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Research Article

A Preliminary Study on the Population Dynamics Parameters of Whiting (*Merlangius merlangus euxinus*) in Turkish Black Sea Coastal Waters

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Abstract: Some population parameters of the whiting (*Merlangius merlangus euxinus*) distributed along the Turkish Black Sea coast, were determined by using age-length data. The mean annual growth rate in length was found to be 3.7 cm. The maximum age group was determined as IX for females and VI for males. The seasonalized von Bertalanffy growth parameters in length were estimated to be L_∞=39.1 cm, K = 0.15 year^{-1}, t_0 = -1.53 year, C=0.23, t_s=0.48. There was a difference in growth rate between male and female fish. The females grow faster than males and reach a greater maximum length. Total mortality and its components were Z=1.63, M = 0.39 and F = 1.24. The highest trawlable biomass was found in the region between Çaltı Cape and Sarp which is an area closed to trawl fishing in the eastern Black Sea. In the trawl catches, the whiting was the dominant fish.

Key Words: Black Sea, *Merlangius merlangus euxinus*, growth parameters, mortality, biomass

Karadeniz'in Türkiye Kıyılarındaki Mezgitin (*Merlangius merlangus euxinus*) Populasyon Dinamiği Parametreleri Üzerine Bir Ön Çalışma

Özet: Karadeniz'in Türkiye kıyılarında yayılış gösteren mezgitin (*Merlangius merlangus euxinus*) yaş-boy verileri kullanılarak bazı populasyon parametreleri tespit edilmiştir. Boyca ortalama yıllık büyüme oranı 3.7 cm olarak bulunmuştur. Maksimum yaş dişiler için IX, erkekler için VI olarak tespit edilmiştir. Mevsimsel salınımlı von Bertalanffy boyca büyüme parametreleri; L_∞=39.1 cm, K = 0.15, t_0 = -1.05, C=0.23, t_s=0.48 olarak saptanmıştır. Erkek ve dişilerin büyüme oranları arasında farklılık olduğu; dişilerin erkeklerden daha hızlı büyüdükleri ve daha büyük maksimum boya ulaştıkları saptanmıştır. Toplam ölüm ve bileşenleri; Z=1.63, M = 0.39 ve F = 1.24 olarak belirlenmiştir. Trolle avlanabilecek en yüksek biyokütle değerinin, Doğu Karadeniz'de trol avcılığına kapalı bölge olan Çaltı Burnu-Sarp arasındaki alanda olduğu bulunmuştur. Trol avlarında en bol bulunan türün mezgit olduğu belirlenmiştir.

Anahtar Sözcükler: Karadeniz; *Merlangius merlangus euxinus*; büyüme parametreleri; ölüm, biyokütle

Introduction

The mean annual landing of all fish from the Black Sea by Turkey and other riparian countries was 183000 t in 1966-1970 (1) and increased up to 737200 t in 1980-1987 (2). The catches were mainly composed of fourteen pelagic and demersal species during 1966-1989. Among the demersal species, the whiting (*Merlangius merlangus euxinus*) was the dominant fish caught, followed by striped mullet (*Mullus barbatus*) and turbot (*Psetta maxima maeotica*). The whiting annual catch exceeded 31000 t in 1988 in the Black Sea. After 1988, the annual nominal catches of whiting have been reduced dramatically, and in 1991, the whiting landings were only 19039 t (3).

The earlier studies on whiting by riparian countries were carried out by Probatov & Ural'skaja (4), Dehnik (5), Owen (6), Kaneva & Marinov (7), Burdak (8), Prodanov (9,10) and Ivanov & Beverton (1). Among these studies, Probatov & Ural'skaja (4), Dehnik (5), Owen (6), Kaneva & Marinov (7) and Burdak (8)'s were on biology; maturity, spawning, fecundity and feeding. Prodanov (9, 10) studied growth and ageing, and estimated the optimal level of exploitation of the whiting along the Bulgarian coast. In the Turkish Black Sea coast, the first information was about the distribution and abundance. Stock assessment studies were also done on the fishing areas between Sinop and Çaltı Cape (11, 12, 13, 14, 15). The data on population dynamics parameters of whiting for the Turkish Black Sea coast are scarce however.

The present study gives estimates of growth and mortality rates using length-age data, as well as annual

average biomass estimations of the whiting in Turkish Black Sea coastal waters.

Material and Methods

The study was conducted aboard R/V Bilim and R/V Surat 1. Sampling by R/V Bilim was carried out in April 1990 and September 1990. Surveys by R/V SURAT 1 were made in September 1991 and October 1992; and monthly between June 1992 and May 1993. Each hauling time was normally restricted to 30 min.

Samples were collected by stratified sampling technique from 66 stations along the Black Sea coast of Turkey (Fig. 1). Locations and hauling numbers are presented together with the number of samples collected each month and survey in Table 1. The area stratification was based on local areas which are divided into regions according to the bottom depth. The depth intervals were chosen as 0-50 m and 50-100 m. In poor hauls, the total catch was considered as the sample size for further analyses. For abundant catches, subsampling was carried out according to the procedure described by Holden & Raitt (16). The samples were preserved in solutions of 4% formaldehyde buffered with borax. The following examinations were carried out at once after sampling.

Length measurements were made to the nearest millimeter with each fish lying on its right side with the mouth closed and body weight to the nearest gramme. Sex was determined by internal examination. In the immature virgin stage, the distinction between sexes was made by binocular microscope examination.

Estimation of age was based almost exclusively on interpretation of otoliths for the presence of hyaline and opaque zones which are assumed to represent winter and summer growth periods respectively. Sagittal otoliths were sectioned across the center of the nucleus, using a scalpel, and the section or surface of otoliths were polished in order to make it much easier to read (16). Otoliths were mounted on sellotape in Plexiglas trays and were fixed by means of white cement, and then were burned at 200 °C for about half an hour. The otoliths were examined in glycerin under a binocular microscope using direct light from above. The burning enhanced the visibility of hyaline zones. These zones appeared brown while the opaque zones remained white.

The length-weight relationships for each sex group and their pooled data were calculated separately by log-log regression ($\ln W = \ln q + b^*\ln L$) and the significance of the differences between regression coefficients were tested by analysis of covariance. For the estimation of growth parameters, seasonally oscillating version of von Bertalanffy Growth Equation, which was modified by Pauly & Gaschutz (17) and Pauly & David (18) was used.

$$L_t = L_\infty [1 - \exp(-K(t - t_o)-(CK/2\pi)^* \sin(2\pi (t - t_w)))],$$

where L_∞ (cm) is the asymptotic length, K (yr^{-1}) is Brody's growth coefficient, t_o (yr) is the age the fish would have had at length of zero, π is the constant (3.14159), and t_w is the winter point; at the time of the year when the fraction tw of the year has elapsed the growth rate is lowest and $t_w = t_s + 0.5$, where ts is the summer point and takes a value between 0 and 1, and C is the amplitude and usually takes values between 0 and 1. The age readings carried out on the annual base were rearranged assuming that the spawning always takes places on the 1st of January, which is partly true since the whiting

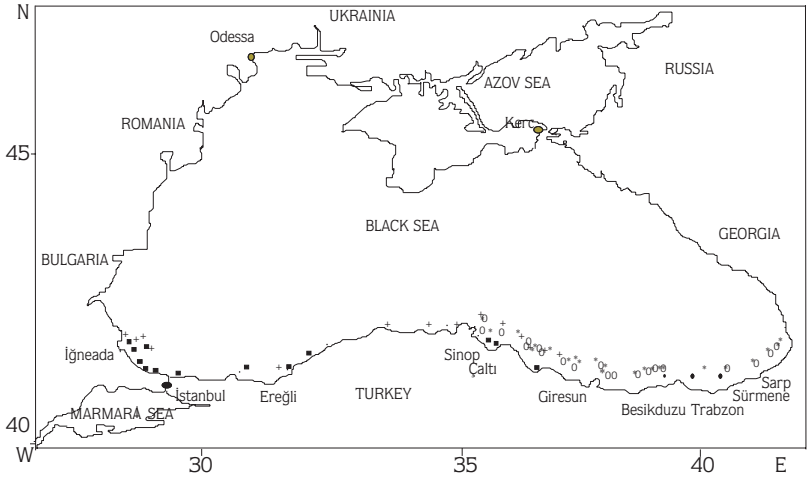

Figure 1. Locations of the sampling stations along the Turkish Black Sea coast. ♦ April 1990 + September 1990 *September 1991 o October 1992 • June 1992-May 1993

Table 1. Location of the sampling stations and hauling number together with number of samples

Date	Location (start and finish points)	Number of trawls	No.of fish
April 1990	414940N-280245E to 412247N-363338E	18	1455
September 1990	414707N-280699E to 411711N-370892E	15	1379
September 1991	415000N-352000E to 412700N-412800E	23	1680
October 1992	415600N-351500E to 412700N-413000E	22	1568
June 1992	410600N-390900E to 405700N-400500E	3	150
July 1992	410600N-390900E to 405700N-400500E	3	131
August 1992	410600N-390900E to 405700N-400500E	3	116
October 1992	410600N-390900E to 405700N-400500E	1	54
November 1992	410600N-390900E to 405700N-400500E	1	39
December 1992	410600N-390900E to 405700N-400500E	2	129
January 1993	410600N-390900E to 405700N-400500E	2	100
February 1993	410600N-390900E to 405700N-400500E	3	119
March 1993	410600N-390900E to 405700N-400500E	3	149
April 1993	410600N-390900E to 405700N-400500E	3	119
May 1993	410600N-390900E to 405700N-400500E	3	169
June92-May 1993	410600N-390900E to 405700N-400500E	27	1275
Total		105	7357

spawn in batches and spawning takes place in mid winter with a maximum in January. The year based age readings were converted into daily readings. The parameters of the equation were estimated by using a program called ETAL (17). The accuracy of the growth parameters were tested using Munro's Phi Prime Test (19) and t-test (20). Fulton's Condition Factor was calculated according to the descriptions given by Ricker (21).

The total mortality rate (Z) was estimated from the survival rate calculated using a portion of the age series formulated by Ricker (21).

$$S = (N_{(t+1)} + N_{(t+2)}) / (N_{(t)} + N_{(t+1)} + N_{(t+2)}),$$

where S is the survival rate, N_t the number of fish at the age of t, $N_{(t+1)}$ the number of fish at the age of (t+1), and $N_{(t+2)}$ the number of fish at the age of (t+2). The relationship between the survival rate and the total mortality coefficient is given by Ricker (21) as:

$$S = e^{-Z},$$

The natural mortality coefficient was estimated using Ursin's (22) Method,

$$M = W^{-1/b},$$

where M is the natural mortality coefficient, W is the mean weight of samples, and b is the regression constant.

The trawlable biomass estimation was based on the swept area method compiled by Sparre et al. (20).

$$B_i = (C / a_i*q) * A_i ,$$

where C is the mean catch in weight per haul in stratum i; A_i the area for stratum i; a_i the sub i^{th} trawling area; q the catchability coefficient of the trawl net (q=1).

Results

A total of 7357 fish were caught during the sampling period (Table 1). In each survey, the number of samples collected was 1455, 1379, 1680, 1568 and 1275 respectively. The range was smaller for males, from 5 to 26 cm (Fig. 2), than that for females. The overall mean total length of females was bigger than males (ANOVA, $P<0.01$). Females were dominant in all sampling periods, and the overall male to female ratio was 1:1.3.

An interannual comparison of the percentage distributions of the fish and other organisms revealed that the whiting (*Merlangius merlangus euxinus*) was the most important demersal fish in the catches followed by striped mullet (*Mullus barbatus*), turbot, (*Psetta maxima maeotica*), and picarel (*Spicara smaris*). Some pelagic or semipelagic fish species such as twaite shad (*Alosa pontica*), picarel (*Spicara smaris*), sprat (*Sprattus sprattus phalericus*) and horse mackerel (*Trachurus mediterraneus*) were also commonly present in the trawl catches.

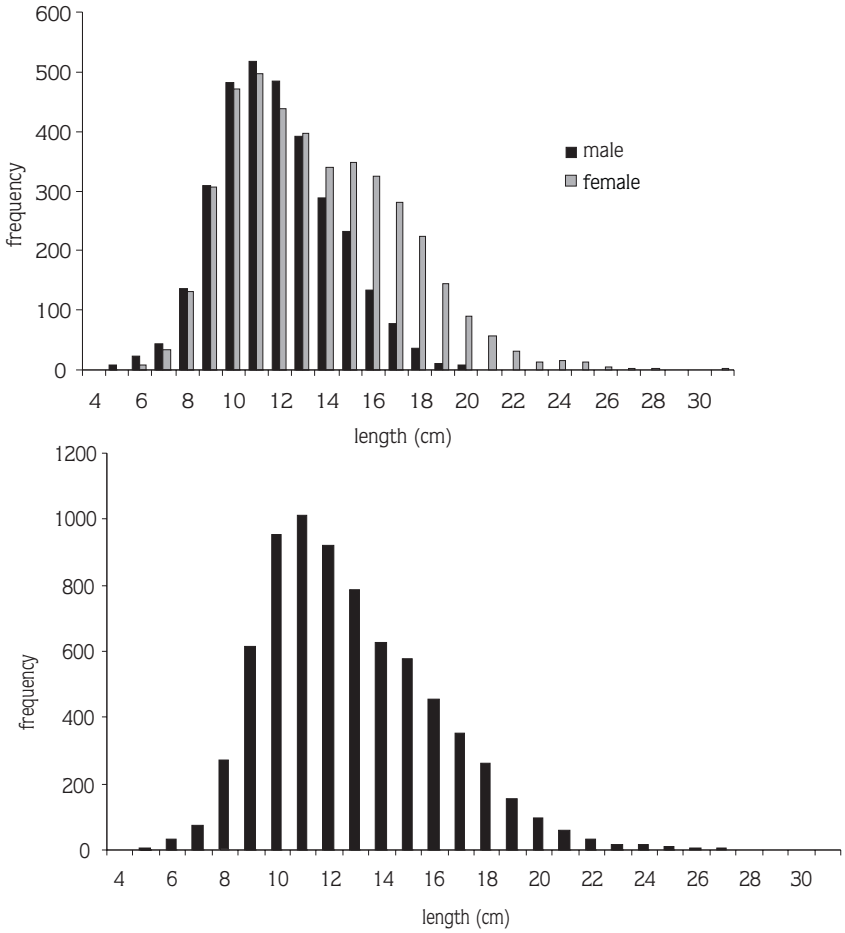

Figure 2. Length-frequency distribution for each sex (A) and their pooled data (B)

The age composition

The maximum age group determined was IX for females and VI for males. Age group I (42.6%) was dominant in females. The age groups II (36.0%), III (18.1%), IV (2.4%), V (0.05%), VI (0.02%), VII (0.01%), and IX (0.01%) follow it, respectively. In males, age group I (58.4%) was dominant, followed by the age groups II (35.6%), III (5.94%), and IV (0.01%), respectively (Table 2). The greater portion of the sample was composed of the age groups I, II, and III, respectively.

Table 2. Percentage sex distributions in each age group

Age group	Male	%	Female	%	Total	%
I	1857	58.4	1779	42.6	3636	49.4
II	1131	35.6	1505	36.0	2636	35.8
III	189	5.94	756	18.1	945	12.8
IV	3	0.01	100	2.40	103	1.40
V	-	-	21	0.05	21	0.29
VI	1	0.01	7	0.02	8	0.10
VII	-	-	5	0.01	5	0.06
IX	-	-	3	0.01	3	0.04
Total	3181	100	4176	100	7357	100

Length-weight relationship and condition

The length-weight relationships calculated for each sex, pooled data and whole sampling period are shown in Table 3. The functional regression b values were found to be greater than 3 for each sex and their pooled data in all sampling periods. Therefore, it could be stated that Black Sea whiting show a positive allometric growth.

Analysis of covariance of the length-weight data for the samples collected in each survey during an annual period did not indicate significant differences (ANCOVA, $P<0.01$) However, analysis of covariance of the length-weight data for the samples collected every month, between June 1992 and May 1993 indicated significant differences (ANCOVA, $P<0.01$) between the regression coefficients of the winter months (February, March) and other months.

Fulton's conditions factors were estimated to compare the condition of whiting in different sampling periods due to their allometric growth characteristics (Table 4). Females had a higher condition than the males in each sampling period. However, certain seasonal changes in the condition of whiting occurred in the monthly seasonal samples between June 1992 and May 1993. Both sexes had their smallest condition during the intensive spawning period (January and February) and also the males had a higher condition than females in this period. After the spawning period, the condition of both sexes began to increase and reach the highest level in summer. A decreasing trend in the condition occurred again until December.

Growth in length

The von Bertalanffy growth parameters for each sex and their pooled data of the Black Sea whiting are given in Table 5 and are shown in Fig. 3.

Table 4. Fulton's Condition Factor for each sex and pooled data in each sampling period.

Sampling period	Male	Female	Pooled data
April 1990	0.0083	0.0086	0.0085
September 1990	0.0083	0.0090	0.0087
September 1991	0.0084	0.0092	0.0090
October 1992	0.0089	0.0104	0.0100
June 1992	0.0098	0.0099	0.0102
July 1992	0.0097	0.0099	0.0102
August 1992	0.0094	0.0094	0.0095
October 1992	0.0087	0.0087	0.0089
November 1992	0.0098	0.0112	0.0106
December 1992	0.0096	0.0096	0.0096
January 1993	0.0091	0.0087	0.0088
February 1993	0.0089	0.0088	0.0089
March 1993	0.0093	0.0104	0.0102
April 1993	0.0089	0.0094	0.0093
May 1993	0.0098	0.0105	0.0105
Overall	0.0090	0.0095	0.0094

Table 5. The von Bertalanffy growth parameters of each sex and their pooled data of Black Sea whiting.

	L_∞ (cm)	K_{year-1}	to (year)*	°C	t_s
Seasonal					
Male	33.5	0.17	-1.08	0.56	0.25
Female	40.4	0.15	-0.92	0.24	0.35
Pooled	39.1	0.15	-1.53	0.23	0.48
Non-Seasonal					
Male	29.1	0.22	-0..97*		
Female	37.3	0.17	-1.05*		
Pooled	37.9	0.16	-1.05*		

* t_0 was calculated from the equation given by Pauly (1984)

Table 3. The length-weight relationship constants of *Merlangius merlangus euxinus* for each sex, pooled data and whole sampling period (a: intercept; b: slope; r: correlation coefficient).

Sampling Period	Male			emale			Pooled data		
	a	b	r	a	b	r	a	b	r
Apr 1990	0.0059	3.08	0.99	0.0059	3.09	0.99	0.0059	3.09	0.99
Sep 1990	0.0048	3.18	0.98	0.0047	3.19	0.99	0.0047	3.18	0.99
Sep 1991	0.0044	3.21	0.98	0.0041	3.23	0.99	0.0043	3.21	0.99
Oct 1992	0.0044	3.24	0.98	0.0037	3.30	0.99	0.0039	3.28	0.99
Jun92-May93	0.0051	3.20	0.99	0.0054	3.18	0.99	0.0052	3.19	0.99
Overall	0.0044	3.22	0.99	0.0040	3.25	0.99	0.0042	3.24	0.99

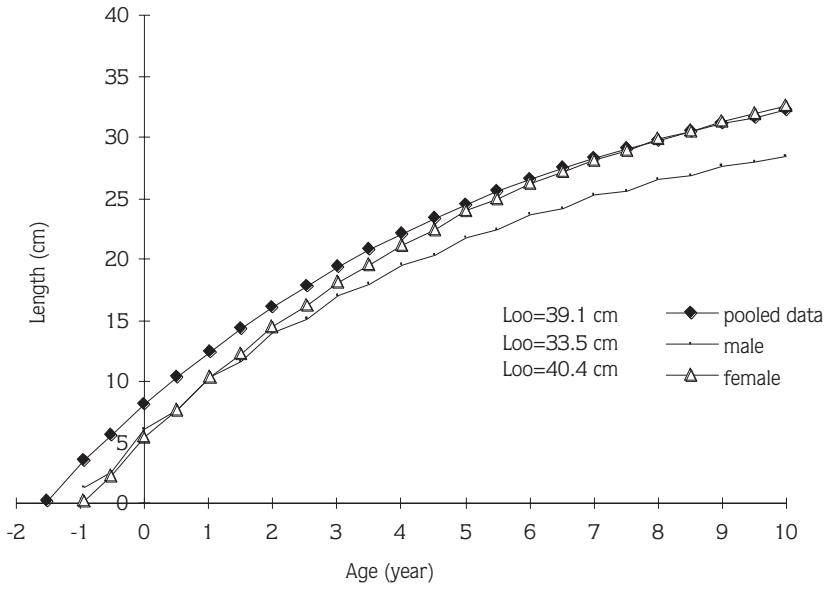

Figure 3. Calculated growth curve in length of whiting for each sex and their pooled data

The results of Munro's phi prime test and students t-test showed that the ∅' values obtained were not significantly different from that of available growth parameters estimated for Black Sea whiting (t-test, $P<0.05$).

The calculated and observed mean lengths for each sex and age group are given in Table 6. During the first year of life, individuals attain 26.5% of the asymptotic size and the growth rate over subsequent years becomes less rapid. Growth is rapid in both sexes for the first year, and the mean length at the end of the year is between 10 and 11 cm. Both males and females grow about 4 cm in the second year. As compared to the high numbers (7217 individuals) of the age groups I-II, only a few fish (140 individuals) could be found in age groups IV-IX to estimate growth. However, the available data suggest that the females continue to grow steadily at a rate of 2 or 3 cm per year until the eighth year, age group VII. The male fish grow less than the females after the second year, and the disparity in the mean length of the male and female fish for each age group increases with increasing age. Nearly all fish older than 3 years old (19 cm) were females.

Mortality estimates

The age composition data used in calculating the total mortality coefficients, Z, are given in Table 7. Data for the first age group has been excluded from all the analyses, since the first age group is not under full exploitation. The total (Z), natural (M) and fishing mortality rates (F) obtained on an annual basis for the whiting in Turkish Black Sea coastal waters are given in

Table 6. Observed and calculated mean lengths of whiting by age group for each sex and their pooled data.

	Age groups								
	I	II	III	IV	V	VI	VII	VIII	IX
Male									
Observed	10.8	13.9	16.8	21.0	-	25.8	-	-	-
Calculated	10.4	14.0	17.1	19.6	21.8	23.6	25.2	26.5	27.6
Female									
Observed	10.9	14.6	18.1	21.6	24.6	26.2	27.6	-	30.6
Calculated	10.3	14.5	18.1	21.2	23.9	26.2	28.2	29.9	31.3
Pooled data									
Observed	10.8	14.3	17.8	21.6	24.6	26.1	27.6	-	30.6
Calculated	12.4	16.1	19.3	22.1	24.5	26.5	28.3	29.7	31.2

Table 7. The age composition data used in calculation of the total mortality coefficients of the whiting

	Year			
Age group	1990	1991	1992	
I	1724	914	810	not used
II	984	576	545	
III	104	170	163	used in
IV	22	7	32	analysis
V	-	5	12	
VI	-	5	3	
VII	-	2	3	not used
VIII	-	-	-	
IX	-	1	-	

Table 8. The total mortality coefficients fluctuated between 1.29 and 2.18 with a mean value of 1.63 for all years (Table 8). The natural mortality coefficients show yearly fluctuations between 1990 and 1992. The natural mortality rates were highest in 1990 and lowest in 1992.

Tablo 8. Mortality coefficients for each year and for the whole period

Year	Z	M	F=Z-M
1990	2.18	0.43	1.74
1991	1.43	0.38	1.05
1992	1.29	0.36	0.93
Total	1.63	0.39	1.24

The magnitude of the change in the level of (F) is relatively higher than that of (M).

Biomass estimation

The computed total trawlable biomass in each depth range and local areas during four successive periods are presented in Table 9. The coverage includes a depth range of 0-100 m. The highest trawlable biomass was found in the region between Çaltı Cape and Sarp which is an area closed to trawl fishing. The trawlable biomass in April 1990 was found to be 696 tonnes between İğneada and Ereğli, 421 tonnes in Ereğli-Sinop and 33 tonnes in the Sinop-Çaltı Cape region. However, in September 1990, the biomass increased from 696 tonnes to 1637 tonnes between İğneada-Ereğli and 33 tonnes to 177 tonnes the Sinop-Çaltı Cape region; but decreased from 421 tonnes to 127 tonnes between Ereğli-Sinop. In September 1991, the trawlable biomass rose sharply and reached 17128 tonnes in the Çaltı Cape-Sarp region while the biomass was calculated to be 2104 tonnes in the Sinop-Çaltı Cape region. In October 1992, the same situation occurred; the biomass was found to be 8293 tonnes in the Sinop-Çaltı Cape region and rose to about three times (21894 tonnes) between Çaltı Cape and Sarp.

The total trawlable biomass was found to be lower in the depth range of 0-50 m than at 50-100 m, except for the Sinop-Çaltı Cape region in September 1991.

Table 9. Total trawlable biomass of whiting in the Turkish Black Sea Coast (q=1) by depth ranges (0-50 and 50-100 m) and local areas (I: İgneada-Ereğli; II: Ereğli - Sinop; III: Sinop- Çaltı Cape; IV: Çaltı Cape-Sarp).

		BIOMASS (tonnes)					
Periods	Depth (m)	Western Black Sea			Eastern Black Sea		
		I	II	Total	III	IV	Total
Apr 1990	0-50	19(±18)	-	19(±18)	1(±0)	-	-
	50-100	677(±211)	421(±226)	1098(±267)	32(±16)	-	-
	Total	696(±162)	421(±226)	1117(±168)	33(±15)	-	-
Sep 1990	0-50	-	-	-	52(±66)	-	-
	50-100	1637(±540)	127(±157)	1764(±453)	125(±97)	-	-
	Total	1637(±540)	127(±157)	1764(±453)	177(±77)	-	-
Sep 1991	0-50	-	-	-	1177(±488)	2580(±331)	3757(±407)
	50-100	-	-	-	928(±239)	14548(±2171)	15476(±1967)
	Total	-	-	-	2105(±467)	17128(±1832)	19233(±1465)
Oct 1992	0-50	-	-	-	1037(±357)	7402(±1547)	8439(±1134)
	50-100	-	-	-	7256(±1528)	14493(±3452)	21749(±2463)
	Total	-	-	-	8293(±973)	21895(±3036)	30188(±2297)

Discussion

The functional regression b value represents the body form, and is directly related to the weight affected by ecological factors such as temperature, food supply, spawning conditions and the characteristics of habitat within a year (21). The seasonal changes in the functional regression b values of Black Sea whiting (Table 3) are in agreement with the intensive spawning and nutrition period (25). In October, the body shape of whiting differed from its ideal form (in April, it displayed a more or less ideal form with the value of b=3.09) due to fattenning and the development of ovaries and testis before spawning. The minumum fattenning was observed after the shedding of gonads in winter.

The smallest condition for both sexes coincides with the intensive spawning period in January and February, during the least feeding period. According to İşmen and Bingel (26), their empty stomach ratio ranged from 18% to 44% throughout the year. In the winter months (especially February), the empty stomach rate increased to a maximum (44%). Therefore, it is clear that the feeding intensity was at its lowest level and the condition of fish reached the lowest value in this intensive spawning period. In fact these authors showed that in November and December, when the significant differences were found compared to March; the stomachs were mostly full in November and December and the gonad development increased sharply to a maximum in January.

The seasonally oscillating version of the von Bertalanffy growth function, which was modified by Pauly & Gaschutz (17) and Pauly & David (18) is derived from the assumption that fish generally grow faster during the period of higher water temperature than the period of lower temperature. By adding an oscillating term that follows a sine wave within a one year period, fluctuation in the annual growth rate is simulated. The inclusion of a sinusoid element into the von Bertalanffy growth function has the accuracy of estimated values of the growth parameters in cases of growth seasonality and the effect of considerably improving the fit of a growth curve. Gulland (27) stated that if samples taken during the high growth part of the year are interpreted as indicative of the overall growth rate K without consideration of seasonal modulation in growth, an upwardly biased K value will be estimated which may strongly affect estimates of yield per recruit, selection curves and the pattern of exploitation.

The conclusions drawn in this study about the growth characteristics for length are close to those of Burdak (8), Prodanov (9) and Uysal (15). The growth in length of whiting shows some fluctuations between 1964 and 1993. However, there are no comprehensive studies on the distribution of primary, secondary and tertiary production capacity in the Soviet, Bulgarian and Turkish coasts for these periods; this may be due to spatial and temporal changes in their different nutritional conditions.

The males of Black Sea whiting grow less than the females after the second year, and that disparity in the mean lengths of male and female fish in each age group increases with increasing age. This is in agreement with the observations of Burdak (8) and Bowers (28), who studied the breeding and growth of whiting from the Isle of Man waters. Bowers (28) stated that males grow less than the females after the second year and the difference in the mean length of males and females in each age group increases with increasing age. The differences between the mean length of males and females after the second year may possibly be due to the difference in the age of sexual maturity. İşmen & Bingel (29) showed that the whiting generally attains sexual maturity at age II, and there is a difference between sexes for length at first maturity (males at 12.5 cm length or at the end of their first year; females at 14.5 cm length or at the end of their second year).

The (Z) value calculated from the samples taken between İğneada and Civa Cape in April-September 1990 is higher than the (Z) values calculated from the 1991 and 1992 data collected between Sinop and Sarp. This may result from the limited fishing activity in September and October as compared to April (the end of the fishing season), and/or the closing of the Çaltı Cape-Sarp region in the eastern Black Sea to bottom trawl fishing. Uysal (15) reported that the fishing mortality rate (F) in the region (closed continuously to bottom trawling since 1973) is about 0.86. It is estimated to be 0.96 in the Sinop-Giresun region, where active fishing occurred. However, these estimates may not be significantly different since a single unit stock of whiting exists off the Turkish Black Sea coast (30), and whiting probably migrate between the closed area and other regions. The natural mortality rates found in the present study are somewhat different. This may be explained by the density of predators and competitors as Sparre et al. (20) stated. The same species may have different natural mortality

rates in different areas depending on the density of predators and competitors, whose abundance is influenced by fishing activities.

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