ege Üniv. Su Ürün. Fak. Derg., 1995; 12: 135-144.
17. Cihangir, B., Uslu, B.: Ege Denizi'nde hamsi balığı (*Engraulis encrasicolus* L., 1758)'nın fekonditesi üzerine bir ön çalışma. Doga-Tr. J. of Zoology, 1992; 16: 301-310.
18. Kayalı, E.: Doğu Karadeniz ekosistemindeki hamsi (*Engraulis Encrasicolus* L.,1758) ve istavrit (*Trachurus mediterraneus*) balıklarının biyolojik özellikleri üzerine bir araştırma. Yüksek Lisans Tezi. KTÜ, Fen Bilimleri Teknolojisi, 1998: 236.
19. Avşar, D., Çelik, M., Çiçek, E.: Kuzeydoğu Akdeniz ve Doğu Karadeniz hamsilerinin (*Engraulis encrasicolus* Linnaeus, 1758) besin bileşenlerinin karşılaştırılması. Ege Üniv. Su Ürün. Fak. Derg., 1999; 16: 327-334.
20. Gözler, A. M., Çiloğlu, E.: Rize-Hopa açıklarında 1997-1998 avlanma sezonunda avlanan hamsi (*Engraulis encrasicolus* L., 1758) balığı'nın bazı popülasyon parametreleri üzerine bir araştırma. Doğu Anadolu Bölgesi III. Su Ürünleri Sempozyumu, 1998: 373-382.
21. FAO: Report of the Technical Consultation on Methodologies Used for Fish Age-Reading. FAO Fisheries Report, 1981: 257.
22. Gulland, J.A.: Manual of methods for fish stock assessment. Part I, Fish Population analysis. FAO. Man. Fish. Sci., 1969; 4: 1-154.
23. Pauly, D.: Gill size and temperature as governing factors in fish growth: A generalization of von Bertalanffy's Growth Formula. Berichte Ins. F. Meereskunde (Kiel), 1979; 63:156.
24. Ricker, W.E.: Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can., 1975; 191: 382.
25. Sparre, P., Venema, S.C.: Introduction to tropical fish stock assessment. Part 1-Manual. FAO Fish. Tech. Pap. Rome, 1992; 306.1, Rev.1: 376 p.
26. Pauly, D.: Some simple methods for the assessment of tropical fish stocks. FAO Fish. Tech. Pap., 1983; 234: 52.
27. Chen, S., Hirayama, N., Ishino, M.: Dynamic equilibrium and interrelationship between some biological parameters in a fish stock. Suisan Kaiyo Kenkyu, 1989; 53: 18-27.
28. Beverton, R.J.H., Holt, S.J.: A Review of methods for estimating mortality rates in fish populations with special references to sources of bias in catch sampling. Rapp. P.V. Reun. Cons. Ins. Explor. Mer., 1956; 140: 67-83.
29. Heince, F.: Investigation on the plaice. General report. 1. The plaice fishery and protective regulations. 1913; Part. I. Rapp.P.-V.Reun.CIFM, 17A:1+Annexes.
30. Robson, D.S., Chapman, D.G.: Catch curves and mortality rates. Trans. Am. Fish. Soc.,1961; 90: 181-189.
31. Gulland, J.A.: Fish Resources of the Oceans. West Byfleet, Surrey, Fishing News (Books) Ltd., 1971: 255.
32. Gulland, J.A.: Fish Stock Assessment: A Manual of Basic Methods. John Wiley and Sons, 1983: 223.
33. Altındağ, A.: Akşehir Gölü'ndeki (Konya) tatlısu kefalinin (*Leuciscus cephalus* L., 1758) bazı popülasyon özellikleri, büyüme ve kondüsyon. Turkish J. of Zoology, 1996; 20: 53-56.
34. Dorn, M.W.: Detecting environmental covariates of Pacific whiting *Merluccius products* growth using a growth-increment regression model. Fish. Bull., 1992; 90: 260-275.
35. İşmen, A.: A preliminary study on the population dynamics parameters of whiting (*Merlangus merlangus euxius*) in the Turkish Black Sea coastal waters. Turkish J. of Zoology, 2002; 26: 157-166.
36. Druzhinin, A.D., Petrova, Ye. G.: Some data on the ecology and growth of psettodes erumel (family Psettodidae Order Pleuronectiformes) of the Gulf of Aden. J. Ichthyol., 1990; 20: 143-147.
37. Charlesworth, B., Leon, J.A.: The relation of reproductive effort to age. Am. Natural.,1976; 110: 449-459.
38. Roff, D.A.: An allocation model of growth and reproduction in fish. Canadian J. Fisher. Aquat. Sci., 1983; 40: 1395-1404.
39. Roff, D.A.: The evolution of life-history variation in fishes, with particular reference to flatfish. Netherlands J. Sea Res., 1991; 27: 197-207.

40. Stearns, S.C.: The Evolution of Life Histories, Oxford University Press. Oxford, 1992: 249.
41. Kideys, A.E.: Fall and rise of the Black Sea ecosystem. Science, 2002; 297: 1482-1484.
42. Saydam, C.: Deniz çölleri yeşeriyor, sahra tozundan alg patlamalarına. Tübitak, Bilim ve Teknik, 1997; Haziran: 68-74.
43. Saydam, C.: Türkiye'nin bilinmeyen kaynağı, Çöl tozundan kar. Tübitak, Bilim ve Teknik, 2000; Ağustos: 68-72.
44. Saydam, C.: Hamsi akli. Tübitak, Bilim ve Teknik, 2002; Şubat: 66-69.
45. Erkoyuncu, İ.: Balıkçılık Biyolojisi ve Populasyon Dinamiği. Ondokuz Mayıs Üniversitesi Yayınları, Samsun, 1995; 95: 265.
46. Demir, N.: Notes on the variations of the eggs of anchovy (*Engraulis encrasicolus* Cuv.) from Black, Marmara, Aegean and Mediterranean Seas. Hidrobiyoloji. 1959; B4: 180-187.
47. Leonardos, I. D.: Ecology and exploitation pattern of a landlocked population of smelt, *Atherina boyeri* (Rissa 1810), in Trichonosis Lake (western Greece). J. Appl. Ichthyol., 2001; 17: 262-266.
48. Patterson, K.: Fisheries for small pelagic species: an empirical approach to management targets. Rev. Fish. Biol., 1992; 2: 321-338.
49. Doğan, M., Zengin, M., Şahin, T., Bozali, M., Özke, M.: Karadeniz'de av araç ve gereçleri ile avlanma teknolojisinin belirlenmesi. TKB Trabzon Su Ürünleri Merkez Araştırma Enstitüsü; 1996.
50. Özdamar, E.: Türkiye'deki balıkçı gemilerinin yapısal özelliklerinin tespiti. Ege Üniv. Su Ürün. Derg., 1995; 12: 329-345.