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Population parameters of sprat (*Sprattus sprattus phalericus* RISSO) from the Turkish Black Sea coast

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Abstract

Population parameters of the sprat (*Sprattus sprattus phalericus* RISSO), collected from the Turkish Black Sea cost between 1990 and 1992 were investigated. The mean annual growth rates in length and weight were 25.1 mm and 2.3 g, respectively. Von Bertalanffy growth constants were calculated as $W_\infty = 15.78$ (g), $L_\infty = 137.59$ (mm), $K = 0.42$ (year^{-1}) and $t_0 = -1.09$ (year). The growth parameters found in this study were compared with those from previous studies in the Black Sea and other areas. Total mortality rate and its components were $Z = 1.64$, $M = 0.73$ and $F = 0.91$. All mortality rates increased during winter–spring and decreased in autumn. A slight over-exploitation was found on the stock of the Turkish Black Sea sprat.

Keywords: Black Sea; Population structure; *Sprattus sprattus*

1. Introduction

The Black Sea provides considerable fish production for riparian countries (GFCM, 1989). The average annual landings of all fish from the Black Sea by Turkey, the former USSR, Romania and Bulgaria have increased during the last decade from 183 000 t in 1966–1970 to 401 000 t in 1976–1980 (Ivanov and Beverton, 1985) with a maximum nominal landing between 1980–1987 of 7 372 000 t (GFCM, 1989). During 1985–1989, catches were dominated by sprat, horse mackerel and anchovy which together comprised 89% of total landings (GFCM, 1989). At the beginning of the 1970s, the most important fish species was anchovy, followed by horse mackerel and sprat. During 1976–1980, sprat catches sometimes exceeded those of horse mackerel, for example the Soviet sprat fishery has increased twenty fold in the last decade and the increasing trend continues (Shul'man et al., 1987). The sprat fishery, with a total annual catch ex-

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ceeding 1 053 000 t in 1989, has become one of the most important in the Black Sea (GFCM, 1989).

There are studies on the biology and population dynamics of Atlantic sprat (*Sprattus sprattus sprattus*) and Baltic Sea sprat (*Sprattus sprattus balticus*) by Iles and Johnson (1962), Johnson (1970); Lopez Veiga (1976); (1978); (1979); Grygiel (1978); Rechlin and Groth (1979) and Bailey (1980), but few on the age and length of the Black Sea sprat (*Sprattus sprattus phalericus* RISSO); the principal contributions are those of Berg et al. (1949); Aslanova (1954); Domashenko and Yurev (1978) for the northern Black Sea, Cautis (1971) for the Romanian coast, and Stoyanov (1965); Ivanov (1983) and Ivanov and Beverton (1985) for the Bulgarian coast. In spite of the considerable information regarding the importance of this sub-species, data on its population parameters for the Turkish Black Sea coast are scarce.

The main purpose of this study is to collect comprehensive information on the population dynamics of sprat together with identification of its population parameters along the Turkish Black Sea coast.

2. Materials and methods

Collections were made from 57 sampling stations located along the continental shelf of the Turkish Black Sea coast (Fig. 1). Stations were sampled using midwater and bottom trawl nets. Bottom trawling was done by R/V "BILIM" from April 1990–September 1990. In September 1991 sampling was performed by R/V "SURAT-1". In December 1990 and January 1992, the first and second midwater trawl surveys were carried out, respectively. Each hauling period was normally restricted to 30 min, but sometimes was changed due to the sea bed topography.

On board the fish were sorted by species. In poor hauls, the total catch was taken as the sample size for further analyses. For abundant catches, sub-sampling was carried out according to the procedure described by Holden and Raitt (1974). Samples were preserved in 10% formalin solution buffered with borax (Ferrerio and Labarta, 1938).

The following examinations were carried out within 2 months of sampling. Total length measurements were made to the nearest millimeter with each fish lying on its right side with the mouth closed. Total length measurement ranges and number of specimens of either sex analysed for each sampling period are presented in Table 1.

Sex was determined by internal examination. In mature specimens, sex differentiation was possible with the naked eye. Those individuals having reproductive organs of a white or grey colour which when flattened to a knife edge shape displaced the ventral edge to be waved, were considered as males. Specimens which had pink tubular and granular gonads were identified as female. In young individuals, sex differentiation was possible by means of a binocular microscope. Sex

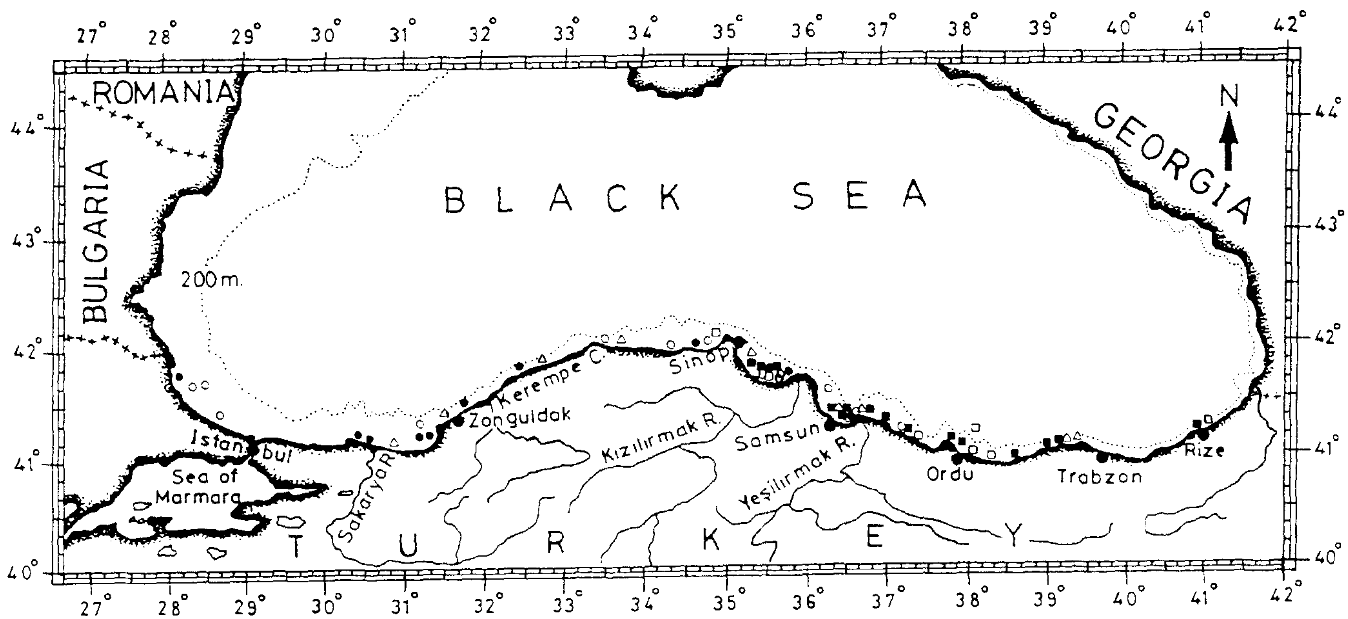

Fig. 1. Location of the sampling stations along the Turkish Black Sea coast. ●, April 1990; ○, September 1990; □, December 1990; ■, September 1991; △, January 1992.

Table 1
The minimum (Min) and maximum (Max) total length measurements (mm) and number of specimens examined (n) in each sex and in each sampling period

Sampling period	Juvenile		Male		Female		Examined fish
	Min–Max	(n)	Min–Max	(n)	Min–Max	(n)	
April 1990	– –	–	58–130	190	58–120	344	534
September 1990	34–46	17	51–119	159	52–125	427	603
December 1990	28–45	37	34–105	118	35–112	238	393
September 1991	– –	–	69–130	47	65–141	295	342
January 1992	– –	–	48–119	887	49–137	1427	2314
Total	28–46	54	34–130	1401	35–141	2731	4186

determination was not possible in some small specimens, which were recorded as juvenile.

Both sagittal otoliths were used together with cleithra for age determination of a single fish. Cloudy or chalky surfaced otoliths were rapidly dipped in a 20% solution of HCL before placing them in water (Chilton and Beamish, 1982). The surface of an otolith was then examined under a binocular microscope (magnification ×20). After immersing the otolith, contained in a petri dish, in glycerine it was studied using a bottom light source. Some otoliths were difficult to read because of their transparency, intense calcification or indistinct rings, and could not be aged. In such cases, besides the otolith, the cleithra was also used for age determination. Growth bands which appeared in the otolith or cleithra as opaque and translucent were accepted as occurring annually.

The length–weight relationship was studied using the formula given by Pauly (1983). Fulton's condition factor was calculated according to the descriptions given by Ricker (1975). For the estimation of individual growth rate, Von Bertalanffy growth equations for length and weight were used. The Ford–Walford plot technique (length–age data) given by Sparre et al. (1989) was used for the estimation of growth parameters. The reliability of these growth parameters was tested applying the 'Munro's phi prime (ϕ') test together with the t test as described by Sparre et al. (1989). The survival rate from the age series (Ricker, 1975) was used for the calculation of the instantaneous total mortality coefficient (Z). Estimation of the instantaneous natural mortality coefficient (M) was made using the formula given by Ursin (1967). The exploitation rate was calculated from the formula provided by Pauly (1984).

3. Results

3.1. Length–weight relationship

The length–weight relationship obtained from the length ranges of individuals given in Table 1 for each sex and the pooled data for different sampling periods are given in Table 2.

Table 2
Length–weight relationship constants (a is intercept, b is slope and r is correlation coefficient) for each sex and their pooled data for each sampling period

Sex sampling period	Male			Female			Pooled data		
	(a)	(b)	(r)	(a)	(b)	(r)	(a)	(b)	(r)
April 1990	0.0037	3.12	0.99	0.0033	3.19	0.98	0.0033	3.18	0.98
September 1990	0.0019	3.51	0.99	0.0017	3.55	0.99	0.0018	3.54	0.99
December 1990	0.0025	3.39	0.99	0.0023	3.46	0.99	0.0022	3.48	0.99
September 1991	0.0023	3.38	0.99	0.0014	3.64	0.98	0.0014	3.61	0.98
January 1992	0.0044	3.09	0.99	0.0046	3.08	0.99	0.0043	3.10	0.99
Overall	0.0031	3.23	0.99	0.0025	3.35	0.99	0.0026	3.33	0.99

Table 3
Fulton's condition factor for each sex and their pooled data for different sampling periods

Sex sampling period	Male	Female	Pooled data
April 1990	0.0059	0.0059	0.0059
September 1990	0.0063	0.0065	0.0067
December 1990	0.0055	0.0059	0.0058
September 1991	0.0070	0.0074	0.0072
January 1992	0.0051	0.0053	0.0056
Overall	0.0060	0.0065	0.0065

Allometric growth was observed in the growth characteristics of Black Sea sprat (Table 2). In January 1992, both sexes showed more or less 'ideal' body form, while in September 1990 and 1991 they displayed mostly positive allometric form. Their body form in April and December of 1990 was morphologically positioned between the form of January 1990 and September 1990 and 1991 respectively (Table 2).

Because of their allometric growth characteristics, Fulton' s condition factor estimated for each sex and for their pooled data in all sampling periods, can be calculated (Table 3).

Females had higher Fulton condition factors than males for each sampling period between April 1990 and January 1992 (Table 3), implying that the females were always in better condition than the males. However, some seasonal fluctuation was observed in the Fulton condition factor for both sexes. Both males and females exhibited highest condition factors in September before their intensive spawning period. A decreasing trend in the condition of both sexes was seen in December at the onset of their most intensive spawning period with lowest condition occurring in January. After this period, they started to regain their condition in April.

3.2. Change in length

Von Bertalanffy growth constants for both sexes of Black Sea sprat were calculated and are shown in Table 4.

Since the Von Bertalanffy growth parameters obtained for each sex are close to each other, pooled data were used to reach the following conclusions. Some studies on the Von Bertalanffy growth constants of the Black Sea sprat are presented in Table 5.

Comparisons of the growth parameters obtained for the length of Black Sea sprat applying the Munro's phi prime test showed that there is no significant difference (t test; $P > 0.05$) between the overall growth performances of the sprat sampled from the former Soviet, Romanian, Bulgarian and Turkish coasts.

Von Bertalanffy length–growth constants calculated for the Atlantic Ocean and Baltic Sea sprat are given together with the results of this study in Table 6.

The Munro's phi prime test implied that there was not only no significant difference (t test; $P > 0.05$) between the growth of sprat sampled from the Black Sea and Mediterranean, but also for sprat sampled from the Black Sea and those of the Atlantic Ocean and Baltic Sea. However, the estimated L_∞ of *S. Sprattus phalericus* population along the Turkish Black Sea coast seems to be smaller, not only than that found for the Atlantic Ocean sprat (*S. sprattus sprattus*), but also than that estimated for the Baltic sprat (*S. sprattus balticus*) (Table 6). Among these studies, there is only one value estimated by Robertson (1938, cited in Pauly, 1978) which deviated from the generally observed trend. The calculated value of

Table 4
Von Bertalanffy growth constants of Black Sea sprat

Sex	L_∞ (mm)	K (year^{-1})	t_o (year)
Male	139.76	0.38	−1.20
Female	137.70	0.42	−1.13
Pooled data	137.59	0.42	−1.09

Table 5
Von Bertalanffy length–growth constants and ϕ' values of the Black Sea sprat

Author	Sampling location	L_∞ (cm)	K (year^{-1})	t_o (year)	ϕ'
Berg et al. (1949)	Soviet coast	11.9	0.31	−0.83	1.64
Aslanova (1954)	Soviet coast	18.0	0.14	−2.50	1.66
Domeshenko and Yurev (1978)	Soviet coast	11.3	0.45	−0.76	1.76
Cautis (1971)	Romanian coast	14.6	0.28	−1.60	1.78
Stoyanov (1965)	Bulgarian coast	14.3	0.22	−2.97	1.65
Ivanov (1983)	Bulgarian coast	13.4	0.45	−1.13	1.91
Present study	Turkish coast	13.8	0.42	−1.09	1.90

Table 6
Von Bertalanffy length-growth constants and ϕ' values calculated for the Atlantic Ocean and Baltic Sea sprat

Location and author	Sampling area	L_∞ (cm)	K (year^{-1})	t_0 (year)	ϕ'
Atlantic Ocean					
Sund (1911)[a]	Norwegian coast	16.0	0.65	-	2.22
Robertson (1938)[a]	North Sea	13.0	0.70	-	2.27
Porche (1976)[a]	Gulf of Biscay	17.5	0.30	-	1.96
Iles and Johnson (1962) (Early spawners)	Western England	16.4	0.53	(0.40)	2.15
Iles and Johnson (1962) (Late spawners)	Western England	14.0	0.63	(−0.20)	2.09
Lopez Veiga (1979)	Galicia	17.3	0.60	−0.04	2.25
Baltic Sea					
Honendorf (1966)[a]	Kiel Bight	14.9	1.02	−0.04	2.36
Grygiel (1978)	Baltic Sea (Gdansk)	(14.2)	(0.62)	(−0.06)	2.10
Grygiel (1978)	Baltic Sea (Bornholm)	(14.7)	(0.71)	(0.07)	2.19
Mediterranean Sea					
Furnestin (1948)[a]	Southern France	14.2	0.36	−2.30	1.86
Zavodnik (1969)[a]	Northern Adriatic	14.4	0.45	-	1.97
Present Study	Turkish Coast	13.8	0.42	−1.09	1.90

[a]Cited in Pauly, 1978.
Figures in parentheses were obtained using simple mean of a given range.

the growth coefficient K in this study lies in the mid-range of those calculated by several western authors for various sprat stocks inhabiting the North Sea and Baltic Sea (Table 6).

The calculated and theoretically estimated mean lengths for each sex and age group are given in Table 7.

A more rapid growth in length at an early age is characteristic of Black Sea sprat (Table 7), which attains 58% of the asymptotic length during the first year of life. After the first year, the annual growth increment reduces drastically (Fig. 2), and from the first year to the second, the growth was 14% of the asymptotic length. Growth was calculated as 9.4%, 6.2%, and 4.1% between second and third, third and fourth, and fourth and fifth years respectively.

Observed and calculated mean total lengths of Black Sea sprat by age group in the present study and those obtained by other scientists from Black Sea countries are given in Table 8.

The Black Sea sprat rarely lives for more than 5 years (Table 8), and its mean length at a given age is much smaller than that of the Atlantic form (*Sprattus sprattus sprattus*) (Wheeler, 1969). The mean annual growth rate of Black Sea sprat for the Turkish coast has been calculated as 25 mm in the present study,

Table 7
Observed and calculated mean lengths (total length mm) of sprat for each age group, sex and their pooled data

Character length (mm)	Age groups (years)					
	0	1	2	3	4	5
Male						
Observed	51.53	78.71	99.09	111.58	118.22	126.60
Calculated	50.87	78.71	97.83	110.96	119.98	126.18
Female						
Observed	50.86	81.16	100.58	111.48	117.90	128.22
Calculated	51.83	81.16	100.47	113.18	121.56	127.07
Pooled data						
Observed	49.67	80.19	100.20	111.47	117.93	127.87
Calculated	50.32	80.19	99.83	112.76	121.26	126.84

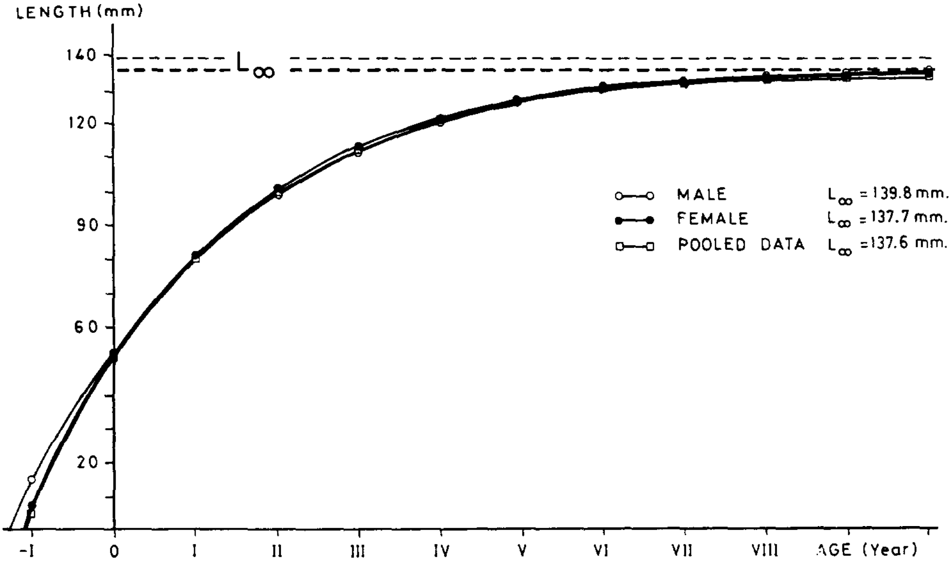

Fig. 2. Calculated growth curve in length of Black Sea sprat for each sex and their pooled data.

which is close to the value of 28 mm given by Stoyanov (1965) and corresponds with that attained by Ivanov (1983) for the Black Sea sprat from the Bulgarian coast, and lies near the value of 29 mm calculated by Cautis (1971) for this species on the Romanian coast.

3.3. Change in weight

The observed and calculated mean weights for each age group and pooled mean weights are presented in Table 9. The annual growth rate in terms of weight was

Table 8
Comparison of the observed and calculated mean length (total length in mm) of Black Sea sprat for different age groups obtained in the present study with other investigators

Region and character	Age groups (years)						Author
	0	1	2	3	4	5	
Bulgarian coastal area							
Observed	–	82.0	94.0	103.0	111.0	–	Stoyanov
Calculated	–	82.1	93.8	103.3	111.0	–	(1965)
Observed	–	83.0	102.0	113.0	120.0	126.0	Ivanov
Calculated	–	82.7	101.3	113.2	120.8	125.6	(1983)
Romanian coastal area							
Observed	–	75.5	91.9	107.0	115.6	–	Cautis
Calculated	–	75.7	92.9	105.9	115.7	–	(1971)
Turkish coastal area							
Observed	49.7	80.2	100.2	111.5	117.9	127.9	Present
Calculated	50.3	80.2	99.8	112.8	121.3	126.8	study

Table 9
Observed and calculated mean weight (total weight g) of sprat for different age groups in each sex and their pooled data

Character weight (g)	Age groups (years)					
	0	1	2	3	4	5
Male						
Observed	0.68	2.52	5.36	8.39	10.05	11.18
Calculated	0.59	2.40	4.84	7.28	9.37	11.02
Female						
Observed	0.66	2.79	5.86	8.71	10.47	12.97
Calculated	0.61	2.75	5.61	8.36	10.62	12.32
Pooled data						
Observed	0.62	2.68	5.74	8.68	10.43	12.58
Calculated	0.55	2.61	5.42	8.13	10.36	11.02

found to be at a maximum between the first and second year (3 g) which corresponds to 19% of the asymptotic weight ($W_\infty = 15.8$ g). After completion of the second year, the annual growth rate decreased to 17%, 14% and 11% of the asymptotic weight between ages 2–3 years, 3–4 years, 4–5 years, respectively due to the decrease in the catabolism to anabolism ratio.

For all age groups, the annual growth increment of sprat was found to be 2.1 g. The increment from age zero to the first age group was smaller than those for the following years. The inflection point of the theoretical growth curve for sprat corresponds to 2.5 years of age, equal to 107 mm or 6.7 g (Fig. 3). It is clear that, the fishing of individuals smaller than 6.7 g (107 mm) is not economically viable for obtaining maximum sustainable yield of the Black Sea sprat stock.

The estimated growth parameters in weight of Baltic Sea and Atlantic Ocean sprat by some authors together with values found in the present study are presented in Table 10.

Considering the growth characteristics in weight of the Baltic Sea, Atlantic Ocean and Black Sea sprat, it can be stated that Black Sea sprat (*S. sprattus phalericus*) and Baltic sprat (*S. sprattus balticus*) have more or less the same asymptotic weight, whereas the Atlantic form (*S. sprattus sprattus*) has the heaviest asymptotic weight among the sub-species of this fish.

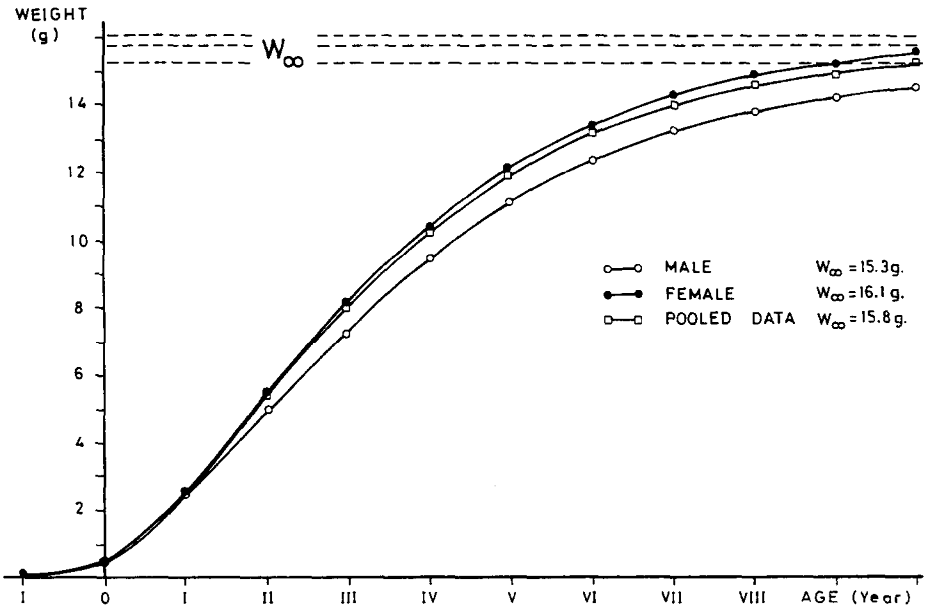

Fig. 3. Calculated growth curve in weight of Black Sea sprat for each sex and their pooled data.

Table 10
Estimated growth parameters in weight of Baltic Sea and Atlantic Ocean sprat

Author	Sampling location and period	W_∞ (g)	K (year^{-1})	t_o (year)
Rechlin and Groth (1979)	Baltic Sea (1964–1970)	14.59	0.443	−1.606
Rechlin and Groth (1979)	Baltic Sea (1971–1978)	17.86	0.451	−1.436
Grygiel (1978)	Baltic Sea (1974–1977)	20.12	0.539	0.050
Johnson (1970)	North Sea	27.00	0.650	1.170
Bailey (1980)	North Sea	22.70	0.530	–
Present study	Turkish Black Sea Coast	15.78	0.419	−1.087

3.4. Mortality estimates

The instantaneous total, natural and fishing mortality rates for each sampling period and over the entire study period are presented in Table 11.

The calculated total mortality coefficients for each sampling period show fluctuations between 0.95 and 2.62 with respect to the sampling season. The (Z) values for September 1990 and 1991, before the start of the fishing season, are smaller than those for the remaining sampling periods (Table 11). The Z value is high at the beginning of the fishing season (December 1990), reaching its maximum towards mid-season (January 1992), and decreasing again at the end of the fishing season (April 1990) (Table 11). This is of course mainly due to observed changes in the instantaneous fishing mortality rates for the related sampling periods.

Instantaneous natural mortality rate fluctuated between 0.58 and 1.12 with a mean value of 0.73 for all sampling periods (Table 11). Instantaneous natural mortality rates were highest in December and lowest in September.

The mortality components (Z, M and F) obtained on an annual basis are given in Table 12. This calculation is based on the whole data set for the year (1990) and is not a simple mean of values given in Table 11).

Mortality coefficients show yearly fluctuations between 1990 and 1992. The magnitude of the change in the level of (F) is relatively higher than that of (M), which implies that, natural mortality is relatively stable but affects the total mortality rates.

Table 11
Mortality components for each sampling period and for the whole period

Period	Z	M	$F=Z-\mathrm{M}$
April 1990	1.69	0.61	1.08
September 1990	1.16	0.60	0.56
December 1990	1.79	1.12	0.67
September 1991	0.95	0.58	0.37
January 1992	2.62	0.72	1.90
April 1990–January 1992	1.64	0.73	0.91

Table 12
Mortality coefficients for Z, M and F

Year	(Z)	(M	($F=Z-M$)
1990[a]	1.32	0.66	0.66
1991	0.95	0.58	0.37
1992	2.62	0.72	1.90

[a]This calculation is based on the whole data set for the year (1990) and is not a simple mean of values given in Table 11.

3.5. Exploitation rate

Exploitation rates fluctuated between 0.4 and 0.7 during 1990 to 1992, indicating optimum exploitation of sprat stock in 1990, under exploitation in 1991 and high over exploitation in 1992. However, the overall exploitation rate for the period 1990–1992 implies that there is slight over fishing ($E=0.55$) on this stock.

4. Discussion

In allometric growth condition, the functional regression value b represents the body form and it is directly related to the weight which is affected by some ecological factors such as temperature, food supply, spawning conditions and the characteristics of biotope etc. within a year (Ricker, 1975). However, in an isometric growth condition, a fish has an unchanging body form and specific gravity (Ricker, 1975). The annual variation in the functional regression b-value of sprat shows good correlation with their intensive spawning (Ivanov and Beverton, 1985) and nutrition period (Caspers, 1957, Sorokin, 1983; Ivanov and Beverton, 1985 and Shchepkin and Minyuk, 1987). Indeed, in September, the body shape of sprat was different from its ideal form (isometric growth condition) due to fattening owing to the development of ova in the ovaries and sperm in the testes prior to intensive spawning. In December, the body starts to get thinner and in January approaches its minimum due to the shedding of gonads.

The highest condition for both sexes coincides with the most intensive feeding rate in September, during their pre-intensive spawning period. The loss of condition in both sexes is probably associated with intensive egg and sperm production (Ivanov and Beverton, 1985) and the reduced feeding rate during winter (Shchepkin and Minyuk, 1987). Thereafter, their feeding rate starts to increase in April (Caspers, 1957; Sorokin, 1983; Ivanov and Beverton, 1985 and Shchepkin and Minyuk, 1987), causing them to regain their condition as seen from the April samples.

The only study concerning the length–weight relationship of Black Sea sprat was carried out by Ivanov and Beverton (1985). The computed mean values of a and b in the present study and those found by Ivanov and Beverton (1985) using sprat sampled from the Black Sea coast of Bulgaria and are presented in Table 13.

Table 13
Mean values of a and b for the Black Sea sprat

	Ivanov and Beverton (1985)		Present study	
	a	b	a	b
Isometric growth	0.0058	3	0.0065	3
Allometric growth	0.0090	2.81	0.0026	3.33

In isometric growth the values of *a* are close to each other, suggesting that the Black Sea sprat inhabiting the coasts of Turkey and Bulgaria are of similar condition. However, in allometric growth the difference between the values of *b* may possibly be due to physiological differences between samples. In addition to this, no indication is given regarding sampling time or the length or age distribution of samples used by Ivanov and Beverton (1985).

No significant differences (*t* test; $P > 0.05$) between the growth performances of Black Sea sprat, Atlantic Ocean sprat and Baltic Sea sprat were observed. However in agreement with previous studies, growth performances were seen to increase slightly at higher latitudes. This trend could possibly be due to different environmental conditions with varying temperatures. In the following, the identification of possible differences not detected statistically on the growth performances of this species from different areas will be discussed.

The lowest L_∞ values calculated by Berg et al. (1949) and Domashenko and Yurev (1978) given in Table 5 probably originated from the differences in the length measurement techniques used. Indeed, total length measurement is used in the present study and in those of Aslanova (1954), Stoyanov (1965) and Cautis (1971), while there is no information on the type of length measurement adopted by Berg et al. (1949) and Domashenko and Yurev (1978). It is highly probable that they used standard length in their studies. In the present study, when standard length is used for estimating Von Bertalanffy length–growth constants, then the L_∞ value is found to be $L_\infty = 11.7$ cm. Additionally, in the data sets of Aslanova (1954), Stoyanov (1965) and Cautis (1971), the values of *K* are consequently low, which might not directly be characteristic of short lived pelagic species like sprat, since the short-lived species should have a steep growth curve with a high value of *K* (Sparre et al., 1989).

The conclusions drawn in this study about the growth characteristics are in good agreement with those of Ivanov (1983), but are different than those given by Stoyanov (1965) and Cautis (1971). Growth in length of Black Sea sprat shows some fluctuations between 1965 and 1991, possibly due to spatial and temporal changes within their different nutritional conditions. However there are no comparative studies on the distribution of primary or secondary production capacity off the Romanian, Bulgarian and Turkish coast for the related period.

Some variations in the growth characteristics of sprat populations from one local area to another within the Black Sea, Adriatic Sea, eastern coast of the Atlantic and also the Baltic Sea, most likely result from the differences in temperature and the quantity and quality of food. However, the reason for the differences in growth parameters, calculated from data collected at different times from the same area could possibly have resulted from annual variations in mean length or weight with age.

The mean weight at any age of the Atlantic sprat given by Bailey (1980) is more than twice that of the Black Sea sprat, and the identified ages by Bailey (1980) from North Sea data have relatively wide ranges (10 years) compared with those of the present study (5 years), which may imply that Atlantic sprat has a longer life span than the Black Sea sprat.

The reason for the lowest (Z) values occurring in both Septembers (1990 and 1991) may be the sampling season itself. According to Demir and Southward (1974) sprat is fished together with other small pelagic species, such as sardines (*S. pilchardus* and *S. aurita*), anchovy (*E. encrasicolus*) and Black Sea shad (*A. fallax nilotica*) along the western coast of the Turkish Black Sea. Amongst these species, sardines and Black Sea shad were fished in the same area throughout the year (Kosswig and Turkmen, 1955). However, the fishing season for sardines as stated by Artuz (1976), is from May to July and the annual landings of European pilchard and also the shad are relatively smaller than that of sprat and anchovy (GFCM, 1989). Therefore, the amount of sprat landed as a by-catch of European pilchard and Black Sea shad can be ignored. On the other hand, the annual landings of anchovy were about 4 or 5 times higher than those of Black Sea sprat between 1976 and 1989 (GFCM, 1984; 1989) hence, it is most probable that sprat is confused with anchovy, since the fishing season of Black Sea anchovy takes place from early November to April (Sahin, 1976; Kara, 1980), and from November to March (Artuz, 1976). In any case, the main fishing season for anchovy can be taken to be from late autumn to early spring. As the fishing seasons for anchovy and sprat are confined to the same time period, it can be stated that there is no active fishery in September. Therefore, the low estimates are due to either zero or limited fishing activity in September, as compared to December 1990, April 1990 and January 1992.

Disregarding the September sampling periods where low fishing intensity (f) prevails, the mortality rates given by Ivanov and Beverton (1985) and those in the present study are similar. However, higher mortality rates found during this investigation probably result from a wider age range (0–5 years) used as compared to that adopted by Ivanov and Beverton (1985) (only age groups 1–3 years).

The calculated (M) values displaying maximum levels in December and minimum in September may be due to the composition of samples. Avsar (1993) found that the age group (O) dominated the samples of December 1990, while older individuals comprised the majority of September 1991 samples. Since predation of younger individuals of a particular fish species is much higher than that of older ones, there exists a critical size for each species (Barnes and Hughes, 1988). However, more rapid growth in length at early ages of Black Sea sprat favours the younger generations surviving to outgrow this critical phase. This can be illustrated by using the mean length (l) and (M) values for each sampling period. The computed mean lengths and instantaneous natural mortality rates (M) for each sampling period are given below:

Table 14
Mean lengths (l) and instantaneous natural mortality rates (M) for each sampling period

Period	l (cm)	Rank	M	Rank
April 1990	9.2	3rd	0.61	3rd
September 1990	9.6	4th	0.60	4th
December 1990	4.9	1st	1.12	1st
September 1991	10.4	5th	0.58	5th
January 1992	8.2	2nd	0.72	2nd

In Table 14, there is an inverse relationship between the mean length and corresponding instantaneous natural mortality rate (M) for all sampling periods. Indeed, the rank of mean lengths agrees with that of instantaneous natural mortality rates for all sampling periods.

The relatively higher (M) values in the winter (December and January) period may be explained by predation. Sprat is consumed intensively by whiting (*Merlangius merlangius*) (Gordon, 1977; Arntz and Finger, 1981; Ivanov and Beverton, 1985; Patterson, 1985 and Casey et al., 1986), and also by piked dogfish (*Squalus acanthias*) (Ivanov and Beverton, 1985). These authors stated that piked dogfish and whiting feed intensively in winter and spring respectively, so the effect of these two predators on their prey reaches its maximum then.

Due to the drastic decrease in anchovy catches, the fishing fleets of the Black Sea countries direct much of their effort to sprat or horse mackerel resources because of their relatively higher abundance. Indeed, since the anchovy stock decreased there was a considerable increase in sprat catches between 1990–1992 and the shift of the fishery from anchovy to, sprat resulted in slight over-fishing of sprat.

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