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Growth parameters of the Black Sea sprat (Sprattus sprattus L.) during the period 1998 – 2000 along the Bulgarian Black Sea coast

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1. Introduction

The age structure and growth rate of the Black Sea sprat are subject of long-term investigations by number of authors – Stoyanov (1953, 1965, 1966), Ivanov (1983, 1991, 1992), Prodanov, Daskalov (1992), Daskalov, Prodanov (1994), Prodanov et.al. (1997) with aim to clarify qualitative and quantitative structure of catches, which represent state of the stocks, as well as the impact of abiotic and biotic factors of the environment on them (Ivanov, 1983).

Black Sea sprat is one of the most abundant fish species in the black Sea, which became a target for fisheries at the beginning of 70's. During the period 1972-1997, Bulgarian catches of sprat range from 2174 (1993) to 18800 tones (1981), (FAO Yearbook for Fishery Statistics, 1997). Since 1981, sharp decline of catches has been recorded - about 2.5 fold and only just previous few years, catches show slow raising – 3646 tones (1997). The drop in catches has been attended with sharp decline in sprat stocks, particularly after 1989 and which is related to preceded overfishing and ctenophore *Mnemiopsis leidyi* expansion (Daskalov, Prodanov, Shljakhov, Maxim, 1996).

The goal of the present paper is to investigate the growth rate of the Black Sea sprat along the Bulgarian Black Sea coast during the period 1998-2000 and comparing of the obtained results with foregoing investigations.

2. Material and methods

There are used data for size and age composition of sprat obtained from monthly collected samples from commercial catches during the followng periods:

(1) March 1998
(2) April - October 1998
(3) November 1998 – March 1999
(4) April – October 1999
(5) November 1999 – March 2000

The total length (L) and weight (W) are measured and the age is determined by reading otolits. The total number of investigated individuals is 15019. The size and age structure are examined by months and subsequently the obtained data are averaged by periods. The selection of periods is relevant to species biology – mass spawning during autumn and winter (October – March) and intensive growth and fattening during spring and summer (April – September).

Parameters L_∞, k and t_o are estimated by von Bertalanffy growth equation (1938):

$$L_t = L_\infty \left\{1 - \exp\left[-k\left(t - t_0\right)\right]\right\} \quad (1)$$

where: L_t is the length of fishes at age t; L_∞ - asymptotic length, k – Brody growth coefficient, t_o – age at zero length.

For establishment of weight-length relationship the following equation is used:

$$W = a*L^n \quad (2)$$

where: W – weight (in g); L –length (in cm); a - coefficient; n- coefficient, characterizing the growth rate.

The condition factors (c.f.) are computed by Fulton's index (Ricker, 1975):

$c.f. = W*100/L^3$ (3)

where: W – average weight by size groups; L – average length by size groups.

3. Results and discussion

The input data for average lengths and weights of sprat by periods are given in Table 1.

According to data in Table 1 and using Equation (2), the coefficients a and n, characterizing weight-length relationship, have been estimated. The obtained results are given in Table 2.

From the results, given in Tabl.2, it is seen that the sprat growth is alometric during the investigated periods and the correlation coefficient is highest for the period November 1998 – March 1999 - $r^2 = 0.999$. For the rest periods, this coefficient varies from 0.991 to 0.997. The rates of the parameter n, which characterizes growth, range between 2.750 and 3.296. The obtained results are close to those, calculated by I v a n o v (1983) for the period 1976-1981: a= 0.009, n= 2.81.

According to the calculated theoretical

Table 1. Average lengths (in cm) and weights (in g)of Black Sea sprat by periods.

L, cm	W, gr.				
	(1)	(2)	(3)	(4)	(5)
5.5		0.88			
6.0		1.17		1.28	
6.5		1.47	1.52	1.65	
7.0		1.81	1.96	1.99	2.144
7.5	2.54	2.21	2.39	2.32	2.46
8.0	2.92	2.92	2.82	2.90	3.07
8.5	3.27	3.49	3.36	3.66	3.63
9.0	3.83	4.14	4.03	4.39	4.12
9.5	4.69	4.69	4.64	4.93	4.71
10.0	5.52	5.99	5.28	5.52	5.46
10.5	6.21	6.97	6.12	6.18	6.36
11.0	6.59	8.56	7.12	7.16	7.62
11.5	8.06	9.60	8.11	8.37	8.35
12.0		11.82	9.62	8.6	
12.5			11.17		9.41

Note: (1) March 1998
(2) April - October 1998
(3) November 1998 – March 1999
(4) April – October 1999
(5) November 1999 – March 2000

Table 2. Values of coefficients a and n in equation (2) by periods.

Coefficients	PERIODS				
	(1)	(2)	(3)	(4)	(5)
A	0.009137239	0.003062083	0.006091426	0.0096189795	0.011291223
N	2.770	3.296	2.953	2.750	2.690
R	0.997	0.999	0.999	0.991	0.994
r^2	0.994	0.998	0.998	0.945	0.973

Note: Periods are the same as in Table 1

weights and by using of Equation (3), the Fulton's condition factors by size groups and by period are estimated – Table 3.

It is seen from Table 3, that during first (March), third (November 1999 – March 2000) and fifth (November 1999 – March 2000) periods, the relationship between average lengths and Fulton's indexes (c.f.) is inversely proportional – i.e. the c.f. decreases with rise in length. This regularity probably is due to the fact, that during the winter, sprat mass spawns and use up the greater part of its energy for forming of sex products and less part – for body growth in length and weight. The more so as the spawning period of sprat is highly long-winded – from October to March, which from other part ensures better possibility for larvae survival. During the second period (April – October), the Fulton's index increases proportionally with rise in length and vary from 0.5071 to 0.6541. During the forth period (April – October 1999), c.f. decreases with growth in lengths – from 0.6282 to 0.5066. According to Ivanov (1991), the distribution and behavior of different size and age groups determine dynamics in length and weight sizes of sprat. During the winter and spring, larger individuals of 1-aged fish usually compose catches, while during the period July – October the bottom sprat concentrations are formed by individuals, which at 1-year age had smaller lengths. Up to age of 2 and 3 years old, have survive or stay in front of Bulgarian coast the smaller individuals at age of 1 and 2 years (Ivanov, 1991). This probably is the reason for decrease in Fulton's index for sprat during the period April – October 1999.

On the Fig. 1 is shown the relationship between sprat length and Fulton's index by periods.

The parameters in von Bertalanffy equation (1) computed in terms of length for the periods November 1998 – March 1999 (3^{rd} period, winter) and April – October 1999 (4^{th} period, summer) were estimated from mean lengths at age data and give following growth equations:

Table 3. Estimated theoretical average weights (in g) and values of condition factor (c.f.) for the Black Sea sprat by size groups and periods.

L,cm	W					c.f.				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
5.5	1.028	0.844	0.936	1.045	1.107	0.618	0.507	0.563	0.628	0.665
6.0	1.308	1.124	1.210	1.328	1.399	0.605	0.520	0.560	0.615	0.648
6.5	1.632	1.463	1.533	1.655	1.735	0.594	0.533	0.558	0.603	0.632
7.0	2.004	1.868	1.908	2.029	2.118	0.584	0.545	0.556	0.591	0.617
7.5	2.426	2.345	2.339	2.452	2.549	0.575	0.556	0.555	0.581	0.604
8.0	2.901	2.901	2.831	2.929	3.033	0.567	0.567	0.553	0.572	0.592
8.5	3.432	3.542	3.386	3.460	3.570	0.559	0.577	0.551	0.563	0.581
9.0	4.021	4.277	4.008	4.049	4.163	0.552	0.587	0.550	0.555	0.571
9.5	4.670	5.111	4.702	4.698	4.815	0.545	0.596	0.549	0.548	0.562
10.0	5.383	6.052	5.471	5.410	5.493	0.538	0.605	0.547	0.541	0.549
10.5	6.163	7.108	6.320	6.187	6.302	0.532	0.614	0.546	0.534	0.544
11.0	7.010	8.286	7.250	7.031	7.142	0.527	0.623	0.545	0.528	0.537
11.5	7.929	9.593	8.267	7.945	8.050	0.521	0.631	0.544	0.522	0.529
12.0	8.921	11.038	9.375	8.932	9.026	0.516	0.639	0.543	0.517	0.522
12.5	9.989	12.628	10.576	9.993	10.073	0.511	0.647	0.542	0.512	0.516
13.0	11.136	14.370	11.875	11.131	11.194	0.507	0.654	0.541	0.507	0.510
Mean						0.553	0.587	0.550	0.557	0.574

Note: periods are the same as in Table 1

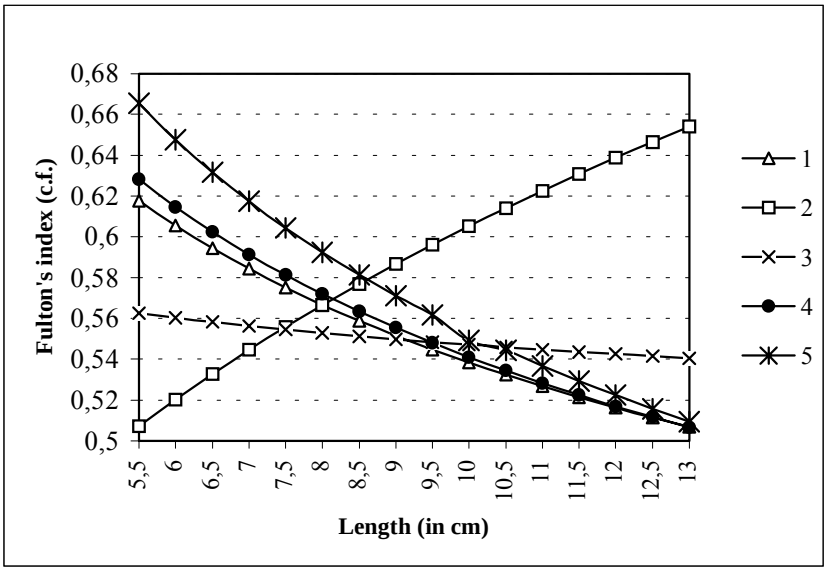

Fig. 1. Relationship between sprat length and Fulton's index during the period 1998 – 2000: (1) March 1998, (2) April - October 1998, (3) November 1998 – March 1999, (4) April – October 1999, (5) November 1999 – March 2000

Fig. 2. Length-at-age relationship of the Black Sea sprat during the periods November 1998 – March 1999 (3rd period) and April – October 1999 (4th period)

$L_t = 14.81\{1-\exp[-0.201(t + 2.795)]\}$
3-rd period

$L_t = 16.64\{1-\exp[-0.146(t + 3.212)]\}$
4-th period

As it is shown in Fig. 2, maximum growth was observed between 0+ and 1 years of age during both periods.

Values of the coefficients in equation (1), obtained from previous investigations and

Table 4. Values of the coefficients in von Bertalanffy equation (1) estimated by different authors for the period 1965 - 1990.

Parameter	Stoyanov (1965)	Cautis (1971)	Ivanov (1983)	Prodanov et. al. (1997)			
				1981	1982	1983	1984
L_∞	14.3	14.6	13.41	12.41	12.80	13.21	12.02
κ	0.215	0.281	0.451	0.594	0.427	0.344	0.544
t_0	-2.97	-1.6	-1.125				

Table 4. Continuation

Parameter	Prodanov et. al. (1997)						3-rd period*	4-th period*
	1985	1986	1987	1988	1989	1990		
L_∞	13.50	12.65	26.03	19.36	15.34	12.27	14.81	16.64
κ	0.282	0.404	0.069	0.129	0.230	0.399	0.201	0.146
t_0							-2.795	-3.212

Note: 3-rd period - November 1998 – March 1999; 4-th period - April – October 1999

estimated from us are given in Table 4.

As it is seen from the table, the obtained values of parameters in Equation (1) for the 3rd period are close to that, estimated by S t o y a n o v (1965) and C a u t i s (1971). The values of parameter L_∞ for the 3-rd and 4-th periods are slightly higher than those, calculated by I v a n o v (1983) and between values, estimated by Prodanov et. al. (1997). The results obtained (Table 4) show that sprat growth parameters undergo considerable variations between different years.

According to the I v a n o v 's data (1983) about coefficients a and n in Equation (2) during the period 1976-1981, theoretical sprat weights and condition factors for alometric growth have been calculated for the pointed period – Table 5 and Fig. 3. The input values of the coefficients in Equation (1) are, as follows:

Alometric growth	Isometric growth
a = 0.009	a = 0.00575
n = 2.81	n = 3

As it is seen from Fig. 1 and 3 and Tables 3 and 5, the mean Fulton's index for the period 1998 – 2000 is lower than those, estimated from I v a n o v 's data (1983). The mean values of c.f. during the periods 1976 – 1981 and 1998 – 2000 are 0.5938 and 0.5644 correspondingly.

Table 5. Mean weights and condition factors of the Black Sea sprat depending on mean lengths during the period 1976 - 1981 (according to Ivanov's data, 1983).

L, cm	W, g	c.f.
5.5	1.08	0.649
6.0	1.38	0.639
6.5	1.73	0.630
7.0	2.13	0.621
7.5	2.59	0.614
8.0	3.10	0.605
8.5	3.68	0.599
9.0	4.32	0.593
9.5	5.03	0.587
10.0	5.81	0.581
10.5	6.66	0.575
11.0	7.60	0.571
11.5	8.61	0.566
12.0	9.70	0.561
12.5	10.88	0.557
13.0	12.15	0.553
mean		0.59381

4. Conclusions

Investigations carried out on the Black Sea sprat and estimated growth parameters allow making the following conclusions:

- the sprat growth during the period 1998 – 2000 is alometric;

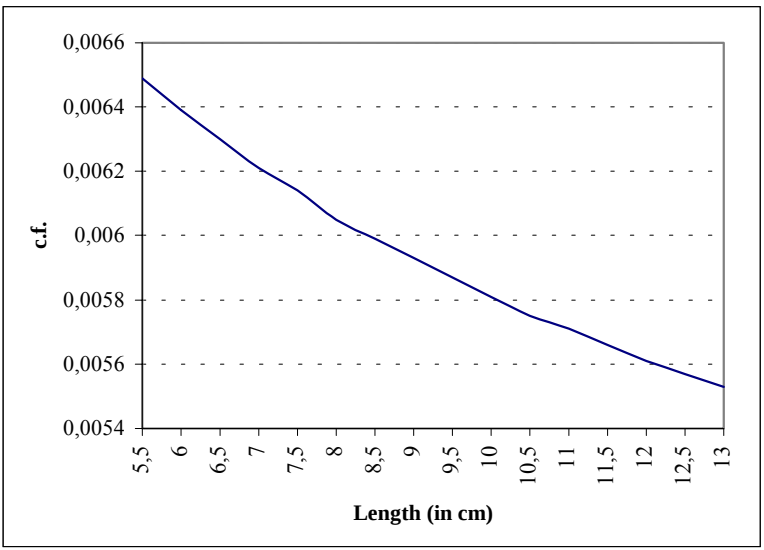

Fig. 3. Relationship between length and Fulton's index (c.f.) for the Black Sea sprat during the period 1976-1981 (according to Ivanov's data, 1983)

- during the autumn-winter season, relationship between body length and Fulton's index is inversely proportional, while during the spring-simmer season, the pointed relationship is proportional;

- sprat growth parameters undergo considerable variations between different years and periods.

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Параметри на нарастването на черноморската трицона (Sprattus sprattus L.) през периода 1998 – 2000 г. пред българския бряг на Черно море

Марина Д. Панайотова

(Резюме)

Настоящата работа изчислява някои основни характеристики за популацията от черноморска трицона (*Sprattus sprattus* L.) като размерен и възрастов състав, параметри и характер на нарастването, зависимост между теглото и дължината и индекса на угоеност по Фултон. Установено е, че нарастването през периода 1998 – 2000 г. е алометрично. Стойностите на параметъра n, характеризиращ нарастването в зависимостта между теглото и дължината, варират от 2.750 до 3.296. Установено е, че през есенно-зимния сезон, зависимостта между дължината на тялото и индекса на Фултон е обратнопропорционална, докато през пролетно-летните месеци същата е пропорционална. Параметрите в уравнението на Von Bertalanffy, изчислени по отношение на дължината за периодите ноември 1998 г. – март 1999 г. и април – октомври 1999 г. са, както следва: $L_t = 14.81\{1-\exp[-0.201(t + 2.795)]\}$ и $L_t = 16.64\{1-\exp[-0.146(t + 3.212)]\}$.

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