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LENGTH-WEIGHT RELATIONSHIP IN SARDINE *(SARDINA PILCHARDUS* WALB.) FROM THE EASTERN ADRIATIC DURING SPAWNING

DUŽINSKO-TEŽINSKI ODNOS SRDELE (*SARDINA PILCHARDUS* WALB.) JADRANA ZA VRIJEME MRIJEŠTENJA

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Length-veight relationship in adult sardine from the samples collected from the northern and central Adriatic during autumn-winter 1980—1981 fishing season was analysed. Length-weight relationship factors were 2.851 and 2.757 respectively with no significant difference between them. Two different condition factors were calculated, that is the empirical and cubic condition factors, the values of which were 1.657×10^{-5} and 0.784×10^{-5} respectively for the northern Adriatic sardine and 2.587×10^{-5} and 0.752×10^{-5} respectively for the central Adriatic sardine. Condition factors significantly differed for both areas.

INTRODUCTION

The evaluation of population size of a commercially important fish species for the purpose of its rational exploitation, requires an essential knowledge of individual body length-weight relationship in the respective population.

The problem of proportionality of fish weight increment in relation to growth in length is usually analysed from two different viewpoints: the observed species is either accepted to be »ideal«, what means that the species is forming and growing harmoniously and homothetically or empirical length--weight relationship is held to be better suitable.

Two methods result from this approach and two types of condition factors are obtained, each with peculiar significance. By the first method, using fixed length-weight relationship, a comparison of the same species populations may be carried out as well as a comparison of variations in body shape of this species individuals. However, the method based on empirical length-weight relationship is used for the study of short-term variations, either individual or collective, within a population.

Length-weight relationship in sardine *(Sardina pilchardus* Walb.) was little studied. Andreu and Fuster de Plaza (1962) and Belveze (1973) studied the Atlantic sardine. Studying sardine migrations in the central

Adriatic, Mužinić (1973) contemporaneously observed the variations in cubic condition factor for the 1952—1953 period. The same author (Mužinić, 1980) analysed the data of Gast on sardine from the catches realized around Vis and Biševo islands in 1922—1923. This author studied the length--weight relationship only on the basis of the data from August 1922 and determined the respective value of allometric growth factor.

In this paper, length-weight relationship and condition in sardine (*Sardina pilchardus* Walb.) population from the eastern Adriatic coast are analysed during spawning. Sardine were divided in two groups one group containing fish from the northern Adriatic and the other from the central Adriatic. These two Adriatic zones are principal fishing grounds of the Yugoslav coastal sea (Grubišić, 1968). This analysis thus rendered possible a comparison between two sardine subpopulations of the eastern Adriatic coastal area.

MATERIAL AND METHODS

Length and weight data of a total of 884 sardines from the northern Adriatic (western Istrian coast, Kvarner, the Rijeka Bay) and 2768 sardines from the central Adriatic (central Adriatic channels, Vis and Biševo islands, Kaštela Bay) were analysed.

Commercial catches of autumn-winter season (November 1980 — March 1981) were sampled. Sardine spawn in this period and thus physiological condition of all fishes was similar.

Total length was measured in milimetres and fish grouped in length classes to the nearest 0.5 mm, each sex separately as well as both sexes together. Weight was mesured with the precisioin of 0.01 g and mean weight was calculated for each respective length class.

Allometric length-weight relationship was described by the equation:

$$W = aL^b \qquad (1)$$

or in logarithmic form

$$\log W = \log a + b \log L$$

where W = weight, L = total length, b = allometric factor or length-weight factor and a = constant.

Two condition factors were calculated, the empirical and cubic ones.

The function of the form

$$C = WL^{-b} \qquad (2)$$

was used for the empirical condition factor (C) calculation, and the function of the form

$$K = WL^{-3} \qquad (3)$$

for the cubic condition factor (K) calculation for every length class.

RESULTS

Length-weight relationships in sardine from the northern and central Adriatic were calculated on the basis of the data on length and weight obtained by measurements of individuals sampled. (Table 1). These relationships are expressed by the following function:

Northern Adriatic

males $W = 1.96 \times 10^{-5} L^{2.819}$
or log $W = 2.819 \log L - 4.708$ $r = 0.996$
females $W = 1.5 \times 10^{-5} L^{2.874}$
or log $W = 2.874 \log L - 4.824$ $r = 0.995$
total $W = 1.67 \times 10^{-5} L^{2.851}$
or log $W = 2.851 \log L - 4.776$ $r = 0.996$

Central Adriatic

males $W = 2.85 \times 10^{-5} L^{2.734}$
or log $W = 2.734 \log L - 4.546$ $r = 0.996$
females $W = 2.53 \times 10^{-5} L^{2.764}$
or log $W = 2.764 \log L - 4.597$ $r = 0.997$
total $W = 2.59 \times {}^{-5} L^{2.757}$
or log $W = 2.757 \log L - 4.587$ $r = 0.997$

Theoretical weights of fish of different lengths (Figs. 1 and 2) were calculated by mean of these equations.

Table 1. Distribution of weight by length classes of male and female sardine from the autumn-winter season 1980—1981

Total length (mm)	Mean weight (g)					
	Northern Adriatic			Central Adriatic		
	♂	♀	♂♀	♂	♀	♂♀
130	17,38	17,25	17,30	17,30	17,25	17,29
135	20,31	20,64	20,38	19,85	20,05	19,87
140	22,42	22,54	22,43	21,93	22,50	21,95
145	24,29	24,56	24,39	22,98	23,75	23,08
150	26,34	26,07	26,12	24,00	24,60	24,40
155	27,76	28,62	28,03	26,45	27,87	27,52
160	31,56	30,58	30,86	30,43	31,52	30,95
165	36,30	35,55	35,98	32,50	34,44	33,73
170	39,03	40,59	40,19	36,77	38,77	37,83
175	42,35	43,90	43,09	39,70	40,56	40,15
180	44,74	47,80	46,44	42,51	44,71	43,68
185	46,14	49,46	48,10	45,26	45,93	45,75
190		51,35	51,75	47,15	49,58	49,06
195		54,01	54,33	51,53	53,30	52,39

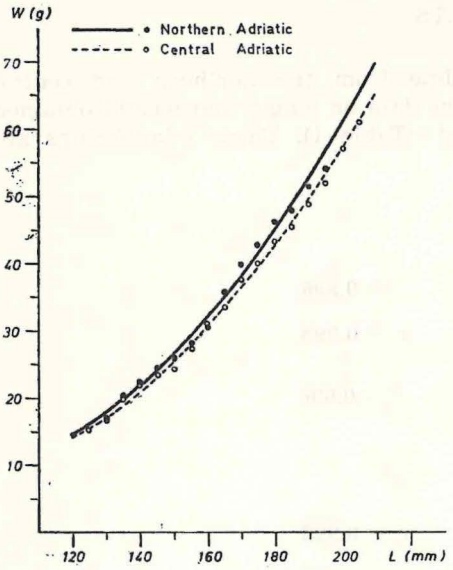

Fig. 1. Length-weight relationship in sardine from northern and central Adriatic sea

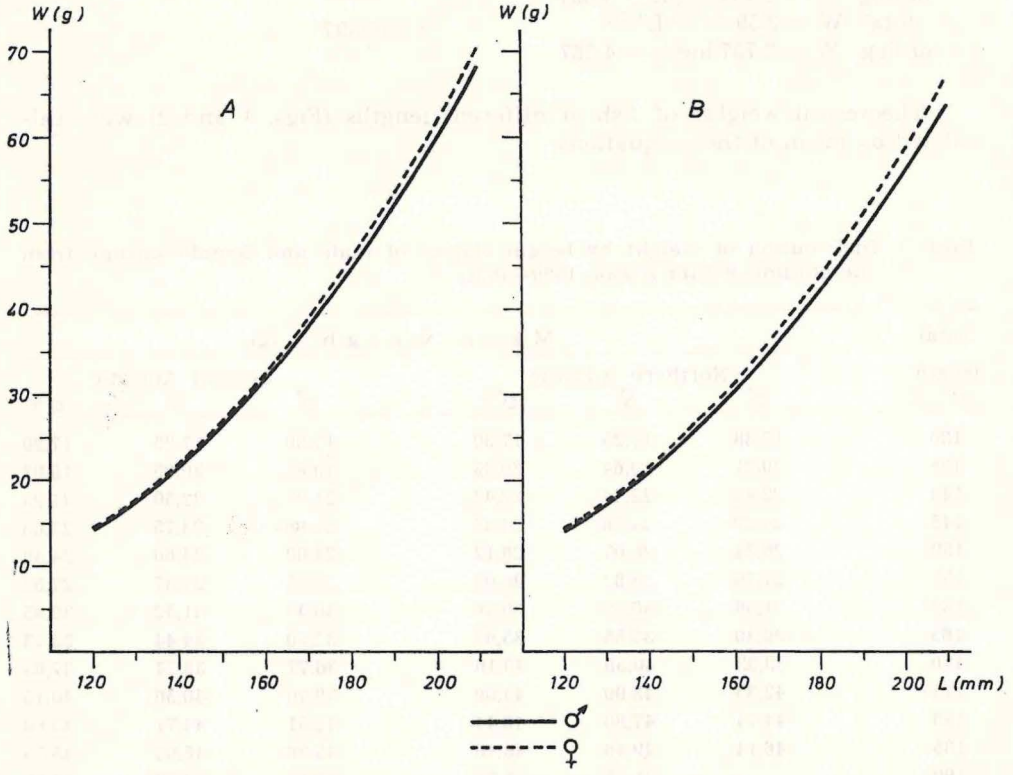

Fig. 2. Length-weight relationship in male and female sardine from northern (A) and central (B) Adriatic sea

It was recorded that empirical weights of smaller length classes varied within narrow ranges in both males and females from both areas, nevertheless the lowest coefficient of variation was recorder for sardine of 145—155 mm in length. Greater length classes showed greater variations which increased in function of length. Higher variation coefficient was recorded for sardine from the central Adriatic.

Calculation of the empirical condition factor (C) gave the following results:

Northern Adriatic

males $C \times 10^5 = 1.957$
females $C \times 10^5 = 1.499$
total $C \times 10^5 = 1.675$

Central Adriatic

males $C \times 10^5 = 2.848$
females $C \times 10^5 = 2.529$
total $C \times 10^5 = 2.587$

Empirical condition factor values were found to vary little in relation to length (Fig. 3). The analysis of variance shows that the difference between empirical condition factor in sardine from the northern Adriatic and that in sardine from the central Adriatic is statistically significant.

Table 2. The analysis of variance of empirical condition factors in sardine from the northern and central Adriatic in autumn-winter 1980—1981

Source of variation	Degree of freedom	SS	MS	F_s	P
Between groups	1	5.8432	5.8432	160.611	.001
Within groups	26	0.9459	0.0364		
Total	27	5.9378			

Cubic condition factor (K) was calculated for each length class (Table 3). Results show better female condition in both areas. It was found that K factor decreased in function of length (Fig. 3) for the period of present observation, even though sardine of 150—160 mm were in poorer condition in relation to te majority of fish. On this basis coefficients of correlation between body lengths and respective condition factor were calculated. Results are given in Table 4.

Significance of condition factor variation in sardine from the northern and central Adriatic was tested by the analysis of variance. It was proved that the analysed groups did not show the same parametric variation.

Table 3. Fluctuations in cubic condition factors (K) in function of total length of sardine from the northern and central Adriatic (e — estimated values)

Length (mm)	K × 10⁵											
	Northern Adriatic						Central Adriatic					
	♂	♂e	♀	♀e	♂♀	♂♀e	♂	♂e	♀	♀e	♂♀	♂♀e
120		0.823		0.819		0.820		0.799		0.818		0.808
125		0.817		0.816		0.814		0.790		0.810		0.800
130	0.791	0.811	0.785	0.812	0.787	0.809	0.787	0.782	0.785	0.803	0.787	0.792
135	0.826	0.806	0.839	0.808	0.828	0.805	0.807	0.774	0.815	0.795	0.808	0.785
140	0.817	0.800	0.821	0.804	0.817	0.800	0.799	0.820	0.789	0.788	0.800	0.778
145	0.797	0.795	0.806	0.800	0.800	0.796	0.754	0.760	0.779	0.782	0.757	0.772
150	0.780	0.790	0.772	0.797	0.774	0.792	0.711	0.753	0.729	0.776	0.723	0.765
155	0.746	0.786	0.769	0.794	0.753	0.788	0.710	0.710	0.748	0.769	0.739	0.759
160	0.771	0.781	0.747	0.790	0.753	0.785	0.742	0.740	0.769	0.764	0.756	0.753
165	0.808	0.777	0.791	0.787	0.801	0.781	0.724	0.734	0.767	0.759	0.751	0.748
170	0.794	0.773	0.826	0.784	0.818	0.779	0.748	0.728	0.785	0.753	0.770	0.742
175	0.790	0.769	0.819	0.781	0.801	0.774	0.741	0.723	0.757	0.748	0.749	0.737
180	0.767	0.765	0.820	0.779	0.796	0.771	0.729	0.717	0.767	0.743	0.749	0.732
185	0.729	0.761	0.781	0.776	0.769	0.768	0.715	0.712	0.725	0.739	0.723	0.727
190		0.757	0.755	0.773	0.755	0.765	0.687	0.707	0.723	0.734	0.715	0.722
195		0.754	0.733	0.771	0.733	0.761	0.695	0.702	0.719	0.729	0.707	0.718
200		0.750		0.768		0.759		0.697		0.725		0.713
205		0.747		0.766		0.756		0.693		0.721		0.709
210		0.744		0.764		0.753		0.689		0.717		0.705
Mean	0.785		0.790		0.784		0.739		0.763		0.752	
Stan. dev.	0.0282		0.0326		0.0295		0.0372		0.0324		0.0308	
C. V.	3.59		4.12		2.76		5.04		4.25		4.09	

Table 4. Statistical parameters of cubic condition factor in sardine from the northern and central Adriatic in relation to total length in autumn-winter 1980—1981

Area	Sex	K×10⁵	r	s^2	t_s	P
Northern Adriatic	♂	0.785	—0.586	0.000793	2.505	.05
	♀	0.790	—0.398	0.001065	1.623	n.s.
	♂♀	0.784	—0.515	0.000871	2.248	.05
Central Adriatic	♂	0.739	—0.791	0.001386	4.837	.001
	♀	0.763	—0.727	0.001049	3.962	.01
	♂♀	0.752	—0.776	0.000946	4.603	.001

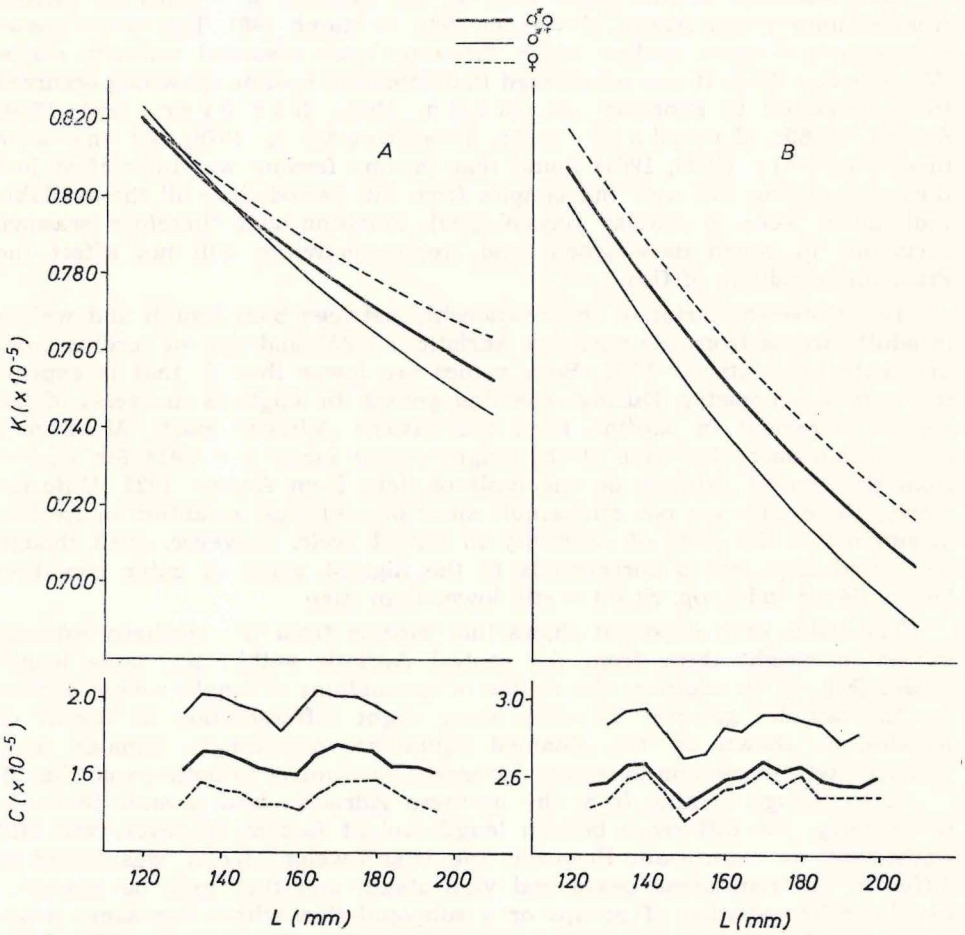

Fig. 3. Relation between empirical (C) and cubic (K) condition factors and total length (L) of sardine from northern (A) and central (B) Adriatic sea

Table 5. The analysis of variance of cubic condition factor in sardine from the northern and central Adriatic in autumn-winter 1980—1981

Source of variation	Degree of freedom	SS	MS	F_s	P
Between groups	1	0.007072	0.007072	7.782	.01
Within groups	26	0.023629	0.000909		
Total	27	0.030701			

DISCUSSION

Data included in this paper refer to the samples of commercial catches from autumn-winter season, November 1980 — March 1981. This is the spawning season of adult sardine which show the most advanced maturity stages (Mužinić, 1954). It was established that intensive sardine spawning occurred from December to February (Gamulin, 1954; Karlovac, 1964, 1969; Štirn, 1969; Zavodnik, 1970; Teskeredžić, 1978). At the same time Vučetić (1963, 1964) found that sardine feeding was intensified just during spawning. We used the samples from this period since all the available individuals were in similar physiological condition and therefore seasonal variations in gonad development and trophic activities will not affect the shape and condition of fish.

Length-weight factor of the relationship between body length and weight in adult sardine from the northern Adriatic is 2.851 and that of sardine from the central Adriatic is 2.757. Both values are lower than 3, that is express the negative allometry. During spawning growth in length is in excess of the weight increment in sardine from the eastern Adriatic coast. Mužinić (1980) established the value of the length-weight factor b = 2.914 for sardine from the central Adriatic on the basis of data from August 1922. Unfortunately, these data are not comparable since physiological condition of sardine in summer is the state of inactivity in sexual cycle. However, even though the found exponent b corresponds to the highest value of cubic condition factor (Mužinić, op. cit.) it is still lower than cube.

The value of b exponent shows that sardine from the northern Adriatic exceed in weight those from the central Adriatic within the same length classes (Fig. 2). In addition, the results of calculations of length-weight factors for the samples grouped by sexes show slight differentation in favour of females, as shown by the obtained equations. Accordingly females show better growth in relation to weight increment than males in both areas (Fig. 2).

Even though sardine from the northern Adriatic show greater tendency to isometry, the difference betwen length-weight factors, however, was still statistically no significant. However, the length-weight factor was found to differ in different areas, sexes and vital stages and thus may be character for the differentiation of groups or a subpopulation within the same population, like for any other morphometric relationship (Le Cren, 1951). Non-significant difference in length-weight factors between analysed areas may be accounted for by the selectivity during sampling since only the individuals

with the advance state of gonad maturity were used. On the other hand, this fact may be an indicator of mixing of different sardine groups during spawning.

The values of empiric condition factor in sardine slightly vary in relation to legth (Fig. 3). Accordingly, a change in fish length does not affect individual fish condition. On the contrary, mean values of condition factor are rather stable in relation to sardine length. Individual variations of empirical condition factor may be understood as a consequence of the different degree of fattening and stomach fullness, inasmuch this factor affects the wariations in short-term changes of fish shape.

Taking into account the established stability of C factor, it may be used for an intraspecies companies of observed group. It was found that the obtained C values belonged to different statistical populations ($F_s = 160.611$, $P < .001$).

Theoretically, if the length-weight factor is lower than $b = 3$, cubic condition factor evolves to the direction opposite to that of the length. Thus larger individuals will have poorer condition and in turn smaller individuals will have more improved condition. This analysis of sardine population of the eastern Adriatic coast show the values of allometric factor to be lower than 3. On this basis the correlation between fish length and condition was also examined. The correlation coefficient obtained are negatively significant at the 99% level in sardine from the central Adriatic. This correlation is poorer in northern Adriatic sardine. It is significant at 95% level in males and both sexes together. In females, however, this correlation is no significant. This may be indicative of some temporary mixing of a subpopulation from another area, the cubic condition factor of which is different during spawning.

Similar assumption may be applied to the statstical nosignificance of the difference in obtained length-weight factors between sardine from the northern Adriatic and those from the central Adriatic.

A theory was earlier postulated that the sardine subpopulation from the northern Adriatic was heterogeneous what meant that different sardine populations possibly mix in the spawning area (Zavodnik, 1962, 1968; Škrivanić and Zavodnik, 1973).

Cubic condition factor is based on an ideal length-weight relationship. Thus it may be held as a measure of fish deviation from the hypotethical ideal fish. If the deviations of populations from different environments are considerable the differences between them may be of genetic origin due to racial differences (Le Cren, 1951). The analysis of variance showed that the difference between both (K) factors was significant. On the other hand, the gill rackers of sardine from the northern Adriatic differ from those in sardine from the central Adriatic. This difference refers to the number, length and intervals between branchispines of the first branchial arch (Alegria Hernandez, unpublished data).

Accordingly, it may be assumed that the sardine population from the northern Adriatic differ in some physiological respect from that from the central Adriatic. This differentiation is probably due to different degrees of food requirements and food supply.

CONCLUSIONS

The paper reports the analysis of length-weight relationships in adult sardine populations from the northern and central Adriatic caught during autumn-winter, that is the spawning season.

Length-weight factor is 2.851 for sardine from the northern Adriatic and 2.757 for those from the central Adriatic. Results show negative allometry, that during spawning growth exceeds weight increment. The values of b exponent show that sardine from the northern Adriatic weigh more than those from the central Adriatic. No significant difference between factors of both areas was established.

Empirical condition factor is 1.675×10^{-5} for sardine from the northern Adriatic and 2.587×10^{-5} for those from the central Adriatic.

Cubic condition factor vas calculated for every 5 mm length interval. It decreases in function of length. Mean value is 0.784×10^{-5} for sardine from the northern Adriatic and 0.752×10^{-5} for those from the central Adriatic. This is indicative of the poorer condition of sardine from the central Adriatic during spawning.

The analysis of variance of obtained data shows that the difference between found condition factors in sardine from the northern Adriatic and those in sardine from the central Adriatic is significant.

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DUŽINSKO-TEŽINSKI ODNOS SRDELE (*SARDINA PILCHARDUS* WALB.) JADRANA ZA VRIJEME MRIJEŠĆENJA

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KRATAK SADRŽAJ

U ovom radu su analizirani dužinsko-težinski odnosi adultne populacije srdele (*Sardina pilchardus* Walb.) sjevernog i srednjeg Jadrana za jesensko-zimsko razdoblje ribolova 1980—1981. godine. Razdoblje odgovara sezoni mriješćenja ove vrste.

Dužinsko-težinski faktor za srdelu iz sjevernog Jadrana iznosi 2,851, a za onu iz srednjeg Jadrana 2,757. Rezultati pokazuju negativnu alometriju, tj. da je u doba mriješćenja, prirast dužine srdele veći od povećanja težine. Vrijednost eksponenta alometrije b pokazuje da su ženke srdele teže od mužjaka (sl. 2), te da je srdela sjevernog Jadrana teža od srdele od srednjega (sl. 1). Nije utvrđena statistička signifikantna razlika između dužinsko-težinskih faktora oba područja.

Empirički faktor kondicije za sjevernu srdelu iznosi $1{,}675 \times 10^{-5}$ i za onu iz srednjeg Jadrana $2{,}587 \times 10^{-5}$. Ove vrijednosti su stabilne za svaku zonu a odstupanja u odnosu na dužini su vrlo mala (sl. 3).

Kubični faktor kondicije računat je za svaki dužinski interval od 5 mm, i on se smanjuje u funkciji dužine ribe (sl. 3). Srednja vrijednost za srdelu iz sjevernog Jadrana iznosi $0{,}784 \times 10^{-5}$ i za onu iz srednjeg Jadrana $0{,}752 \times 10^{-5}$. U doba mriješćenja kondicija srdele srednjeg Jadrana je slabija od kondicije srdele sjevernog Jadrana.

Analizom varijance dobivenih podataka utvrđeno je da postoji signifikantna razlika između nađenih faktora kondicije za srdelu iz sjevernog i srednjeg Jadrana.

Prema navedenoj razlici može se pretpostaviti da postoje fiziološke razlike između obe grupe srdele uvjetovane vjerojatno, različitim stupnjem potrebe za hranom i njene dostupnosti.