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Fish biology

**BIOLOGICAL CHARACTERISTICS OF THE SARDINE
(*SARDINA PILCHARDUS* WALB.) OFF WEST SAHARA**

**BIOLOGICZNA CHARAKTERYSTYKA SARDYNKI
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The paper presented, being a result of research carried out in the years 1972–1977 off West Sahara, contains data on distinct features and distribution of the Sahara sardine stock, its feeding, condition, spawning, age, growth rate and mortality.

INTRODUCTION

The commercial exploitation of live resources of the North West Africa shelf was undertaken by the Polish fleet in 1962. As a result of expanding, in 1973, exclusive fisheries zones by Morocco, Mauretania and Senegal, the area of traditional Polish ships' operation shrank practically to the West Sahara Shelf. This fact markedly affected the structure of Polish catches. The sardine (*Sardina pilchardus* Walbaum, 1792), previously caught in small amounts, became suddenly the dominant component of the catches, making up for instance in 1973 and 1976 44.7% and 82.0% respectively, of the Polish catches on the NW Africa Shelf.

This situation created the need to take up wide-scale studies on the sardine. The work present includes the results of observations made by the author on the species' biology.

Fig. 1. The distribution of major sardine fishing grounds on the shelf off North – West Africa and the area of sampling

MATERIALS AND METHODS

The material forming the basis of the work present were obtained within the years 1972–1977. Their fundamental part was collected on the West Sahara fishing grounds, between Cap Juby and Cap Blanc (Fig. 1) durring the following cruises of commercial fishing vessels:

– MT „Langusta” (B-18 trawler)	March – June	1973
– MT „Langusta“	January – June	1974
– MT „Barakuda” (B-23 trawler)	March – May	1975
– MT „Langusta”	June – October	1975
– MT „Narwal” (B-18 trawler)	March – July	1976
– MT „Narwal”	May – September	1977

Numbers of individuals measured and examined for the biological analysis are summerised in Table 1.

Table 1

Studies carried out during sardine fishing on the West Sahara shelf in the years 1972–1977

Year	Number of individuals					
	Mass measurements	otoliths	stomachs	viscera fat	gonads	vertebrae
1972	4 283	–	–	–	–	–
1973	12 140	912	2 924	2 719	2 510	821
1974	23 664	989	4 848	5 084	1 614	1 000
1975	20 471	–	609	625	625	–
1976	47 300	469	1 798	1 718	1 790	300
1977	31 445	570	–	–	–	–

The mass measurements were taken to the nearest cm below.

The vertebrae were counted with the urostyl, treated as a vertebra.

The weight of the sardines in each length class was measured for whole fish, stomachs and gonads being retained. Weighings were usually made in the morning, before noon, that is at the time when the species feeds with the lowest intensity.

The stomach filling was determined according to a 4-score scale:

- 0 – empty stomach,
- 1/4 – stomach filled in 1/4,
- 1/2 – stomach filled in 1/2,
- 1 – full stomach.

The ammount of fat around intestines was determined according to the following scale:

- 0– no white layers of fat on the blind stomach sac, stomach inlet, pylorus and on the further parts of the alimentary tract, including the pyloric processes,
- 1– 1-mm wide lamellae of white fat on the dorsal side of the stomach inlet and on the

lower side of the blind sac (it should be pointed out that fat appears first on these parts of the stomach). The remaining parts of the alimentary tract show strongly marked blood vessels and lamellae of hyaline fat;

- 2— upper and lower surfaces of the stomach inlet are fairly thickly covered with fat (about 1-mm wide lamellae of white fat). On the lower wall of the blind sac two lamellae of fat, each about 2-mm wide. A single lamella found on the upper surface of the blind sac was narrow (about 1-mm wide). Further parts of the alimentary tract (including pyloric processes) begin to be covered with fat forming hyaline-white structures;
- 3— 3–4 mm wide lamellae of white fat on various parts of the stomach. Distinct fat cover on the remaining parts of the alimentary tract.
- 4— the blind sac completely covered by layers of white fat which is particularly well visible on a partly filled stomach. The remaining parts of the stomach covered with large, irregular slabs of fat, further parts of the alimentary tract covered with fat.

The chemical determination of fat in the flesh include 314 assays carried out within the years 1973–1976 by means of the Soxhlet and Grossweld technique.

The fish maturity stage was determined according to the 8-score Maier scale.

The age and growth rate of the species discussed were calculated from otolith direct readings. The otoliths were viewed in incident light. When interpreting the age readings January 1 was adopted as the date of fish birth, age classes being established according to principles accepted by the CECAF Working Group on sardine age determination (Anon., 1978; Anon., 1979).

The linear growth of the sardines was described by means of the von Bertalanffy equation.

GEOGRAPHICAL DISTRIBUTION AND DISTINCTIVENESS OF THE STOCK EXAMINED

The sardine, a moderate zone species, inhabits the shelf waters off western and southern Europe and North- West Africa, from the North Sea to Cap Blanc. Its largest concentrations occur at the depth of 100 m, seldom deeper.

The large variability of environmental conditions in this vast area causes the species discussed to form a variety of local races and stocks.

With reference to the sardine of the North- West Africa waters three more or less independent stocks have been separated to data (Furnestin, 1952; Belveze, 1972a; Maigret, 1974; Bravo de Laguna et al., 1976; Domaniewski and Barkowa, 1976). They are distributed in three areas:

- A — from Gibraltar to the area off Ifni;
- B — from Ifni to 27°N;
- C — from Cap Bojador to Cap Barbas (Cap Blanc).

Table 2

Fluctuations in the vertebrae counts of the sardines caught on the West Sahara shelf
in the years 1973–1976

Year	Date	Position	vertebrae count						parameters		
			48	49	50	51	53	53	$\bar{x}$	σ	n
1973	07.02	28°03'N 13°03'W	—	—	44	57	2	—	50.59	0.53	103
	20.02	24°20'N 16°05'W	—	—	39	58	7	—	50.69	0.59	104
	23.03	24°40'N 16°15'W	—	3	30	60	8	—	50.72	0.65	101
	03.04	24°35'N 15°45'W	—	—	28	65	7	—	50.79	0.56	100
	15.05	24°48'N 15°30'W	—	—	40	58	2	—	50.62	0.53	100
	08.06	24°52'N 15°18'W	—	—	43	58	7	—	50.67	0.60	108
	15.10	26°35'N 13°42'W	—	1	34	64	—	—	50.64	0.50	103
	22.10	26°30'N 13°30'W	—	—	32	65	5	—	50.74	0.54	102
1974	19.02	22°15'N 17°03'W	—	—	35	61	4	—	50.69	0.55	100
	22.02	20°58'N 17°27'W	—	—	30	68	2	—	50.72	0.50	100
	05.03	24°36'N 15°47'W	—	—	31	67	2	—	50.71	0.50	100
	02.04	23°57'N 16°06'W	—	—	41	58	1	—	50.60	0.51	100
	21.04	25°22'N 15°16'W	—	—	37	58	5	—	50.68	0.57	100
	09.05	24°17'N 15°59'W	—	1	40	56	3	—	50.61	0.57	100
	30.05	25°23'N 15°09'W	—	—	32	59	9	—	50.77	0.60	100
	01.07	24°32'N 15°37'W	—	1	44	49	6	—	50.60	0.62	100
	16.08	26°57'N 13°46'W	—	—	35	64	1	—	50.66	0.50	100
	14.09	26°49'N 13°52'W	—	1	35	59	5	—	50.68	0.58	100
	23.04	25°08'N 14°58'W	—	—	32	59	9	—	50.77	0.60	100
1976	20.05	24°58'N 15°29'W	—	1	37	51	11	—	50.72	0.67	100
	16.06	24°12'N 15°57'W	—	3	43	49	5	—	50.56	0.64	100
Total			—	11	762	1243	105	—	50.68	0.57	2121

An attempt to explain if the catches and relevant ichthyological analyses refer to the same stock and to what extent the stocks observed are different from the remaining ones was made by determining the vertebrae count of the fish caught. As a basis of calculation made to detect the homogeneity of the stock studies a mean vertebrae count was adopted (Table 2). The analysis of variance applied showed no significant differences. Thus it was assumed that the studies were performed on individuals belonging to the same stock. The vertebrae counts of sardines from different areas of the North-West African shelf are presented in Table 3. The mean vertebrae count found ($\bar{x} = 50.68$) does not differ significantly from data reported by Bravo de Laguna (1976) for the sardine from the Cap Juby area and by Belveze (pers. comm.) off Agadir ($\bar{x} = 50.65$).

Table 3

Results of studies on the vertebrae count of the sardine
inhabiting the shelf off North-West Africa

Author	Geographical region	vertebrae count					parameters		
		49	50	51	52	53	N	$\bar{x}$	δ
Rodriguez-Roda (1970)	Gibraltar Strait	—	63	367	91	3	524	51.06	0.56
Belveze (pers. com.)	Casablanca	1	84	204	35	1	325	50.85	0.61
Belveze (pers. com.)	Agadir	8	136	200	23	—	367	50.65	0.63
Bravo de Laguna et al (1976)	Cap Juby						1174	50.65	0.59
Domaniewski, Bar-kowa (1976)	Cap Juby— Cap Blanc							49.8–50.1	
present study	Cap Juby— Cap Blanc	11	762	1243	105	—	2121	50.68	0.57

Due to large differences between the means from the area off Casablanca ($\bar{x} = 50.85$) and the present data, they were compared by Student's test. The results of the test speak in favour of accepting the presence of an essential difference between the stocks inhabiting the West Sahara shelf and the area off Casablanca.

SEASONAL MIGRATIONS

The hydrological regime of the North-West Africa shelf undergoes considerable changes over a year, which causes the sardine to migrate to areas with most suitable thermal and feeding conditions.

Basing on the Polish commercial catches from the years 1972–1977 the author made

Fig. 2. Seasonal distribution of sardine stock "C" (according to Polish commercial catches in 1972-77)

an attempt to follow migrations of the stock „C“, the migrations being parallel to the coastline. During the period mentioned the sardine was fished by a large fleet composed of various vessels, which allowed to locate the densest concentrations. It should be noted that vessels heading to Cap Blanc for unloading and those voyaging to the fishing grounds were surveying the areas outside those operated on by the fleet. This resulted in a considerable extension of the area penetrated. Therefore the following considerations assume that the commercial vessels fished mostly in the areas of the largest concentrations of the sardine.

Based on analyses of the catches the seasonal distribution of the stock studied off the West Sahara region is presented in Fig. 2.

Winter on the shelf off North-West Africa is the coldest season with the most intensive influence of the Canary Current. Under these circumstances the sardine, proceeding through its spawning peak is fished for closer to the coast in the waters not affected by the Canary Current.

In the spring, despite certain changes in the circulation of the current discussed, no serious changes in the distribution of the sardine are observed, the fishes remaining in the area between 22° and 25°N.

In the summer and autumn the intensity of the Canary Current decreases, as does the upwelling off West Sahara, warm waters flowing in from the South, which causes the environmental conditions to deteriorate. Therefore the concentrations of the species move from the hitherto occupied areas to those farther north. As a result, in the second half of the year the sardine occurs mainly in the waters of the northern part of the West Sahara Shelf in two bays north of Villa Cisneros and Cap Bojador. A tendency of the stocks to enter sheltered bays and to form dense concentrations in areas of contact of thermally different water masses is similar to the sardine behaviour off Morocco (Furnestin and Furnestin, 1966).

Based on surface water temperature data for the fishing grounds under study the sardine concentrations can be assumed to remain mostly in cool waters affected by the upwelling and the Canary Current.

SEASONAL AND DIEL CHANGES IN FEEDING INTENSITY

The sardine is a plankton feeder ingesting both phyto- and zooplankton. For instance, according to Nieland (1980) in the period between March and August 1974 the contribution of phytoplankton to the food of the sardine from the Sahara Shelf was 90–100%. In February the contribution of this component was lower and reached 50% only. In the neighbouring fishing ground Cap Juby, in the period from November to February zooplankton was dominant, making up 50–100% of the food. Thus the proportions of both components change depending on the season and area. They also depend on a number of other factors, as the age and physiology among others.

Based on observations made by the author within the years 1973–1976 the mean

Fig. 3. Monthly mean stomach filling of the sardine in 1973-76

stomach filling was determined for each month (Fig. 3). In 1973 and 1974 the feeding intensity was at approximately the same level, while in the next two years it was considerably higher. Despite these differences the changes in feeding intensity have a similar character in all these years. In January and February, that is during the spawning

Fig. 4. Mean stomach filling of the sardine at different times of the day

peak, the sardine feeds with the lowest intensity. From March until May the feeding intensity increases, which is the result of an abundant food supply and of the physiological condition of the sardine. In June and July the Canary Current weakens, deteriorating the conditions. Before the autumn and winter spawning peaks the sardine migrates north to the regions of constant upwelling (Bravo de Laguna et al., 1976) where, in August and September the feeding intensity increases once more.

From February until July 1974 and from April until July 1976 information on the sardine diurnal feeding rhythm was collected. The species' intensive feeding was found to last from late afternoon until early evening (Fig. 4). During the rest of the day the fishes discussed ingest much smaller quantities of food. The lowest degree of stomach filling was noted in the morning and before noon. These observations agree with the results of Cushing's studies (after Riedel, 1968), who states that sardines from the English Channel feed only during daylight and have the fullest stomachs in the afternoon.

STOMACH FILLING AND THE TOTAL LENGTH AND PHYSIOLOGICAL CONDITION OF THE SARDINE

The observations on 14–24 cm long fish show that the smallest individuals (14–16 cm) have the fullest stomachs, in 17–23 cm long ones the degree of filling remains at approximately the same level to decrease markedly in the largest individuals. The differences observed are, however, small; thus the feeding intensity of individuals belonging to different length classes is similar.

Fig. 5. Mean stomach filling vs. size of the sardines

Fig. 6. Mean stomach filling vs. gonad maturity

The stomach filling of fish at different stages of gonad maturity is also similar (Fig. 6). Small differences found show that sardines whose gonads are at resting and maturing stages feed more intensively.

FAT IN THE FLESH AND VISCERA

One of the most important methods in studying the sardine spawning and growth biology is to follow the cyclic changes in the fat amount.

Observations made by the author (Fig. 7) show that the smallest amount of fat in the stock surveyed is noted during the winter spawning peak and just after it, that is from December until March. After spawning the sardine feeds intensively, taking advantage of the abundance of food, which is the cause of the amount of fat in the flesh (reaching 15% in June and July). A relatively high amount of fat is sustained approximately until October when the species begins to prepare to spawning and its feeding intensity drops.

Comparing the changes of the factor discussed in various years it may be noted that large differences do not occur; it is only the data from June, July, September and October 1974 that differ markedly from the mean, probably as a result of better feeding conditions.

Studies on the fat layer of the viscera were carried out with regard to the sex (Fig. 8). In winter the fat amount is at its lowest, growing from March until July rapidly, after

Fig. 7. Monthly fat content of the sardine flesh in 1973 – 76

which in August and September it drops somewhat. In October the fat amount grows once more and finally in November and December it drops so rapidly that at the end of the year it is at its lowest. Similar seasonal changes were recorded by Barraca et al. (1977) off the coast of Portugal.

The markedly lower amount of viscera fat in the females, as observed by the author, could evidence a much more intensive turnover of body- and energy-producing matter during the spawning and after it, at the time of recovery of spent gonads.

Fig. 8. Monthly mean fat amount of sardine viscera in 1973 – 76

The viscera and flesh fat amount show a constant correlation ($r = 93\%$). This allows to determine the amount of fat in the flesh by analysing the viscera fat amount.

CONDITION FACTOR

The condition of the fish is described by means of the Fulton condition factor:

$$K = \frac{W \times 100}{l^3}$$

where: W = fish weight (g),
 l = fish length (cm).

The coefficient K was calculated for the years 1973–1976 on the basis of weights of sardines belonging to the 18–22 cm length groups. By analysing its changes over an annual cycle it may be noted that from January until March and probably also in December the condition of the stock surveyed is the poorest. In the next period, that is from March until July, the coefficient grows rapidly. From July until October the condition of the sardine dropped, with a slight change to the better in August and September. In November the condition factor grew once more, which may have resulted from the intensive development of the gonads. Annual changes of the coefficient discussed are different depending on the fish length. The large fishes are dominated by females. It was previously shown (Fig. 8) that during the whole year the fat amount of females is lower than that of males. Thus the females, feeding more intensively use more of their food to prepare to spawning and later to compensate for the loss of weight. This may explain the larger changes in condition of big fishes.

Fig. 9. Fat amount of the sardine viscera (A) vs. flesh fat content (B)

Studies on the feeding coefficient of the sardine off Cap Juby were performed by Bravo de Laguna et al. (1976). According to their data the coefficient reaches the highest values (0.830–0.880) from June until August and the lowest (0.650–0.700) from January until March, with no visible difference between males and females. On the basis of studies in 1969–1971 Belveze (1972b) also found seasonal fluctuations of the condition coefficient (0.699–0.915) pointing out that its highest values in the succeeding years were noted in October, September and July. The coefficients mentioned in both works are markedly lower than those found by the author. Small differences could be explained by the fact that on the shelf off Morocco and in the region off Cap Juby smaller fish were examined, but different trophic conditions in all three regions seem to play the major role.

SPAWNING

The Sahara sardine stock spawns in two main regions, that is off Cap Bojador and off Villa Cisneros (Siedleckaja, 1973; Rubies and Palonera, 1977). The first spawning ground is of the greatest importance for the stock mentioned.

The sardine, as most fish from areas influenced by the tropical climate, undergo portional spawning, which means that eggs of various sizes are present simultaneously in maturing ovaries.

The smallest maturing individuals observed by the author were 13 cm males and 15 cm females, while the sex was distinguishable at the length of 8–10 cm.

Individuals with mature gonads, just after or just before spawning were occurring throughout the year. (Table 4).

The data reported allow to distinguish three basic spawning periods: March – April, August – September and November – December. The winter and spring spawning peaks are also described by other workers (Bravo de Laguna et al., 1976; Domaniewski and Barkowa, 1976; Rubies and Palonera, 1977), while the spawning period observed by the author in August and September, despite a distinct correlation with the changes in condition and fat amount coefficients (Fig. 7, 8, 10) has no confirmation in literature available. Holzlöhner's work (1975) may speak in favour of three spawning periods when studying the length structure of fish born in 1971, belonging to the age group III he found a relatively wide span of lengths with three peaks: 17.3 cm, 18.4 cm and 19.3 cm. This fact may be connected with portional spawning and differing actual dates of birth within one year.

A further analysis of data in Table 4 shows that the relative amount of males in catches diminishes before every spawning peak. This fact agrees with the earlier migration of males to the spawning grounds, which, judging by a small amount of mature fish found in the catches, lay beyond the fishing grounds exploited by the Polish fleet at the time.

Table 4

Percentages of male and female sardines in Polish commercial catches vs. maturity, years and months

Year	Month	sex maturity of gonads												♂♂ ♀♀ total						
		II		III		IV		V		VI		VII			VIII		♂♂ ♀♀ I-VIII			
		♂♂ ♀♀		♂♂ ♀♀		♂♂ ♀♀		♂♂ ♀♀		♂♂ ♀♀		♂♂ ♀♀			♂♂ ♀♀					
1974	II	48	55	45	35	5	10	2	-	-	-	-	-	-	7	2	51	49	100	100
	III	25	37	45	36	23	24	7	3	-	-	-	-	-	30	27	33	67	100	100
	IV	27	37	35	42	7	3	5	4	1	-	23	10	38	21	36	64	100	100	
	V	64	80	8	6	2	2	-	1	-	-	9	4	28	14	50	50	100	100	
	VI	72	71	1	1	-	-	-	-	-	-	19	23	27	28	53	47	100	100	
	VII	40	71	35	18	25	11	-	-	-	-	-	-	25	11	42	58	100	100	
	VIII	11	14	3	30	56	45	17	7	-	-	5	2	86	56	46	54	100	100	
	IX	5	21	13	11	67	31	15	32	-	5	-	-	82	68	51	49	100	100	
	XI	10	32	5	29	60	39	25	-	-	-	-	-	85	39	42	58	100	100	
1975	II	23	65	15	5	1	5	-	-	2	-	41	9	58	34	50	50	100	100	
	III	23	28	-	2	-	-	-	-	-	-	56	23	77	70	42	58	100	100	
	IV	-	-	-	3	2	13	-	7	-	7	93	47	100	97	58	42	100	100	
	V	24	17	28	38	17	30	7	7	-	-	17	5	48	45	42	58	100	100	
	VI	47	48	18	8	6	8	-	-	4	-	23	4	35	40	41	59	100	100	
	VII	40	40	30	12	20	15	-	15	-	-	10	9	30	48	23	77	100	100	
	VIII	-	3	-	3	38	11	57	22	-	14	5	47	100	97	43	57	100	100	
	IX	43	62	14	14	33	19	10	5	-	-	-	-	43	24	50	50	100	100	
	X	33	47	28	23	28	27	11	3	-	-	-	-	39	30	38	62	100	100	
	XI	14	5	14	19	36	48	36	28	-	-	-	-	72	76	40	60	100	100	
	XII	-	-	3	17	23	67	74	16	-	-	-	-	97	83	63	37	100	100

Fig. 10. Changes in the feeding coefficient (K) during the year at various lengths of the sardines

AGE AND GROWTH RATE

The central problem in studying the fish age is to follow the succeeding stages of annual ring formation on scales and otoliths and to determine the birth date for the stock. The observations made allow to state that the hyaline rings (slow growth rings) originate in November – February in sardine otoliths. It should be mentioned that this is a period of lowest feeding and condition of the fish studied. From March until June the species discussed feeds intensively producing a strong opaque ring. The fluctuations of feeding

Table 5

Length and age of sardines fished on the West Sahara shelf in the second quarters of the years 1973, 1974, 1976 (no. of individuals)

Length (cm)	males						females						males + females					
	males						females						males + females					
	age groups						age groups						age groups					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
11	1					1	1						1					I-VI
12	7					7	4						11					11
13	26					26	13						13					39
14	35	1				36	45	1					46	2				82
15	35	18				53	44	20					64	38				117
16	6	72				78	27	43	1				71	115	1			149
17	1	103	3			107	6	90	9				105	193	12			212
18		106	39			145		105	20				125	211	59			270
19		38	96	10		144		57	78	10			145	95	174	20		289
20		8	77	29	1	115		9	119	30			158	17	196	59	1	273
21			41	23	5	69			94	63	7		164		135	86	12	233
22			3	11	5	19			35	77	22	2	136		38	88	27	155
23					2	2				28	19	6	53			28	21	7
24						-					3	2	5				3	2
Total	111	346	259	73	13	802	139	325	356	208	51	10	1089	250	671	615	281	1891
Mean length	14.06	19.47	21.62				14.48	17.49	20.04	22.35				14.22	19.80	22.20		
	17.27	20.48								21.40	23.00			17.38	21.16	23.00		

intensity and conditions occurring in the next months and the succeeding spawning peaks are shown in the structure of the otoliths, narrower hyaline and wider opaque rings forming as a result an annual ring consisting basically of a wide and a narrow hyaline ring and of a wide and narrow opaque ring. It should be noted that not all otoliths are easy to read and not on all such a regular structure is clearly visible.

Bravo de Laguna et al. (1979) state, with reference to stock „B“, that the formation of an annual ring begins in the period from February till March.

The above statements allow to accept January 1 as the birth date.

In Table 5 the results of age readings of sardines caught in 1973–1976 are compiled. This data allowed to calculate the parameters of fish growth:

sex	L_{∞}	k	t_0
males	23.16	0.437	-1.123
females	24.53	0.381	-1.353
males+females	24.62	0.371	-1.318

On the basis of these values and applying the von Bertalanffy equation, the theoretical lengths of fish in each age group were calculated (Table 6, Fig. 11).

As can be seen the sardine shows the largest growths up to the third year, the females having a higher growth rate than males.

An increase in the sardine weight, for both sexes inclusive was described on the basis of materials from 1973–1976.

Table 6

Theoretical length of sardines in age groups and mean annual increments
in the years 1973, 1974, 1976 (cm)

Sex		age groups						mean annual increments
		I	II	III	IV	V	VI	
males	theoretical length	14.00	17.23	19.33	20.69	21.56	22.13	3.68
	annual increment	14.00	3.24	2.09	1.36	0.87	0.57	
females	theoretical length	14.51	17.69	19.86	21.34	22.35	23.04	3.84
	annual increments	14.51	3.18	2.17	1.48	1.01	0.69	
males + females	theoretical length	14.20	17.43	19.66	21.19	22.25	22.99	3.83
	annual increments	14.20	3.23	2.23	1.53	1.06	0.74

Fig. 11. Theoretical length growth curves of male and female sardines calculated on the basis of multiannual means

Using the following lower mean empiric weights of fish in each age group:

age group	I	II	III	IV	V	VI
weight (g)	28.07	51.52	78.23	93.08	109.86	129.71

the parameters of an equation formulating the fish weight – age relationship were calculated by means of the least squares methods:

$$c = 0.0058; \quad n = 3.1875$$

This equation served to calculate the value of $W_{\infty} = 157.81$ g.

In order to characterise the weight growth of the species discussed, the von Bertalanffy equation modified by Gulland was used:

$$W_t = W_{\infty} [1 - e^{-k(t-t_0)}]^n$$

where: W_t = fish weight at the age „t”
 W_{∞} = fish weight at the length L_{∞} ,
 k, t_0, n = coefficients calculated in previous two equations.

The values obtained served to plot the growth curves (Fig. 12). As can be noticed, the sardine shows large growths of weight in the first four years of life, diminishing later.

Fig. 12. Theoretical weight growth curves of the sardine calculated on basis of multiannual means, both sexes inclusive

In literature available, a few works only on the age and growth rate of the sardine of North-West Africa can be found. The results of studies of different authors are reported below:

Region	Author	mean lengths in age groups					
		I	II	III	IV	V	VI
Marocco	Belveze (1972a)	13.8	16.9	18.6	19.8	20.5	21.0
Marocco	Furnestin (1950)	10.9	16.0				
Sahara	Domaniewski, Barkova (1976)	10.8	16.3	18.0	19.1	20.3	
Sahara	present study	14.2	17.4	19.7	21.2	22.2	23.0
Cap Juby	Bravo de Laguna et al. (1979)	14.81	18.84	20.43	21.24	21.74	21.99

Fig. 13. Composition of Polish sardine catches from the West Sahara region in terms of length and age in 1972 - 77

The lower growth rate of the sardine from the shelf off Morocco may be explained by worse trophic conditions, while the differences between results from the regions off Sahara and Cap Juby probably arise from different methods of readings and age interpretation adopted by the respective authors.

LENGTH AND AGE OF SARDINES IN POLISH CATCHES AND TOTAL MORTALITY COEFFICIENTS

The Polish catches from the years 1972–1977 contained individuals of 7–26 cm length, representing age groups I to VI+ (Fig. 13). In the succeeding years of studies the proportions between respective length classes and age groups changed, the changes resulting probably from fluctuations in the abundance of the age groups caught. This was the time when fishery, because of its small intensity, had no large impact on the length and weight structure of the catches. On the basis of data referred to it may be stated that the 1972–1977 catches were dominated by age groups II, III and IV. The high and stable contribution of the age group III in catches evidences its stability in the period discussed.

In the second quarters of the years 1972–1977 observations on the catch per unit effort of chosen B–18 trawlers were carried out. The results obtained were shown as absolute amounts of fish from respective age groups caught during one hour of trawling (Table 7).

Table 7

Catch per unit effort by B-18 trawlers in the second
quarter of the years 1972–77 (ind./hours trawling)

Year	age groups						total	
	I	II	III	IV	V	VI	ind./h	t/h
1972	6382	31039	25567	6605	607	—	70200	4.3
1973	5638	48512	46908	16995	1395	133	119581	7.8
1974	8945	34735	65867	6782	212	13	116554	7.5
1975	1344	7518	43202	22758	4386	469	79677	6.2
1976	976	11195	30855	22473	4066	367	69932	5.4
1977	191	9230	32248	18994	4192	2306	67161	5.3

Comparing the number of individuals from the same generation, caught in succeeding years, the coefficient of instantaneous mortality (Z) was calculated (Table 8) from the following equation:

$$Z = \ln \frac{N_t}{N_{t+1}}$$

where: N_t = amount of fish from generation „t” caught in a given year during one hour of trawling,
 N_{t+1} = amount of fish from generation „t” caught during hour of trawling in the next year.

Table 8

Total mortality coefficients of the sardine in 1972--77

Year of catch	age groups			total mortality coefficient	
	III/IV	IV/V	V/VI	weighed mean	Jackson's mean
1972/73	0.3535	1.5550	1.5182	0.62	0.57
1973/74	1.9339	4.3841	4.6757	2.63	2.23
1974/75	1.0627	0.4358	0.7940	1.00	0.97
1975/76	0.6535	1.7223	2.4808	1.11	0.96
1976/77	0.4851	1.6792	0.5671	0.96	0.81
$\bar{Z}$	0.8977	1.9552	2.0071	1.26	1.10

Since in the age groups I and II recruitment exceeds mortality this is the period of recruitment to the commercial stock; only the age groups III and IV were used to calculate the total mortality coefficient. The means calculated for various years differ only slightly, and only in the first period of studies larger differences may be observed as a result of changes in the length and age structure of the catches.

Belveze (1972a) and Barkowa (1977) describe similar large fluctuations in total mortality coefficients over succeeding years. It should also be noted that the values of Z given by these authors are slightly higher than those calculated in this study.

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MACIEJ KRZEPROWSKI

BIOLOGICZNA CHARAKTERYSTYKA SARDYNKI (*SARDINA PILCHARDUS* WALB.)
Z REJONU SACHARY ZACHODNIEJ

STRESZCZENIE

Na podstawie badań liczby kręgów stwierdzono, iż będące przedmiotem obserwacji saharyjskie stado sardynki wykazuje odrębność w stosunku do stada z rejonu Casablanki. Nie stwierdzono natomiast istotnych różnic w tym zakresie w odniesieniu do stada z rejonu Agadiru.

Omawiane stado zimą i wiosną wraz z chłodnym frontem hydrologicznym wędruje w kierunku południowym osiągając Cap Barbas, a nawet Cap Blanc. Latem i jesienią przemieszcza się ono ku północy w okolicy Cap Bojador.

Sardynka z rejonu Sahary najintensywniej żeruje w pierwszej połowie roku, szczególnie od marca

do czerwca. W dobowym rytmie żerowania, popołudnie i wczesne godziny wieczorne zaznaczają się jako okres najbardziej intensywnego pobierania pokarmu.

Najwyższą zawartość tłuszczu w tkance mięsnej oraz najwyższe wskaźniki kondycji i odtłuszczenia narządów wewnętrznych osiąga badany gatunek w lipcu. Najniższe wartości wymienionych wskaźników notowane są w styczniu i w lutym.

Sardynka charakteryzuje się tarłem porcyjnym. Autor obserwował trzy okresy nasilenia tarła w ciągu roku: marzec-kwiecień, sierpień-wrzesień, listopad-grudzień.

Wiek sardynki określono na podstawie odczytów bezpośrednich z otolitów. Obliczono następujące parametry równania wzrostu von Bertalanffy'ego (łącznie dla samców i samic):

$$L_{\infty} = 24,62 \quad K = 0,371 \quad t_0 = -1,318$$

W okresie badań podstawową część połowów stanowiły ryby należące do II, III, IV grup wiekowych.

Porównując ilości ryb z poszczególnych grup wiekowych, łowionych w kolejnych latach w ciągu godziny tarłowania obliczono współczynnik śmiertelności całkowitej $\bar{Z} = 1,10-1,26$.

М. Кржептовски

БИОЛОГИЧЕСКАЯ ХАРАКТЕРИСТИКА АТЛАНТИЧЕСКОЙ САРДИНЫ (SARDINA PILCHARDUS WALB.) РАЙОНА ЗАПАДНОЙ САХАРЫ

Р е з ю м е

На основе исследований количества позвонков доказали, что являющиеся объектом наблюдений сахарская популяция атлантической сардины отличается от популяции района Касабланка. Не обнаружено, в тоже время, существенных различий в этой области в отношении популяции района Агадира. Исследуемая популяция зимой и весной вместе с холодным гидрологическим фронтом мигрирует в южном направлении достигая мыса Барбас и даже мыса Бланк. Летом и осенью стая перемещается к северу в район мыса Боядо. Атлантическая сардина района Сахары наиболее интенсивно питается в первой половине года, в особенности с марта по июнь. В суточном режиме питания послеобеденные и ранние вечерние часы являются периодом наиболее интенсивного приема пищи. Самое высокое содержание жира в мышцах а также самые высокие коэффициенты упитанности и ожирения внутренних органов достигает исследуемый вид в июле. Самые низкие значения выше названных показателей отмечали в январе-феврале. Атлантическая сардина характеризуется порционным нерестом. Автор наблюдал три периода интенсификации нереста в течение года: март-апрель, август-сентябрь, ноябрь-декабрь. Возраст сардины определяли на основе непосредственных отсчетов отолитов. Подсчитали следующие параметры уравнения роста по-Бергаланфи (совместно для самцов и самок):

$$L = 24,62 \quad K = 0,371 \quad t_0 = -1,318$$

В период наблюдения основную долю уловов составляли рыбы принадлежащие к II, III, IV возрастным группам. Сравнивая количество рыб в отдельных возрастных группах отлавливаемых в течении нескольких последующих лет за час траления подсчитали коэффициент общей смертности: $\bar{Z} = 1,10 - 1,26$

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