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SOME DATA ON TAXONOMY AND BIOLOGY OF ANTARCTIC ICEFISH, *CHAMPSOCEPHALUS GUNNARI* LÖNNBERG, 1905

NIEKTÓRE DANE Z TAKSONOMII I BIOLOGII KERGULENY (*CHAMPSOCEPHALUS GUNNARI* LÖNNBERG, 1905)

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The paper contains results of biological studies on the Antarctic icefish. The materials were collected within 1975–1979 from various regions of the Antarctica. Presented are: distribution of the species, analysis of two meristic characters (vertebrae and fin ray counts), and some biological features (growth, maturation, fecundity, feeding). Based on the results, several Antarctic icefish stocks and their taxonomic positions are described. The stocks are analysed in terms of their length and age distributions in several fishing seasons.

INTRODUCTION

The Antarctic icefish (*Champsocephalus gunnari* Lönnberg, 1905) occupies an important position among the Antarctic ichthyofauna. Its wide distribution and abundant concentrations favour fishing operations, hence the species: importance for fisheries. The rational exploitation of the species calls for knowledge on its biology, distribution of stocks, identification of individuals from various areas as definite taxonomic categories as well as age distribution dynamics of various stocks exploited commercially.

The aim of the present paper is to analyse some biological and meristic characters of the species in order to gain more insight into the issues listed above.

MATERIALS AND METHODS

Biological materials for studies on the Antarctic icefish have been collected since the Antarctica was first explored by Polish research and fishing vessels.

In the Indian Ocean sector of the Antarctica the studies were carried out off the Kerguelen Islands. The materials were collected during the following cruises:
- RV "Profesor Siedlecki", April 1975;
- MT "Manta", 1977/1978 fishing season;
- MT "Lacerta", December 1979.

The studies in the Atlantic sector were carried out off South Georgia and Shag Rocks, South Sandwich Islands, Souts Orkneys, Elephant Island, South Shetlands, and SW along the Antarctic Peninsula to Peter the First Island. The Antarctic icefish was found in most of the regions listed. No representatives of the species were encountered off South Sandwich Islands and off the Antarctic Peninsula south of the Palmer Archipelago.

The materials from the Atlantic sector were collected during the following cruises:
- RV "Profesor Siedlecki", 1975/1976 fishing season;
- MT "Gemini" and MT "Rekin", 1976/1977 fishing season;
- MT "Gemini" and MT "Sirius", 1977/1978 fishing season;
- RV "Profesor Siedlecki" and MT "Sirius", 1978/1979 fishing season.

As the studies progressed, it turned out that the materials from some of the fishing ground could be put together into groups corresponding to regions of the Antarctica, the fish from which showed similarities in their characters studies. Thus, in the Atlantic sector, the regions of northern and southern fishing grounds were separated, the first including the grounds off South Georgia and Shag Rocks and the other covering those off South Orkneys, Elephant Island, South Shetlands (King George, Livingston, and Deception Island), and the Palmer Archipelago.

Table 1 lists the biological data collected from the stocks studied.

Individuals to be examined were picked out at random; their total length was measured to 1 cm and weighed (to 1 g). Gonad maturity stage was determined according to Maier's scale. Age was determined from the number of hyaline zones on the surface of broken otoliths. The date of transition from one age group to the next is set on 1 July.

Feeding intensity was determined from the extent of stomach fullness, according to a 5-score scale. Individual fecundity was determined by couting eggs in a pre-weighed sample. The gonads were preserved in 4% formalin.

The otolith length-total body length relationship and individual fecundity relationships in different versions were calculated on an Hewlett-Packard 9805 A computer.

Taxonomic analysis was based on two meristic characters: vertebrae and fin ray counts.

Table 1

Biological materials collected within 1975–1979 (no. of individuals)

Region	Age reading	Length	Weight	Stomach fullness	Sex and gonad maturity	Fecundity	Otolith measurement	Vertebrae count	Fin ray count
Atlantic sector, northern fishing grounds	2,370	28,943	4,232	3,845	4,735	401	1,207	380	95
Atlantic sector, southern fishing grounds	950	59,834	5,643	5,761	5,773	128	419	949	183
Indian Ocean sector: Kerguelen Islands	635	9,506	871	1,009	1,009	80	286	99	32
Total	3,955	98,283	10,746	10,615	11,517	609	1,912	1,428	310

The significance of differences between the meristic characters was looked for by using two tests:

$$1)\ \text{Mdiff} = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}}$$

2) "Affinity", after Ginsburg (1938).

DISTRIBUTION

Observations made in the Atlantic sector during Polish scientific expeditions (1976–1979) on board research vessels as well as the analysis of the distribution of fishing grounds operated on by the Polish fishing fleet allowed to describe the Antarctic icefish distribution in detail (Fig. 1):
off the northern and eastern coasts of South Georgia, around Shag Rocks, off the northern, and eastern coasts of South Orkneys, off the western coast of Elephant Island, between Elephant and Joinville Islands, around South Shetlands. The southern boundary of the *Ch. gunnari* distribution is the Palmer Archipelago.

In the Indian Ocean sector, the species was found to occur on the shelf off Kerguelen Islands, on the Skif Shoal (W of Kerguelen Islands), and on a shoal between Kerguelen and Heard Islands (Fig. 2).

In the Atlantic sector, the species was observed to occur down to 600 m depth. The most abundant catches were made at 200 to 400 m. Off Kerguelen Islands. Polish vessels were catching the species at 220 to 445 m, the best catches being obtained at about 300 m.

MERISTIC CHARACTERS

The meristic characters studied included the vertebrae count and fin ray counts.

Vertebrae count

Table 2 shows the total verterbrae counts in individuals caught on different fishing grounds. The data show the samples collected from the same fishing ground to have similar mean vertebrae numbers and distribution of counts; those parameters proved characteristic of a fishing ground.

To further analyse the data in terms of their between-grounds variability, the question was asked if the vertebrae counts were fish length-dependent. Mean counts were calculated for length classes (Table 3), whereby no vertebrae count-fish length rela-

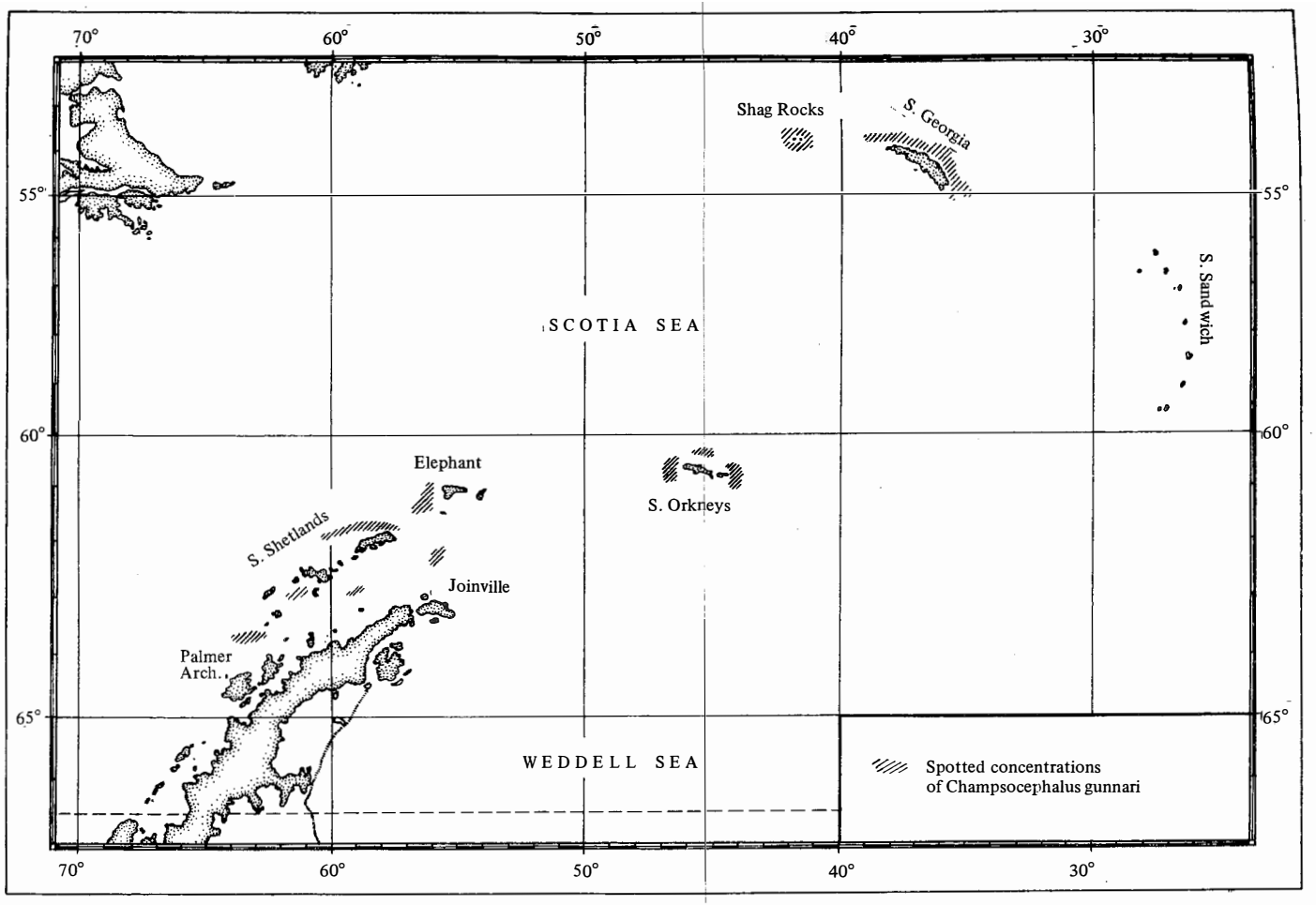

Fig. 1. Distribution of *Champsocephalus gunnari* in the Scotia Sea off the Antarctic Peninsula

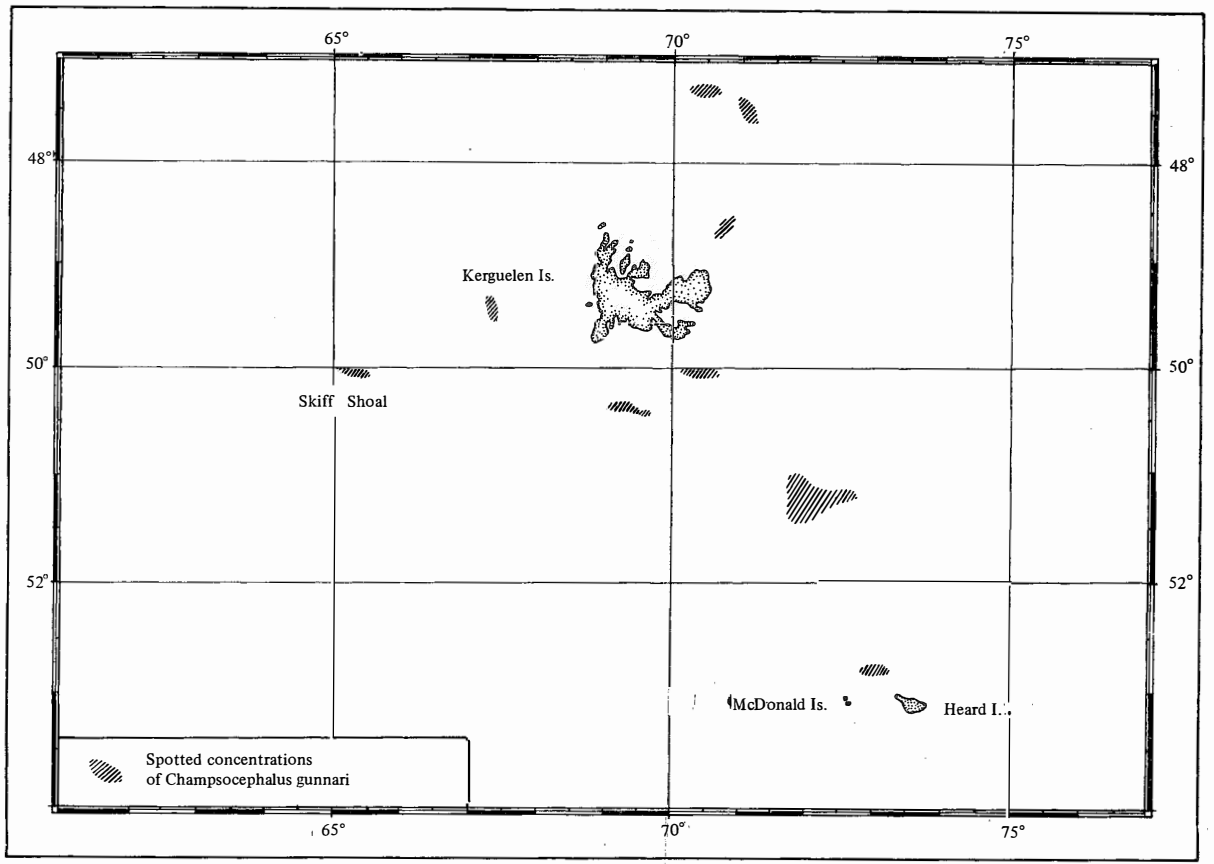

Fig. 2. Distribution of *Champsocephalus gunnari* off Kerguelen Islands

Table 2

Vertebrae counts in *Ch. gunnari* from various Antarctic fishing grounds (no. of individuals)

Vertebrae count	Fishing ground															Kerguelen Is.
	South Georgia		Shag Rocks		South Orkneys		Elephant I.				King George I.			Deception I.		
	Date of examination															
	I 1979	III 1979	I 1979	III 1979	XII 1978	III 1978	XII 1978	I 1979	II 1979	III 1979	I 1979	II 1979	III 1979	II 1979	II 1979	XII 1979
58	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
59	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	42
60	2	16	2	8	1	1	–	–	1	1	–	–	–	–	–	46
61	56	55	54	61	20	16	30	12	31	31	1	7	11	15	1	6
62	23	27	37	30	68	65	64	72	58	52	38	47	58	51	13	–
63	3	1	4	–	11	15	6	16	7	11	22	23	29	29	3	–
64	–	–	–	–	–	2	–	–	1	1	1	1	1	3	1	–
n	85	99	97	99	100	99	100	100	98	96	62	79	99	98	18	99
$\bar{X}$	61.29	61.13	61.44	61.22	61.89	62.01	61.80	62.04	61.75	61.79	62.37	62.19	62.20	62.20	62.22	59.33
	61.21		61.33		61.95		61.84				62.24			62.21		59.33

Table 3

Mean vertebrae counts in length classes from various Atlantic sector fishing grounds

Length class (cm)	Fishing ground											
	South Georgia		Shag Rocks		South Orkneys		Elephant I.		King George I.		Deception I.	
	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
18	–	–	61.00	1	–	–	–	–	–	–	–	–
19	–	–	61.25	4	–	–	–	–	–	–	–	–
20	62.00	1	61.00	8	–	–	–	–	–	–	–	–
21	60.50	4	61.29	7	–	–	–	–	–	–	–	–
22	61.50	2	61.00	1	–	–	–	–	–	–	–	–
23	61.33	3	–	–	–	–	–	–	–	–	–	–
24	61.25	8	61.00	2	–	–	–	–	–	–	–	–
25	61.27	11	61.00	4	–	–	62.50	2	–	–	61.00	2
26	61.29	7	61.00	5	–	–	62.25	4	–	–	63.00	1
27	61.14	7	61.25	4	–	–	62.00	1	–	–	63.00	1
28	61.00	7	61.00	4	–	–	–	–	–	–	–	–
29	60.80	5	61.18	11	–	–	63.00	1	–	–	–	–
30	61.00	14	61.08	13	–	–	–	–	–	–	63.00	1
31	61.18	17	61.35	23	61.00	1	–	–	61.67	3	–	–
32	61.11	18	61.54	28	–	–	61.57	7	63.00	1	61.50	2
33	61.39	23	61.30	27	61.00	2	61.80	15	62.50	2	62.00	11
34	60.92	13	61.55	20	61.83	6	61.89	19	62.23	13	62.31	13
35	61.20	15	61.29	7	61.79	14	61.73	41	62.43	7	62.00	20
36	61.33	9	61.67	6	62.05	18	61.75	53	62.00	5	62.20	25
37	61.75	4	61.60	10	61.92	37	61.85	39	62.00	9	62.35	20
38	61.50	4	61.40	5	62.09	22	61.76	59	62.14	22	62.62	8
39	60.60	1	61.25	4	61.93	41	61.90	40	62.00	17	–	–
40	62.00	1	61.50	2	62.13	31	61.82	45	62.45	33	62.33	3
41	–	–	–	–	61.83	12	61.87	32	62.25	28	62.25	4
42	61.50	2	–	–	61.87	8	61.88	17	62.19	36	62.00	3
43	62.00	1	–	–	61.67	3	61.91	11	62.23	31	–	–
44	62.00	1	–	–	62.00	3	62.50	4	62.40	10	–	–
45	61.50	2	–	–	62.00	1	62.50	4	62.50	10	–	–
46	62.00	2	–	–	–	–	–	–	62.00	5	62.50	2
47	–	–	–	–	–	–	–	–	62.50	4	–	–
48	61.00	1	–	–	–	–	–	–	62.50	2	–	–
49	–	–	–	–	–	–	–	–	–	–	–	–
50	–	–	–	–	–	–	–	–	61.50	2	–	–
51	–	–	–	–	–	–	–	–	–	–	–	–
52	–	–	–	–	–	–	–	–	–	–	–	–
53	61.00	4	–	–	–	–	–	–	–	–	–	–
Total	61.21	184	61.33	196	61.95	199	61.84	394	62.24	240	62.21	116

tionship was detected. When mean counts for the same length classes within 33–38 cm (the classes comprising representative numbers of individuals examined) from different Atlantic sector fishing grounds are compared, it can be seen that the means differ from one fishing ground to another. Close values are typical of the Antarctic icefish caught off: South Georgia and Shag Rocks, South Orkneys and Elephant Island, King George Island and Deception Island.

The individuals caught off King George Island and Deception Island have, as can be seen, vertebrae counts similar to those off South Orkneys and Elephant Island; in both groups 62 vertebrae is the prevailing count. On the other hand, the two groups differ in their mean counts and in the distribution of counts. The individuals from the four fishing grounds listed differ widely from those caught off South Georgia and Shag Rocks.

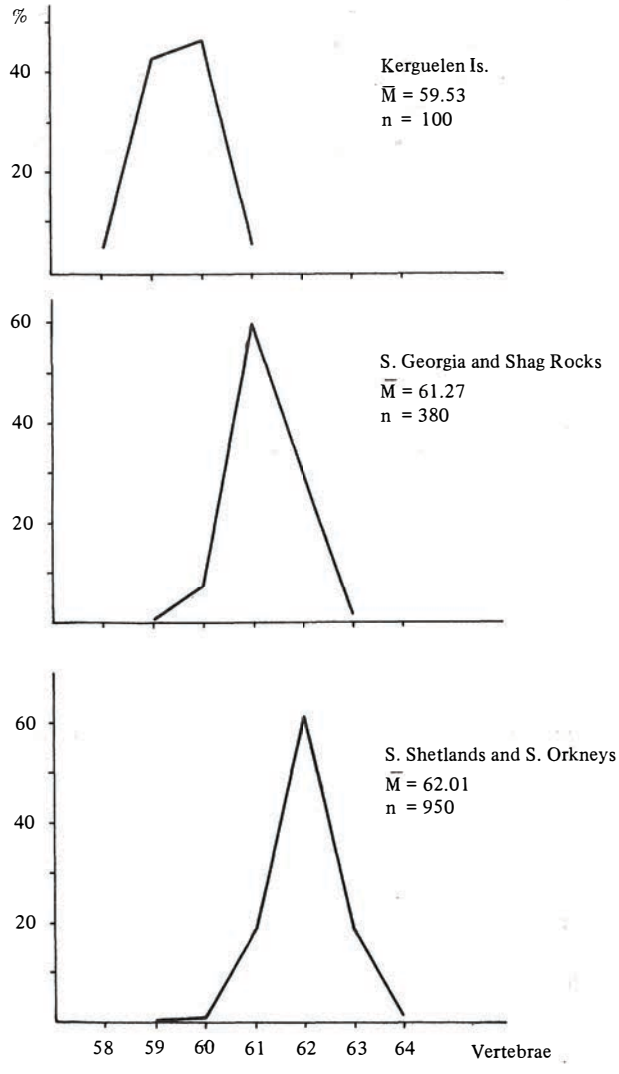

Fig. 3. Vertebrae count distribution in *Ch. gunnari* caught in Antarctic regions

Fig. 3 shows the total vertebrae count distribution for the four fishing grounds (South Orkneys, Elephant Island, King George Island, Deception Island), the plot being denoted S. Shetlands and S. Orkneys; another plot shows the distribution for S. Georgia and Shag Rocks, and the third one is for Kerguelen Islands in the Indian Ocean sector. It is evident that the three groups of the Antarctic icefish differ in their vertebrae counts.

Arithmetic means (M), standard deviations (δ), and standard errors of the mean (m) were calculated for the vertebrae counts from different fishing grounds (Table 4) in order to test for the significance of differences between the counts in various groups of *Ch. gunnari,* using the Mdiff test.

Table 5 gives the results of the statistical test. As shown by the Mdiff values obtained, no significant differences exist between the individuals caught: off South Georgia and Shad Rocks, off South Orkneys and Elephant Island, off King George Island and Deception Island; in those cases Mdiff does not exceed 3.

On the other hand, significant are the differences between the first group (individuals from off South Georgia and Shag Rocks) and the remaining Atlantic sector fishing grounds as well as between the Kerguelen Islands individuals and those from various Atlantic sector grounds.

Table 4

Arithmetic means (M), standard deviations (δ), and standard errors of the mean (m) of vertebrae counts in *Ch. gunnari* from various Antarctic fishing grounds

Fishing ground	M	δ	m	n
S. Georgia	61.21	0.66	0.05	184
Shag Rocks	61.33	0.60	0.04	196
Total	61.27	0.63	0.03	380
S. Orkneys	61.95	0.62	0.04	199
Elaphant I.	61.84	0.62	0.03	394
Total	61.87	0.62	0.02	593
King George I.	62.24	0.65	0.04	240
Deception I.	62.21	0.71	0.07	116
Total	62.23	0.67	0.03	356
Atlantic sector total	61.80	0.73	0.02	1 329
Kerguelen Is., Indian Ocean sector	59.53	0.69	0.07	99

Table 5

Significance of differences between mean vertebrae counts in *Ch. gunnari* from various Antarctic fishing grounds

Fishing ground*	$Mdiff = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_1^2}}$
1–2	1.87 < 3
3–4	2.20 < 3
5–6	0.37 < 3
3–5	3 < 5.13 < 10
3–6	3 < 3.25 < 10
4–5	3 < 8.00 < 10
4–6	3 < 4.87 < 10
1–3	10 < 11.56
1–4	10 < 10.86
1–5	10 < 16.09
1–6	10 < 11.63
2–3	10 < 10.96
2–4	10 < 10.20
2–5	10 < 16.09
2–6	10 < 11.00
(1,2)– (3,4)	10 < 14.59
(1,2)– (5,6)	10 < 19.94
(3,4)– (5,6)	3 < 8.14 < 10
(1,2) – (3–6)	10 < 18.91
7–1	10 < 19.53
7–2	10 < 22.50
7–3	10 < 30.25
7–4	10 < 30.39
7–5	10 < 33.62
7–6	10 < 27.07
(1–6) – 7	10 < 31.07

* 1. S. Georgia, 2. Shag Rocks } northern grounds

3. S. Orkneys, 4. Elephant I., 5. King George I., 6. Deception I. } Southern grounds — Atlantic sector

7. Kerguelen Is. — Indian Ocean sector

The significance of differences between the individuals from off South Orkneys, Elephant Island, King George Island, and Deception Island is questionable. Although the Mdiff value does exceed 3, it is much lower than that separating the S. Georgia and Shag Rocks individuals from the remaining ones.

Presumably, owing to a relatively large number of individuals examined, the critical Mdiff value should be increased. If Mdiff = 10 (and not 3) is taken as a criterion of significance, no significant difference is found between those individuals from the southern fishing grounds.

Accordingly, the individuals from off South Georgia and Shag Rocks from one group of fish, and those caught in the fishing grounds situated more to the south (South Orkneys, Elephant, King George, and Deception Islands) form another one. The two groups were next compared by Mdiff. The value obtained was very high (18.91), indicating the significant difference between the two groups.

A still higher difference (Mdiff = 31.07) exists between the vertebrae count off Kerguelen Island and that for the Atlantic sector fishing grounds.

The significance of differences was also tested for by means of a procedure given by Ginsburg (1938).

Table 6 gives "affinity" values calculated in the Ginsburg test. The results obtained with this test confirm the conclusions drawn from Mdiff. When the criterion of race identity is sharpened from 40% to 35%, the "affinities" of individuals from various fishing grounds are as follows:

- the individuals caught off South Georgia and Shag Rocks form a separate race;
- the individuals caught off South Orkneys and Elephant Island form a separate race;
- the individuals caught off King George Island and Deception Island form a separate race.

No racial difference exists between the South Orkneys (Elephant Island individuals and those off King George) Deception Island; on the other hand, a racial difference does exist between the South Georgia (Shag Rocks individuals and those) caught more to the south (South Orkneys, Elephant, King George, and Deception Island). The individuals off Kerguelen Island show only a slight "affinity" with those from the Atlantic sector. Based on the Ginsburg criterion, the individuals caught off Kerguelen Islands are, with regard to those from the Atlantic sector, not only a separate race or a separate sub-species, but can be even regarded as a distinct species. Based on mean vertebrae counts, the appearance of vertebrae count distribution curves, and values of the mode, the sharpened significance tests indicate the Atlantic sector individuals caught in the northern fishing grounds (South Georgia and Shag Rocks) can be thought of as belonging to a race different than the one formed by those caught in the regions more to the south (South Orkneys, Elephant, King George, and Deception Island).

A still greater difference is observed to exist between the Kerguelen Islands individuals (Indian Ocean sector) and those from the Atlantic sector. To be on the safe side, it is preferred to regard the two groups as two sub-species of *Champsocephalus gunnari*

Table 6

Significance of differences between mean vertebrae counts in *Ch. gunnari* from various Antarctic fishing grounds

Fishing ground*	"Affinity" of the Ginsburg test
1–2	35 < 46.5%
3–4	35 < 45.8%
5–6	35 < 46.0%
3–5	35 < 40.8%
3–6	35 < 41.5%
4–5	35 < 39.1%
4–6	35 < 39.8%
1–3	24.2% < 35
1–4	28.1% < 35
1–5	18.8% < 35
1–6	21.6% < 35
2–3	27.6% < 35
2–4	31.5% < 35
2–5	22.0% < 35
2–6	25.0% < 35
(1,2) – (3,4)	28.5% < 35
(1,2) – (5,6)	21.4% < 35
(3,4) – (5,6)	35 < 39.8%
(1,2) – (3,6)	25.8% < 35
7–1	8.1% < 10
7–2	5.5% < 10
7–3	3.5% < 10
7–4	3.2% < 10
7–5	3.2% < 10
7–6	3.0% < 10
(1–6) – 7	4.3% < 10

* denoted as in Table 5

rather than to regard them as two species of the genus *Champsocephalus*. The individuals from the Indian Ocean sector show the lowest vertebrae counts.

Fin Ray count

Fin ray count is - along with vertebrae count – a very important meristic character frequently used in studies on fish races. Table 7 summarises the relevant data for the samples examined. As no substantial differences between fin ray counts of the South Georgia and Shag Rocks (northern part of the Atlantic sector) fish studied were found, the fin ray count formula was developed for the region as a whole. Similarly, data for the South Orkneys and South Shetlands (Elephant, King George, and Deception Island) Antarctic icefish are grouped together and the formula developed for the southern part of the sector. The results are given in Table 8. along with data for the Kerguelen Islands fishing grounds.

The materials presented show the pectoral (P) fin ray count distribution to be similar in the Antarctic icefish from various fishing grounds. In the first dorsal fin (D), the ray count differs between the northern and southern fishing grounds of the Atlantic sector. The D_1 ray count distribution for the Indian ocean sector (Kerguelen Islands) fish resembles that of the Atlantic sector fishing grounds.

The second dorsal (D_2) and anal (A) fins are the most suitable ones for fin ray count studies.

The data contained in Table 8 and Fig. 4 show that there is no substantial difference between the northern and southern fishing grounds of the Atlantic sector. On the other hand, the Indian Ocean sector Antarctic icefish differ considerably from those of the Atlantic sector.

Similarly to the vertebrae counts, significance of differences was tested for the fin ray counts as well (Mdiff and Ginsburg tests). Arithmetic means (M), standard deviations (δ), and standard errors of the mean (m) were calculated prior to testing for significance (Table 9).

The results of tests for the Antarctic icefish of the three basic regions of study are given in Table 10. The table contains also the results of tests comparing the Kerguelen Islands fish with those from the whole Atlantic sector.

The sharpen the race differentiation criterion, Mdiff = 5 is regarded as the critical value of the test instead of commonly used Mdiff = 3. The data contained in Table 11 show the fish of the Atlantic sector southern fishing grounds to differ significantly in their D_1 counts from those of the northern grounds and off Kerguelen Islands. On the other hand, the individuals of the Atlantic sector nothern fishing grounds show no significant differences in this respect relative to the fish caught off Kerguelen Islands.

The pectoral (P) fin ray count cannot be used as a race-differentiating character since the counts and their distributions were almost identical in all the Antarctic icefish groups studied, hence very low Mdiff values.

Fin ray counts in *Ch. gunnari* from various Antarctic fishing grounds

	Fishing ground																	
	S. Georgia			Shag Rocks			S. Orkneys			Elephant I.				King George I.				Deception I.	Kerguelen Is.
	Fin ray count																		
	III 1977	III 1979	Σ	III 1977	III 1979	Σ	XII 1978	XII 1978	Σ	XII 1978	I 1979	II 1979	Σ	I 1979	II 1979	II 1979	Σ	II 1979	IV 1975
D_1																			
VIII	3	–	3	–	–	–	4	4	8	1	–	–	1	–	–	–	–	–	3
IX	29	15	44	17	16	33	11	6	17	6	14	9	29	9	9	7	25	7	21
X	3	4	7	3	4	7	–	–	–	22	15	6	43	6	15	18	39	10	8
XI	–	1	1	–	–	–	–	–	–	1	1	–	2	–	1	–	1	1	–
D_2																			
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
36	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	11
37	2	–	2	–	1	1	–	–	–	–	2	1	3	–	3	–	3	–	12
38	10	4	14	4	8	12	4	3	7	7	10	4	21	4	10	10	24	9	3
39	19	12	31	13	9	22	7	4	11	12	13	9	34	7	9	15	31	6	–
40	3	4	7	3	1	4	4	3	7	11	5	1	17	3	3	–	6	3	–
41	1	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P																			
24	1	–	1	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	1	–
26	9	4	13	1	6	7	3	2	5	6	5	2	13	9	3	5	17	5	1
27	17	13	30	18	12	30	9	8	17	19	18	10	47	4	16	11	31	10	8
28	6	2	8	1	1	2	1	–	1	4	7	3	14	2	6	8	16	2	1
29	2	1	3	–	1	1	–	–	–	1	–	–	–	–	–	1	1	–	1
A																			
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
36	6	2	8	–	–	–	4	1	5	–	3	–	3	5	4	2	11	–	13
37	15	4	19	7	8	15	9	6	15	13	13	6	32	7	11	12	30	4	8
38	14	14	28	12	10	22	2	2	4	12	14	9	35	3	9	9	21	12	1
39	–	–	–	1	1	2	–	–	–	5	–	–	5	–	1	2	3	2	–
40	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 8

Fin ray counts in *Ch. gunnari* from various Antarctic sectors

Fin ray count	Antarctic sector							
	Atlantic				Indian Ocean			
	northern fishing grounds (1,2)*		southern fishing grounds (3,4,5,6)*		total		Kerguelen Is. (7)	
–	ind.	%	ind.	%	ind.	%	ind.	%
D_1								
VIII	3	3	9	5	12	4	3	9
IX	77	81	78	43	155	56	21	66
X	14	15	92	50	106	38	8	25
XI	1	1	4	2	5	2	–	–
D_2								
35	–	–	–	–	–	–	5	16
36	–	–	1	1	1	+	11	35
37	3	3	6	3	9	3	12	39
38	26	27	61	35	87	31	3	10
39	53	56	82	45	135	49	–	–
40	11	12	33	18	44	16	–	–
41	2	2	–	–	2	1	–	–
P								
24	1	1	1	1	2	1	–	–
25	–	–	2	1	2	1	–	–
26	20	21	40	22	60	22	1	10
27	60	63	105	57	165	59	8	80
28	10	11	33	18	43	15	1	10
29	4	4	2	1	6	2	–	–
A								
33	–	–	–	–	–	–	1	3
34	–	–	–	–	–	–	2	6
35	–	–	1	1	1	+	7	22
36	8	8	19	10	27	11	13	41
37	34	36	81	44	115	41	8	25
38	50	53	72	39	122	44	1	3
39	2	2	10	6	12	4	–	–
40	1	1	–	–	1	+	–	–

* 1. S. Georgia, 2. Shag Rocks, 3. S. Orkneys, 4. Elephant I., 5. King George I., 6. Deception I., 7. Kerguelen Is.

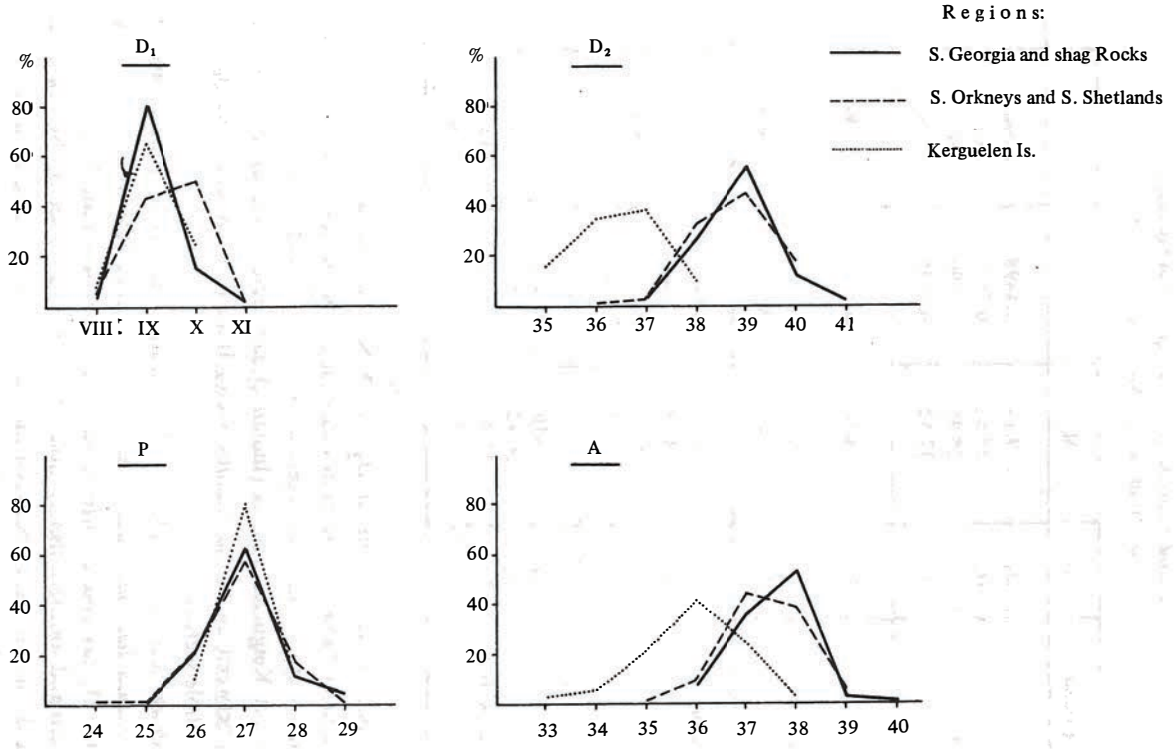

Fig. 4. Fin ray count distributions in *Ch. gunnari* from various Antarctic regions

Table 9

Arithmetic means (M), standard deviations (δ), and standard errors of the mean (m) for fin ray counts in *Ch. gunnari* from various Antarctic fishing grounds

Fishing ground	Fin	M	δ	m	n
S. Georgia	D_1	9.14	0.4498	0.0461	95
	D_2	38.82	0.7537	0.0773	95
Shag Rocks	P	26.95	0.7590	0.0779	95
	A	37.52	0.7235	0.0742	95
S. Orkneys	D_1	9.50	0.3921	0.0290	183
	D_2	38.77	0.7992	0.0591	183
S. Shetlands	P	26.95	0.7297	0.0531	183
	A	37.39	0.8124	0.0600	183
Atlantic sector	D_1	9.37	0.5971	0.0358	278
	D_2	38.78	0.7842	0.0470	278
total	P	26.95	0.7399	0.0444	278
	A	37.43	0.7544	0.0452	278
Kerguelen Is.	D_1	9.16	0.3193	0.0564	32
	D_2	36.42	0.7597	0.1364	31
Indian Ocean sector	P	27.00	0.4472	0.1414	10
	A	35.87	1.0533	0.1862	32

It seems that the ray counts of D_2 and A are most suitable as race-differentiating criteria. As seen in Table 10, the individuals caught in the northern and southern regions of the Atlantic sector form a homogenous group in terms of their counts and differ from those caught off Kerguelen Islands (Indian Ocean sector), the differences occurring in comparisons between individual Atlantic sector/Indian Ocean sector fishing grounds and between the whole sectors.

The Ginsburg test results (Table 11) confirm the above conclusions. After the "affinity" criterion had been sharpened here, too, from 40% to 35%, a conclusion was drawn that the D_1 ray counts differed significantly between the Antarctic icefish caught in the northern and southern fishing grounds of the Atlantic sector. Non-significant is, on the other hand, the difference between the fish of the two regions and those caught off Kerguelen Islands. Ray counts in D_2 and A, the two most important fins, show no difference to exist between the individuals of the two regions of the Atlantic sector; these individuals are, however, significantly different from those off Kerguelen Islands. The low "affinity" of D_2 counts could even indicate the presence of two separate species, according to the Ginsburg criteria.

Table 10

Significance of differences between mean fin ray counts in *Ch. gunnari* from various Antarctic fishing grounds (based on

$$\text{Mdiff} = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_1^2}})$$

Fishing ground*	Fin			
	D_1	D_2	P	A
(1,2) – (3–6)	5 < 6.60	0.51 < 5	0.00 < 5	1.36 < 5
(1,2) – 7	0.27 < 5	5 < 15.31	0.31 < 5	5 < 8.23
(3–6) – 7	5 < 5.36	5 < 15.81	0.33 < 5	5 < 7.75
(1–6) – 7	3.14 < 5	5 < 16.35	0.34 < 5	5 < 8.14

*denoted as in Table 5

Considering the results of the two tests performed, the Indian Ocean sector's *Ch. gunnari* can be regarded as significantly different, in terms of fin ray counts, from the representatives of the species caught in the Atlantic sector. In the latter, the fish occurring in the northern fishing grounds are not different from those caught in the southern grounds. Although there is a difference between their D_1 counts, it is lower than the differences in D_2 and A counts separating the individuals of the two sectors.

Table 11

Significance of differences between fin ray counts in *Ch. gunnari* from various Antarctic fishing grounds (Ginsburg test)

Fishing ground*	Fin			
	D_1	D_2	P	A
(1,2) – (3–6)	31.0% < 35	35 < 43.5%	35 < 45.5%	35 < 42.5%
(1,2) – 7	35 < 42.0%	6.5% < 10	35 < 41.5%	18.0% < 35
(3–6) – 7	35 < 36.5%	7.0% < 10	35 < 38.5%	19.5% < 35
(1–6) – 7	35 < 42.5%	6.5% < 10	35 < 39.5%	19.2% < 35

* denoted as in Table 5.

The results obtained here are in agreement with data given by Norman (1938) and Regan (1913) who gave ranges of fin ray counts in *Ch. gunnari*. Detailed data for the species off South Georgia can be found in Olsen (1955). His formula of the fin ray count is almost identical to that calculated in this study for the individuals of the Atlantic sector northern fishing grounds (South Georgia, Shag Rocks). On the other hand, the ray counts for D_2 and A in the Kerguelen Islands *Ch. gunnari* found in this study are much lower than the ranges given by the authors mentioned.

ANTARCTIC ICEFISH (*CH. GUNNARI*) GROWTH

Otolith size

Otoliths grow with a fish. In the present study, the otolith size is regarded as a parameter used to discriminate separate stocks of the species. Otoliths were measured along their loneger axis.

The measurements were made to calculate parameters of the linear equation $y = a+bL$, describing the otolith size-total fish length relationship. The parameters were calculated for individuals caught in three regions: off Kerguelen Islands; off South Georgia and Shag Rocks; off South Orkneys and South Shetlands. The values of the parameters are given in Table 12 and Fig. 5.

Table 12

Parameters of linear equation describing otolith size (y)–total body length (L) relationship in *Ch. gunnari*

Fishing ground	Period of study	n (no. of ind.)	Fish length range (cm)	R*	Relationship as in formula Y (mm) = a + b L (cm)		
					a	b	r^2 **
Kerguelen Is.	IV 1975	286	15–40	0.9889	0.5935	0.0655	0.9780
S. Georgia and Shag Rocks	II 1977	1207	18–57 (68)	0.9675	0.9961	0.0499	0.9361
S. Orkneys and S.Shetlands	XII 1978 II 1979	419	23–47	0.9313	1.0293	0.0458	0.8674

* R = correlation coefficient; ** r^2 = coefficient of determination of theoretical values relative to empirical ones

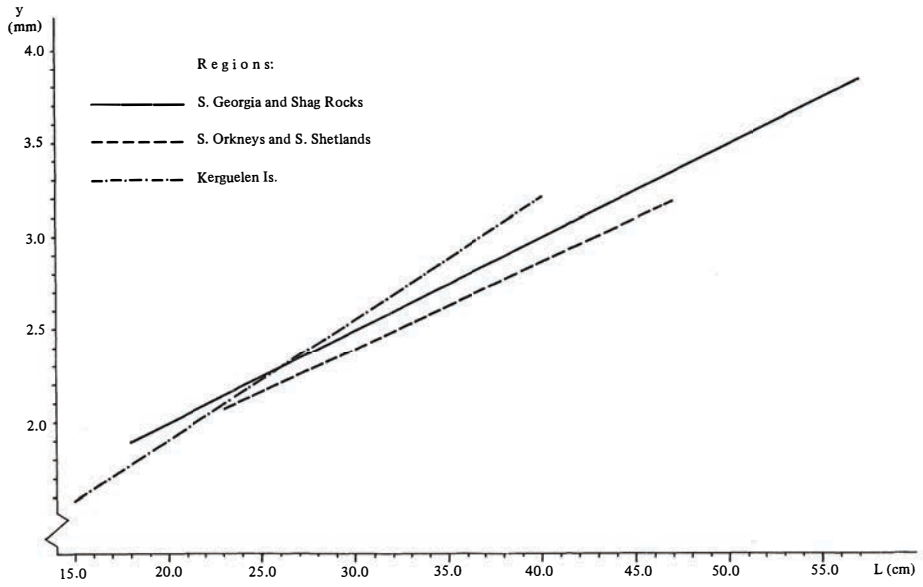

Fig. 5. Otolith length (y) – total length (L) relationship in *Ch. gunnari*

Fig. 5 shows the slope of the lines regressing the otolith size on the fish length off South Georgia and Shag Rocks to be similar to that off South Shetlands and South Orkneys, the otoliths of the first region being larger than those of the other.

The line fitting the Kerguelen Islands data shows a slightly different slope, the individuals about 24 cm long having otoliths larger than these from the Atlantic sector. A comparison between the lines shows the otolith size to increase southward.

Although the lines mirror the otolith size-fish length relationship pretty well, as evidenced by high determination coefficients given in Table 12, the question is: are the straight lines the best fit? The problem was tackled using otoliths of the South Georgia individuals as they were distributed over the widest length range (18–57 cm). Apart from the rectilinear relationship presented above (following the equation $y = a + bL$), curvilinear relationships were tried. Equation parameters were calculated for a logarithmic curve ($y = a + bl_n L$) and for a parabolic one ($y = a + bL + cL^2$). The parameters calculated are reported in Table 13 and the curves obtained are presented in Fig. 6.

The coefficients of determination given in Table 13 show the log curve to be the best fit to the data within the 18–57 cm fish length range. Also the parabolic curve is a better fit than a straight line.

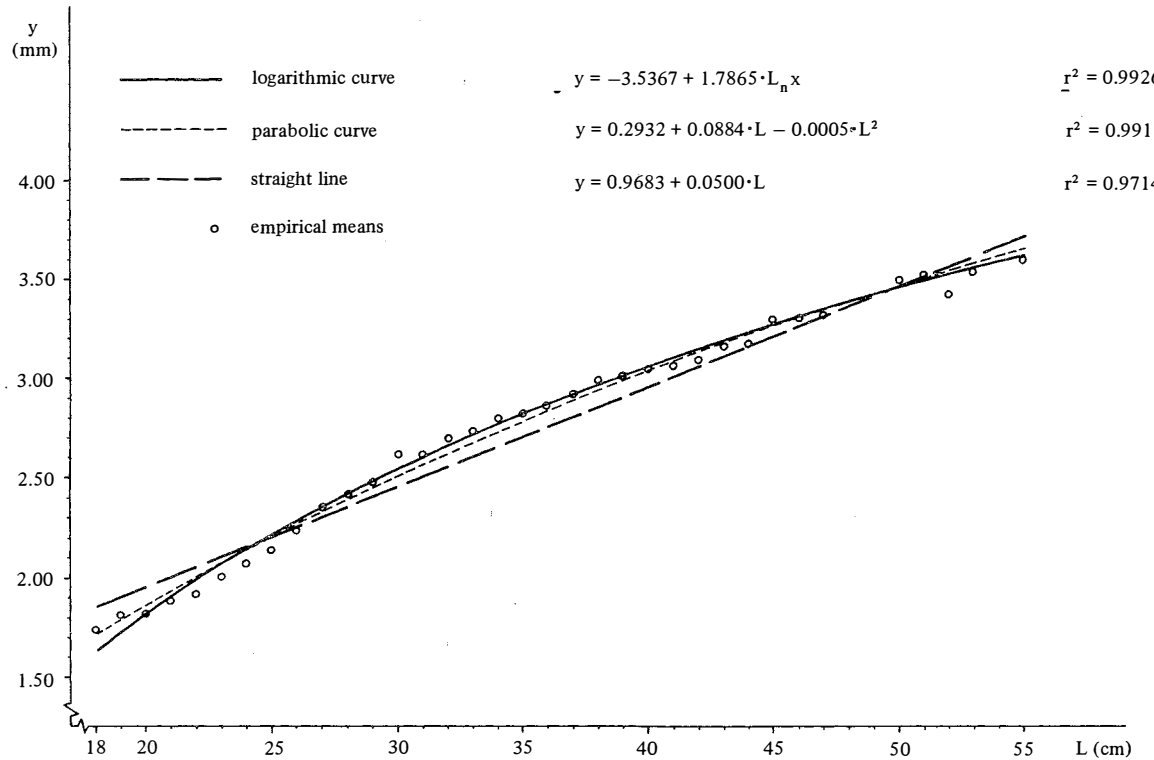

Fig. 6. Otolith length (y) – total length (L) relationship in *Ch. gunnari* off South Georgia

Table 13

Parameters of equations describing otolith length-total body length relationship in *Ch. gunnari* off South Georgia

Parameter	Logarithmic equation $Y_{(mm)} = a+bl_nL_{(cm)}$	Parabolic equation $Y_{(mm)} = a+bL_{(cm)}+cL^2_{(cm)}$	Linear equation $Y_{(mm)} = a+bL_{(cm)}$
a	– 3.5367	0.2932	0.9683
b	1.7865	0.0884	0.0500
c	–	– 0.0005	–
r^2	0.9926	0.9911	0.9714

Fish length growth

In the present work the Antarctic icefish growth rate is compared for individuals from various regions. Calculations were made from direct measurements of individuals belonging to various age groups. To avoid large discrepancies which might result from different time of sampling, only those individuals caught from January through May were examined. The date of 1 July is considered the time when an individual passes from one age group to another.

Owing to a small distance between certain Atlantic sector regions and also due to the fact of mean fish lengths for each age group being similar within a group, the data were grouped so that the fish growth rate is calculated separately for South Georgia/Shag Rocks and for two southern regions of South Orkneys and South Shetlands. Results and the corresponding data for Kerguelen Islands are given in Table 14 and Fig. 7.

The values were calculated for males and females jointly, as no greater between-sexes difference was observed, similarly to Olsen (1955). It is difficult to read *Ch. gunnari* age from otoliths, particularly in older individuals. Their rings are fairly well visible until age group XI, readings for older groups involving large errors. Therefore, for the South Georgia and Shag Rocks individuals, age readings up to group XI are regarded as representative. With respect of the other group of fishing grounds, readings up to group IX are taken as representative due to a low number of older fish examined. The individuals caught off Kerguelen Islands did not exceed age group V.

As shown by the data in Table 14, *Ch. gunnari* grows relatively fast until age group III, the mean annual increment amounting then to about 7 cm. Olsen (1955) obtained similar

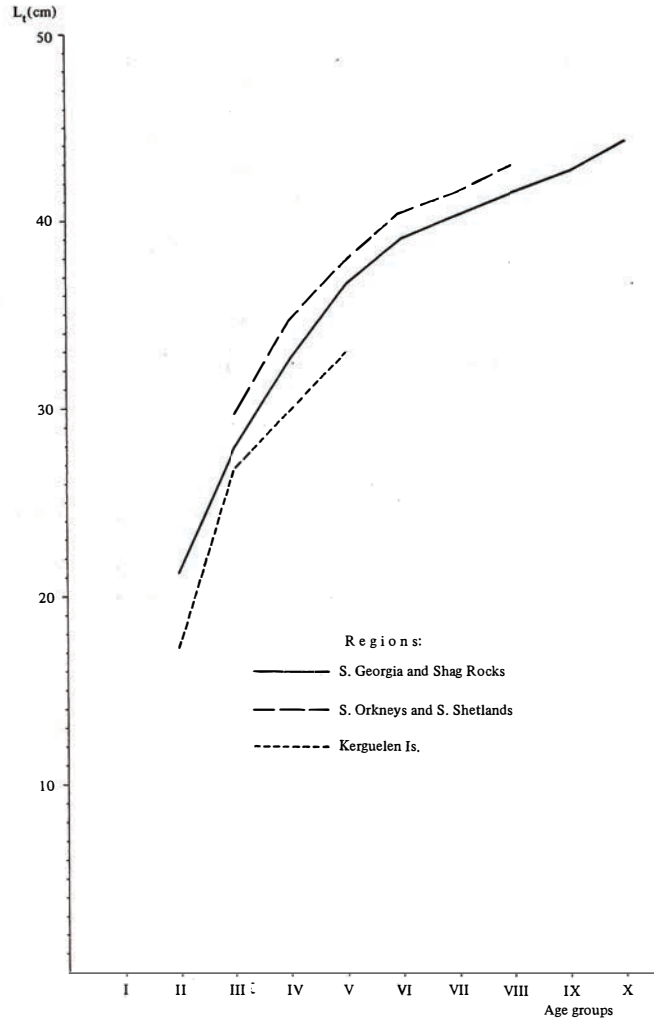

Fig. 7. Mean length in age groups of *Ch. gunnari*

results. The fish in that group of age mature to spawn. The growth rate decreases thereafter to reach the mean annual increment of 1 cm at group X.

The materials examined comprised individuals from group II on, i.e., at the age of 2+ years. The size of group 0 can be assessed from the other authors' data. Olsen (1955) found 6.9–7.7 cm long Antarctic icefish individuals off South Georgia in March and April 1951. During the First Polish Antarctic Expedition, individuals 5.1–7.1 cm long were being caught off Palmer Archipelago in January 1976 (Rembiszewski et. al., 1978). During the Fourth Expedition, off South Georgia from 26 March till 26 April 1979, individuals 3.2–5.2 cm long (a mean of 4.3 cm) were found (10).

Table 14

Mean lengths and increments in various age groups of *Ch. gunnari* from different Antarctic fishing grounds

Age group	Fishing ground								
	S. Georgia and Shag Rocks			S. Orkneys and S. Shetlands			Kerguelen Is.		
	$\bar{l}$	n	$l_{t+1}-l_t$	$\bar{l}$	n	$l_{t+1}-l_t$	$\bar{l}$	n	$l_{t+1}-l_t$
II	21.27	212	6.70	–	–	–	17.27	105	9.63
III	27.97	313		29.80	179		26.90	10	
			4.78			4.92			3.13
IV	32.75	519		34.72	210		30.03	299	
			3.91			3.30			2.92
V	36.66	230		38.02	286		32.95	216	
			2.45			2.52			
VI	39.11	164		40.54	116		–	–	
			1.21			1.12			
VII	40.32	160		41.66	57		–	–	
			1.31			1.44			
VIII	41.63	104		43.10	20		–	–	
			1.12			2.82			
IX	42.75	71		45.92	13				
			1.71						
X	44.46	46	0.29	44.25	4		–	–	
XI	44.75	24		46.00	1		–	–	
XII	44.67	15		50.00	1		–	–	
XIII	48.71	7		–	–		–	–	
XIV	48.86	7		–	–		–	–	
XV	51.40	5		–	–		–	–	
XVI	–	–		–	–		–	–	
XVII	45.00	1		–	–		–	–	
XVIII	58.00	1		–	–		–	–	
XIX	54.00	1		–	–		–	–	

With the data referred to on mind, one can conclude that the group 0 individuals of *Ch. gunnari* attain, at the end of their first year of life, 3.2–7.7 cm, depending on a place and date of their birth. Assuming a relatively linear length growth between groups 0 and II, one can conclude that the group I individuals should measure, on the average, 12–14 cm. Such values attained in groups 0 and I could be read from more legible otoliths.

Fig. 7 shows growth rates of individuals caught in the three regions. The differences between them are easily seen. The lowest growth rate is typical of the Kerguelen Islands individuals. Those from the Atlantic sector grow faster; among them, the southern stocks show a higher growth rate than is typical of the South Georgia/Shag Rocks stocks.

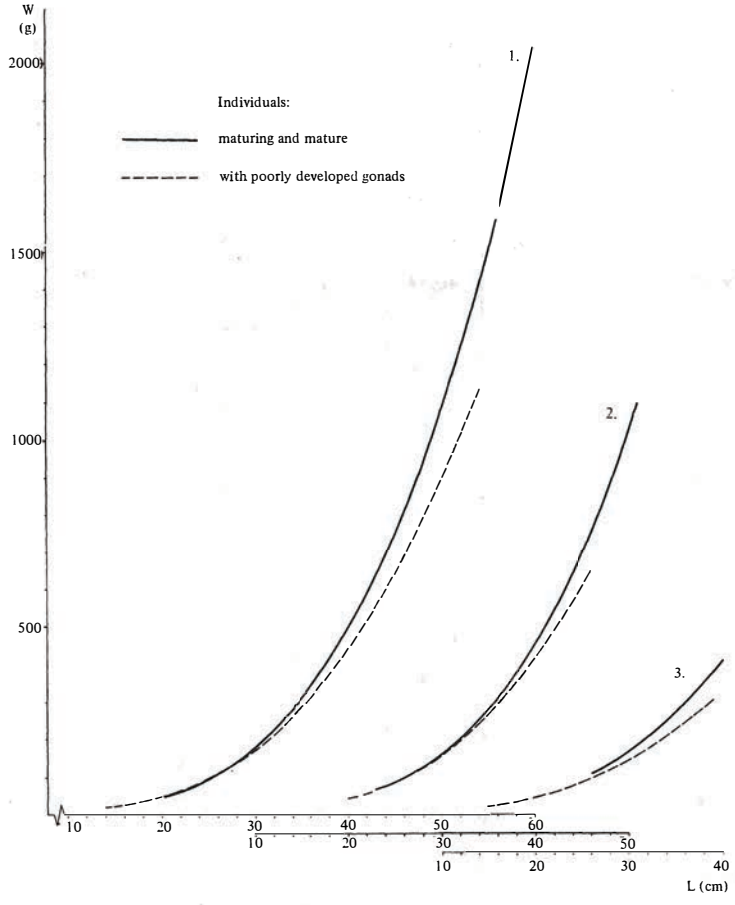

Fig. 8. Weight-total length relationship in *Ch. gunnari* from: 1. off South Georgia and Shag Rocks, 2. off South Orkneys and South Shetlands, 3. off Kerguelen Islands

Table 15

Parameters of weight-length relationship ($W = kL^n$) in *Ch. gunnari* from various Antarctic fishing grounds

Fishing ground	Gonad maturity							
	gonads poorly developed				gonads maturing and mature			
	K	n	number of fish	fish length range (cm)	K	n	number of fish	fish length range (cm)
S. Georgia and Shag Rocks	0.0039	3.1536	1292	14–54	0.0014	3.4672	2940	20–80
S. Orkneys and S. Shetlands	0.0025	3.2587	3944	20–46	0.0009	3.5645	1699	23–51
Kerguelen Is.	0.0090	2.8484	425	15–39	0.0051	3.0648	446	26–40

Length-weight relationship

The weight growth of the Antarctic icefish was followed as the function of length. The relationship is described by the formula:

$$W_{(g)} = k\, L^{n}_{(cm)}$$

The equation parameters were determined with the least squares method. Results are given in Table 15. The relationship is presented graphically as curves in Fig. 8.

The curves are restricted by the fish length ranges. As seen from the figure, within a length class there is a difference between the individuals with poorly developed gonads and that of maturing and mature individuals. The difference, however, is relatively small and visible in the fish longer than 30 cm: in the 40 cm class the difference amounts to 40–60 g, i.e., about 10% of the mature fish weight.

The fish weight in function of length is similar within the Atlantic sector, the curves differing slightly from that for Kerguelen Islands (Indian Ocean sector), the latter curve ascending more slowly.

The following equations express the relationship regardless of maturity stage:

$W = 0.0017\, L^{3.3934}$ for *Ch. gunnari* from the Atlantic sector, and

$W = 0.0063\, L^{2.9793}$ for *Ch. gunnari* from the Indian Ocean sector.

REPRODUCTION

Gonad maturation cycle

Tables 16 and 17 give the per cent distribution of fish over the gonad maturity stages (Maier's scale). The data are incomplete, which makes it difficult to describe from them the full annual cycle. Most data were obtained in the NE shelf of South Georgia where both commercial catches and the studies were made. Based on a 4-yr mean (1976–1978), a graph (Fig. 9) was drawn; the graph shows the maturation to take a short time only.

Fully mature individuals (stage VI) were being found from March through May and were most abundant in April. The Antarctic icefish spawn not only in fjords, but on the shelf adjacent to the island, too, as found also by Permitin (1973). A large proportion of fish with juvenile (stage I) gonads in May resulted from immigration of juveniles to the fishing grounds.

The data contained in Table 16 allow to conclude that in the Atlantic sector of the Antarctica, *Ch. gunnari* matures and spawns first off South Georgia and Shag Rocks. The Antarctic icefish occurring off South Orkneys mature somewhat later, as found also by Permitin (1973), and the stocks living by the Antarctic Peninsula reach maturity at the latest. Females were observed to have gonads more advanced (by 1 score of the scale) than males. The sex ratio varied from year to year and from month to month, but was usually approaching 1:1.

Table 16

Maturation of *Ch. gunnari* in various Atlantic sector fishing grounds (in °/₀₀)

Season	Fishing ground	Month	Gonad maturity stage								Sex ratio ♂ : ♀ (in °/₀₀)	n
			I	II	III	IV	V	VI	VII	VIII		
1975/77	S. Georgia	III	17	75	78	160	663	7	0	0	323 : 677	294
1976/77	S. Georgia	I	3	73	348	556	20	0	0	0	533 : 467	302
		II	0	41	86	589	284	0	0	0	533 : 447	197
		III	14	8	20	234	628	96	0	0	538 : 462	355
		IV	444	48	37	21	249	201	0	0	280 : 720	189
		V	604	197	36	53	28	51	3	28	444 : 556	356
	Shag Rocks	II	310	230	50	110	250	50	0	0	480 : 520	100
		III	436	149	53	128	223	11	0	0	479 : 521	100
		V	693	188	0	0	0	0	10	109	520 : 480	100
1977/78	S. Georgia	IX	0	910	80	10	0	0	0	0	710 : 290	100
		X	10	900	80	10	0	0	0	0	440 : 560	100
		I	99	331	431	118	21	0	0	0	447 : 553	483
		II	10	140	340	510	0	0	0	0	480 : 520	100
		III	63	53	33	440	403	8	0	0	427 : 573	300
		IV	82	90	18	481	302	27	0	0	230 : 770	600
	S. Orkneys	II	164	643	165	28	0	0	0	0	455 : 545	1948
		III	155	585	172	86	2	0	0	0	507 : 493	1404
1978/79	S. Georgia	XI	10	930	60	0	0	0	0	0	470 : 530	100
		XII	170	670	100	40	20	0	0	0	520 : 480	200
		I	10	400	450	120	10	10	0	0	480 : 520	100
		III	10	300	160	370	140	20	0	0	523 : 477	459
	Shag Rocks	I	40	170	530	250	10	0	0	0	430 : 570	100
		III	190	220	50	170	350	20	0	0	270 : 730	100
	S. Orkneys	XII	10	760	230	0	0	0	0	0	567 : 433	300
		II	0	85	910	5	0	0	0	0	590 : 410	200
		III	0	60	370	480	90	0	0	0	520 : 480	100
	Elephant I.	XI	0	940	248	5	3	0	3	3	483 : 517	300
		XII	0	980	0	0	0	0	5	15	565 : 435	200
		I	0	755	240	5	0	0	0	0	675 : 325	400
		II	160	660	160	10	0	10	0	0	545 : 455	200
		III	30	230	660	80	0	0	0	0	575 : 425	200
	S. Shetlands	I	100	510	390	0	0	0	0	0	610 : 390	103
		II	0	160	430	410	0	0	0	0	513 : 487	300
		III	0	100	450	430	20	0	0	0	580 : 420	100
	Palmer Archipelago	II	0	110	720	110	0	0	0	0	610 : 390	18

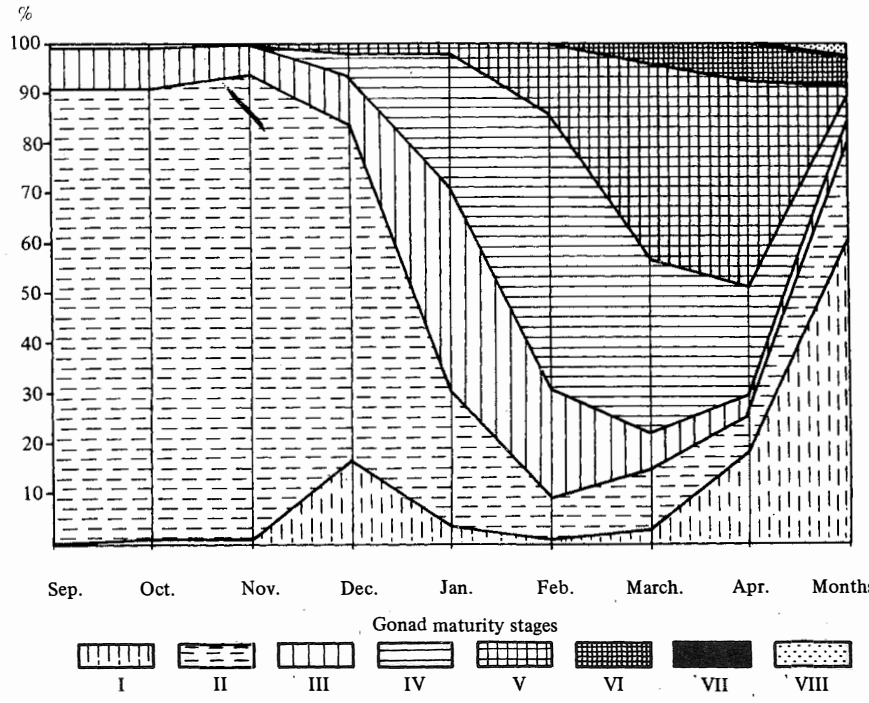

Fig. 9. Maturation of *Ch. gunnari* off South Georgia over the year

Ch. gunnari off Kerguelen Islands spawns more or less at the same time as do the Atlantic sector stocks (Table 17); the fish in the Heard Shoal fishing ground were less advanced in maturation than those in the Skif Shoal, a fishing ground located more northerly. No fully mature individuals (stage VI) were recorded, thus it is difficult to say if spawning takes place there.

The first maturity

Knowledge on fish length at the first maturity is important for deciding on measures to be taken to protect the stocks from overfishing.

Olsen (1955) reported the smallest mature individuals, 4-yr-old, to measure 23 cm. According to Permitin (1973), males reach maturity at 21–26 cm, and females at 21–25 cm. Kock (1979) recorded the smallest mature female measuring 21 cm.

In the present study an attempt was made to determine fish length at the first maturity. The proportion of individuals with gonads at stages I and II was calculated for each length class. The calculations were separate for each fishing ground and concerned the fish caught between January and May.

Table 17

Maturation of *Ch. gunnari* in various fishing grounds off Kerguelen Islands (Indian Ocean sector) (in °/₀₀)

Season	Fishing ground	Month	Gonad maturity stage								Sex ratio ♂: ♀	n
			I	II	III	IV	V	VI	VII	VIII		
1974/75	Island shelf	IV	692	0	186	122	0	0	0	0	550 : 450	156
	Skif Shoal	IV	0	0	0	425	575	0	0	0	590 : 410	200
	Heard Shoal	IV	0	10	763	227	0	0	0	0	520: 480	300
1977/78	Island shelf	XII/I	34	921	45	0	0	0	0	0	220 : 780	89
	Heard Shoal	I	80	840	80	0	0	0	0	0	400 : 600	25
		II	0	494	506	0	0	0	0	0	510 : 490	239

The smallest lengths of maturing and mature individuals differed between the fishing grounds (Fig. 10).

The data obtained off South Georgia are the most representative set owing to many seasons of numerous observations. The smallest maturing individuals found in the region were assigned to the 20 cm length class and made up 3% of the total number of individuals. The classes: 21 and 22 cm contained a similar proportion of maturing and mature individuals. They belonged to age group II, i.e., were terminating their third year of life. The proportion of maturing and mature individuals increased with length to reach 82% in the 27 cm class.

In the other Atlantic sector fishing grounds the smallest lengths of mature individuals were larger, up to 32 cm off South Shetlands. The data from off Kerguelen Islands were less representative. Among the individuals caught in April 1975, all those smaller than 24 cm had immature gonads, while all those larger than 26 cm matured to spawn (Fig. 10). Among the individuals examined between January and May, many large ones had their gonads at stage II (dormant); presumably, they had not spawned. Some of them, particularly those measuring 26–30 cm, might not have reached their first maturity yet, but it is unwarranted to draw such a conclusion with respect to those larger than 40 cm.

Off South Georgia, in April 1977, abundant catches consisting of large and old individuals with stage II gonads were being taken; certainly, those individuals did not spawn that year.

These observations show that the Antarctic icefish do not spawn every year.

As seen from Fig. 10, adult individuals with immature gonads occurred off South Georgia in all length classes. They were much less numerous than those spawning in a given year. One can thus conclude that only a part of non-spawners approach the shelf, the rest remaining dispersed in the pelagic zone.

Fecundity

The work presented contains results of studies on the Antarctic icefish fecundity, carried out in 1975–1977 and 1979 off South Georgia, Shag Rocks, South Orkneys, South Shetlands, and Kerguelen Islands. The fecundity of 609 females was determined. The individual fecundity was found to range from 1700 eggs in a 32-cm long female weighing 320 g to 17,338 eggs in a 51-cm long female weighing 1119 g. The smallest female examined measured 22 cm and contained 2,174 eggs. Individual fecundity in fish increases with fish length and weight. Parameters of a function which describes this relationship are given in Table 18. For comparative purposes, appropriate calculations were made separately for *Ch. gunnari* from various fishing grounds. Fecundity correlates well with length and weight, as evidenced by the high values of R.

As shown by the data presented, fecundity was better correlated with fish length. Somewhat worse correlations with weight were presumably caused by the fact that all the

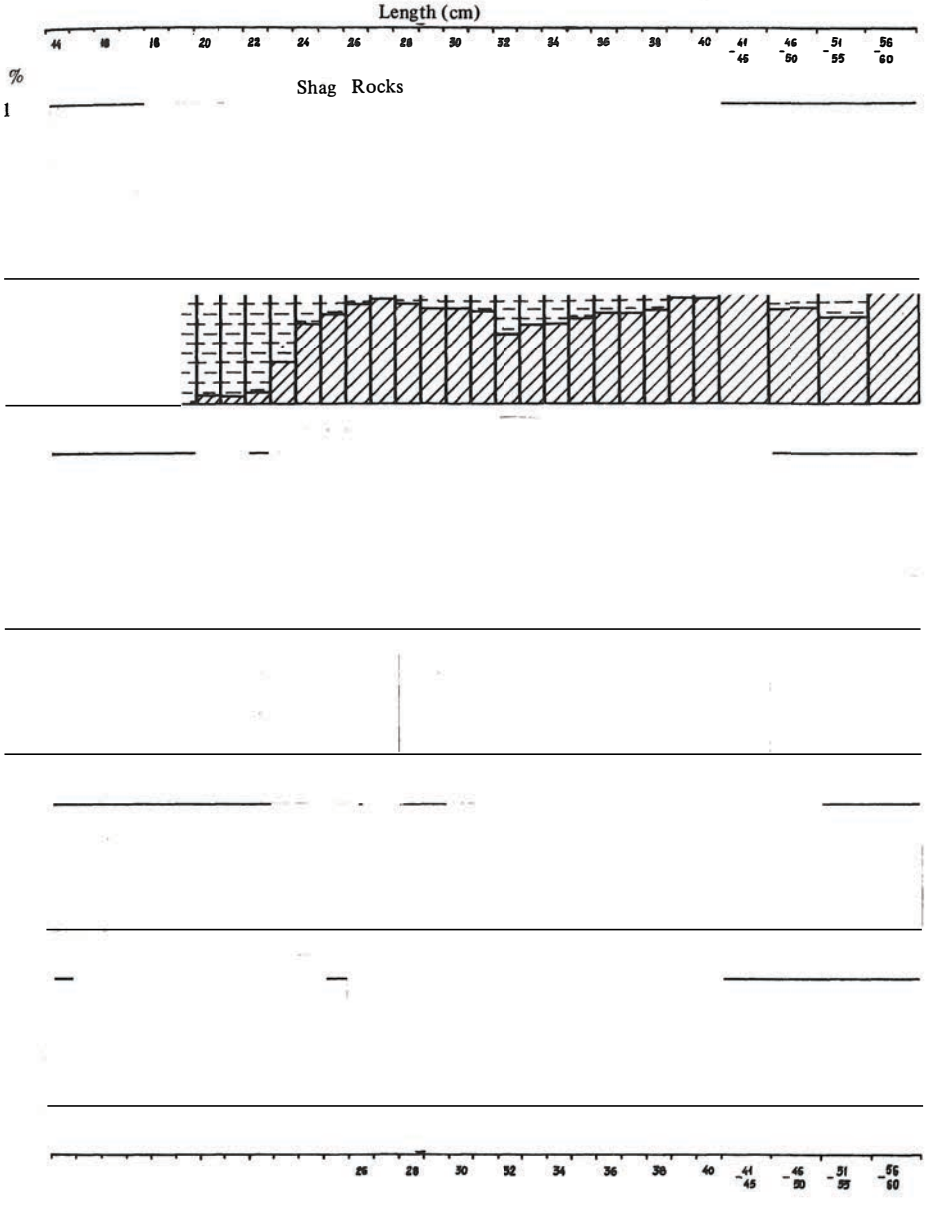
Length (cm)
%
1
Shag Rocks

Table 18

Individual fecundity of *Ch. gunnari* from various Antarctic fishing grounds

Fishing ground	Date	N	Mean		Fecundity		Fecundity – fish length relationship							Fecundity – fish weight relationship							
			length (cm)	weight (g)	(no of eggs range	mean	n	R	$F = aL^b$			$F = a+bL$			n	R	$F = aW^b$			$F = a+bW$		
									a	b	r^2	a	b	r^2			a	b	r^2	a	b	r^2
S. Georgia	II–III 1976 1977 1979	345	31.33	353	1750 -17338	5063	345	0.9695	0.2223	2.8882	0.9145	–9482	464.22	0.8874	194	0.8874	0.8955	0.9153	0.8955	801.00	16.0200	0.8615
Shag Rocks	III 1977	56	33.36	293	1700 –7332	4051	56	0.9110	0.4900	2.5600	0.6200	–6842	326.54	0.7001	56	0.8943	55.5555	0.7531	0.5298	792.66	11.1100	0.6397
S. Orkneys	III 1979	67	39.52	518	5169 –9889	7012	67	0.9014	0.2574	2.7744	0.6765	-12619	496.72	0.6601	67	0.8999	66.8156	0.7442	0.6652	1753.05	10.1400	0.6558
S. Shetlands	III 1979	61	42.59	–	–5710	8294	61	0.8614	3.7740	2.0487	0.5576	–8837	402.25	0.5507	–	–	–	–	–	–	–	–
Kerguelen Is.	IV 1975	80	30.65	181	2000 -10645	4320	80	0.9031	0.0055	3.9498	0.7663	-13976	596.97	0.7924	65	0.9313	17.3661	1.0403	0.7884	57.14	21.4200	0.7522

N = total no. of individuals examined, n = no. of individuals examined for a given type of relationship, R = correlation coefficient, r^2 = coefficient of determination of theoretical values relative, to empirical ones, L = fish total length (cm), W = fish total weight (g), F = individual fecundity

weighings were done at sea, where vessel's vibrations and tilt affected the result. Usually, the fecundity-length or fecundity-weight relationships are expressed by a curve described by $F = aL^b$ ($F = aW^b$) or a straight line described by $F = a + bL$ ($F = a + bW$). Most authors use the first type of equation for the fecundity-length relationship and the, other type for the fecundity-weight one. In the present work, both types of functions were fitted to the two relationships; in each case the coefficient (r^2) of determination of theoretical values relative the empirical ones was calculated. The analysis of r^2 values obtained shows the $F = aL^b$ curve to be a better fit to the fecundity-fish length relationship. This is particularly evident in the South Georgia individuals where $r^2 = 0.9145$. On the other hand, the linear function $F = a + bL$ is also a good fit, the value being rather high (0.8834). A curve described by $F = aW^b$ fits the fecundity-weight relationship better than a linear function, although r^2 of the latter does not deviate much from that of the first. Further considerations on the fecundity of *Ch. gunnari* from various fishing grounds follow the tradition and employ the curvilinear equation for the fecundity-length relationship and the linear function for the fecundity-weight one.

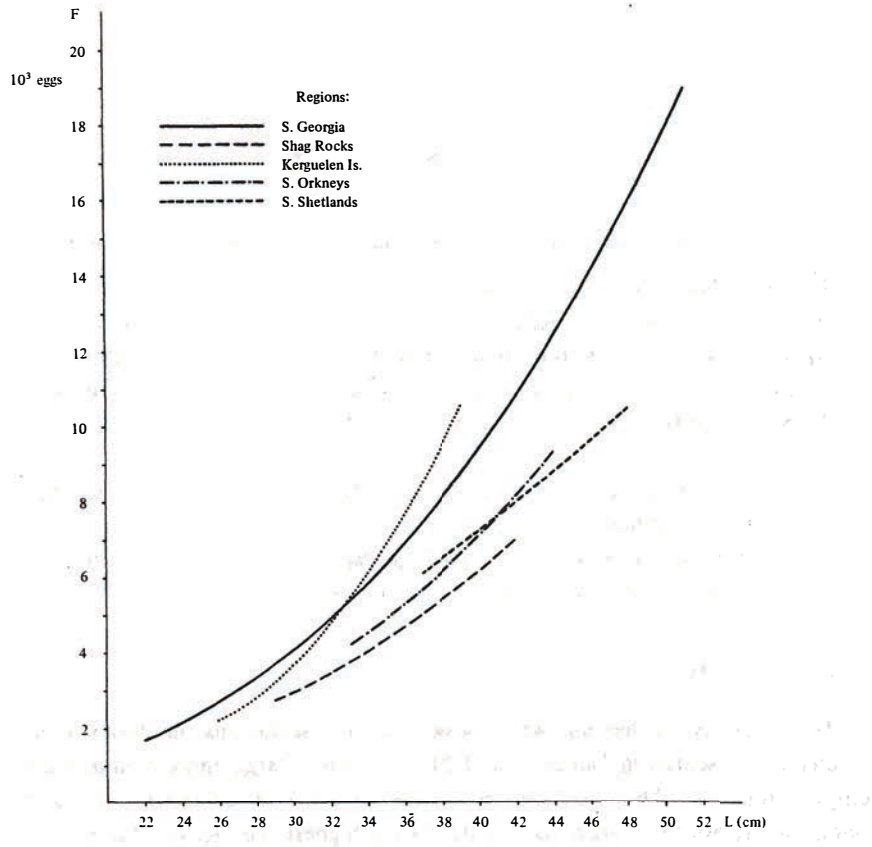

Fig. 11. Individual fecundity-body length relationship in *Ch. gunnari* from various regions ($F = aL^b$)

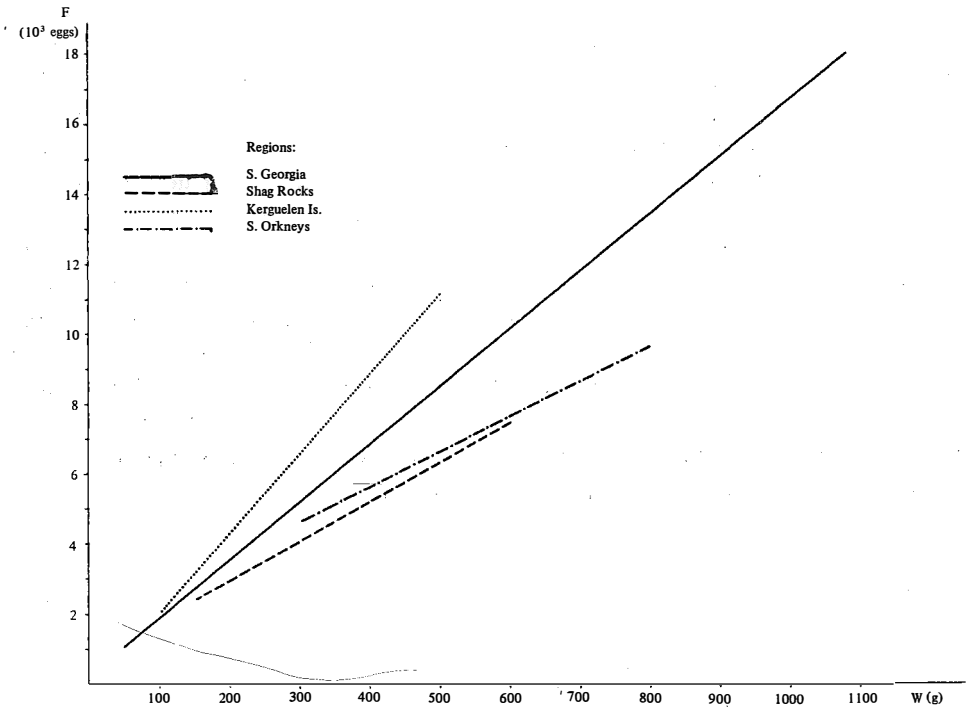

Fig. 12. Individual fecundity-body weight relationship in *Ch. gunnari* from various regions (F = a + bW)

The two relationships are presented graphically in Figs. 11 and 12.

As the data show, the highest fecundity is typical of *Ch. gunnari* from off South Georgia and Kerguelen Islands. When related to individual weight, those fish from the latter ground show even higher fecundities. This is the result of lower individual weights of the Kerguelen Islands *Ch. gunnari* as compared to the individuals caught in the Atlantic sector.

The individuals caught off South Orkneys, South Shetlands, and Shag Rocks show a clearly lower fecundities.

The results on the South Georgia *Ch. gunnari* fecundity obtained in this study are similar to those reported by Permitin (1973) and Kock (1979).

Feeding intensity

The intensity of feeding was assessed from observations on stomach fullness. The results are presented in Tables 19 and 20. Generally, a large proportion of individuals had empty stomachs. The most representative set of data, presented in Fig. 13, is that obtained off South Georgia, as it contains the highest number of observations collected

Table 19

Stomach fullness of *Ch. gunnari* from various Atlantic sector fishing grounds (‰)

Season	Fishing ground	Month	Degree of stomach fullness					n
			0	1	2	3	4	
1975/76	S. Georgia	III	870	80	20	20	10	296
1976/77	S. Georgia	I	250	160	220	170	200	303
		II	370	240	220	60	110	200
		III	700	200	80	10	10	304
		IV	740	170	50	10	30	100
		V	690	80	120	40	70	97
	Shag Rocks	II	390	180	160	60	210	100
		III	500	240	180	50	30	100
		V	220	90	20	13	36	100
1977/78	S. Georgia	IX	570	250	100	60	20	100
		X	860	60	10	40	30	100
		I	450	160	210	90	90	483
		II	200	300	160	240	100	100
		III	520	270	160	40	10	300
		IV	410	340	140	70	40	599
	S. Orkneys	II	150	230	310	150	160	1957
		III	110	300	300	180	110	1403
1978/79	S. Georgia	XI	610	330	60	0	0	100
		XII	540	210	120	90	40	200
		I	130	290	300	230	50	100
		III	550	250	140	60	0	459
	Shag Rocks	I	610	300	90	0	0	100
		III	800	160	20	20	0	100
	S. Orkneys	XII	530	320	110	40	0	299
		II	180	300	270	200	50	200
		III	60	150	200	320	270	100
	Elephant I.	XI	570	260	90	70	10	300
		XII	270	380	150	170	30	200
		I	650	90	90	150	20	400
		II	250	380	240	120	10	200
		III	220	290	200	230	60	200
	S. Shetlands	I	220	330	330	120	0	203
		II	100	290	310	300	0	199
		III	130	420	190	220	40	100

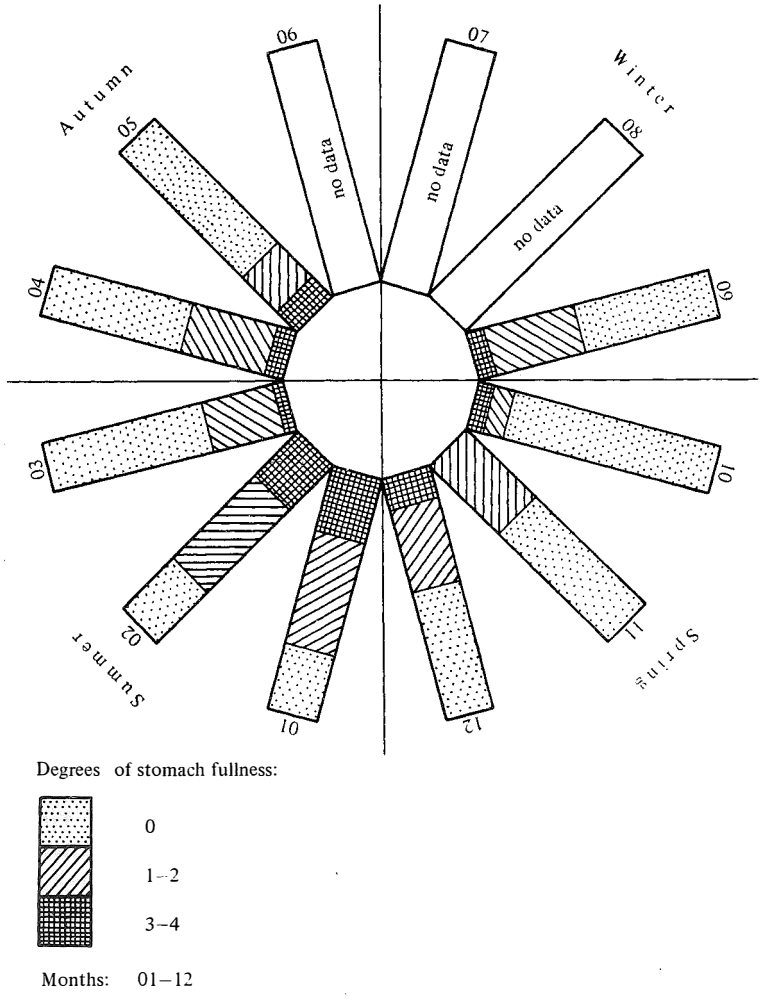

Fig. 13. Feeding intensity of *Ch. gunnari* off South Georgia over the year

over the longest period of time. The data show the lowest percentage of empty stomachs to be observed from December through February, i.e., in summer.

Observations on the diel feeding cycle allow to suppose that the Antarctic icefish feed with a higher intensity in the afternoon and in the evening.

Length and age of *Ch. gunnari* caught

The length of the Antarctic icefish examined covered a wide range of values, from 12 to 68 cm. The age range was also wide: the youngest individuals belonged to age group II

Table 20

Stomach fullness of *Ch. gunnari* from various fishing grounds off Kerguelen Islands (Indian Ocean sector) (‰)

Season	Fishing ground	Month	Degree of stomach fullness					n
			0	1	2	3	4	
1974/75	Island shelf	IV	430	210	110	130	120	155
	Skif Shoal	IV	960	10	20	10	0	200
	Heard Shoal	IV	520	250	60	90	80	299
1977/78	Island shelf	XII	100	200	200	330	170	60
		I	30	200	300	300	170	30
	Heard Shoal	I	640	320	40	0	0	25
		II	480	250	130	120	20	240

(i.e., they were 2+ –yr-old). It was difficult to determine age in older individuals; therefore, when describing the age composition of the stocks, age group X was the limiting one. As most of the individuals could be allotted to this age range, it was considered sufficient for further analyses of stock fluctuations. The few older individuals attained up to 19 years of life. The fish length and age differed between the regions and between periods of observations.

Figs. 14–17 show length and age distributions of *Ch. gunnari* caught in various regions of the Atlantic sector.

In 1975/1976 and 1976/1977, the South Georgia stock consisted mainly of large individuals belonging to older age groups. In the two subsequent seasons, owing to intensive fisheries, the stock was considerably younger, with age group III individuals, recruited to the commercial stock and attaining the first maturity, prevailing.

Off Shag Rocks, the Antarctic icefish stock consisted of younger age groups than that off South Georgia.

In the South Orkneys region in 1977/1978, the Antarctic icefish were caught off Laurie Island, in the eastern part. The stock composition was similar to that off South Georgia, with age group III prevailing. In the next season (1978/1979), the fishing operations were transferred to the western part, off Coronation Island. The stock exploited was older, age group V prevailing.

Ch. gunnari caught off South Shetlands in 1978/1979 were older than those caught at that time off South Georgia. The stock present off Elephant Island was similar in its age structure to that occurring off South Orkneys, while that off King George Island was older.

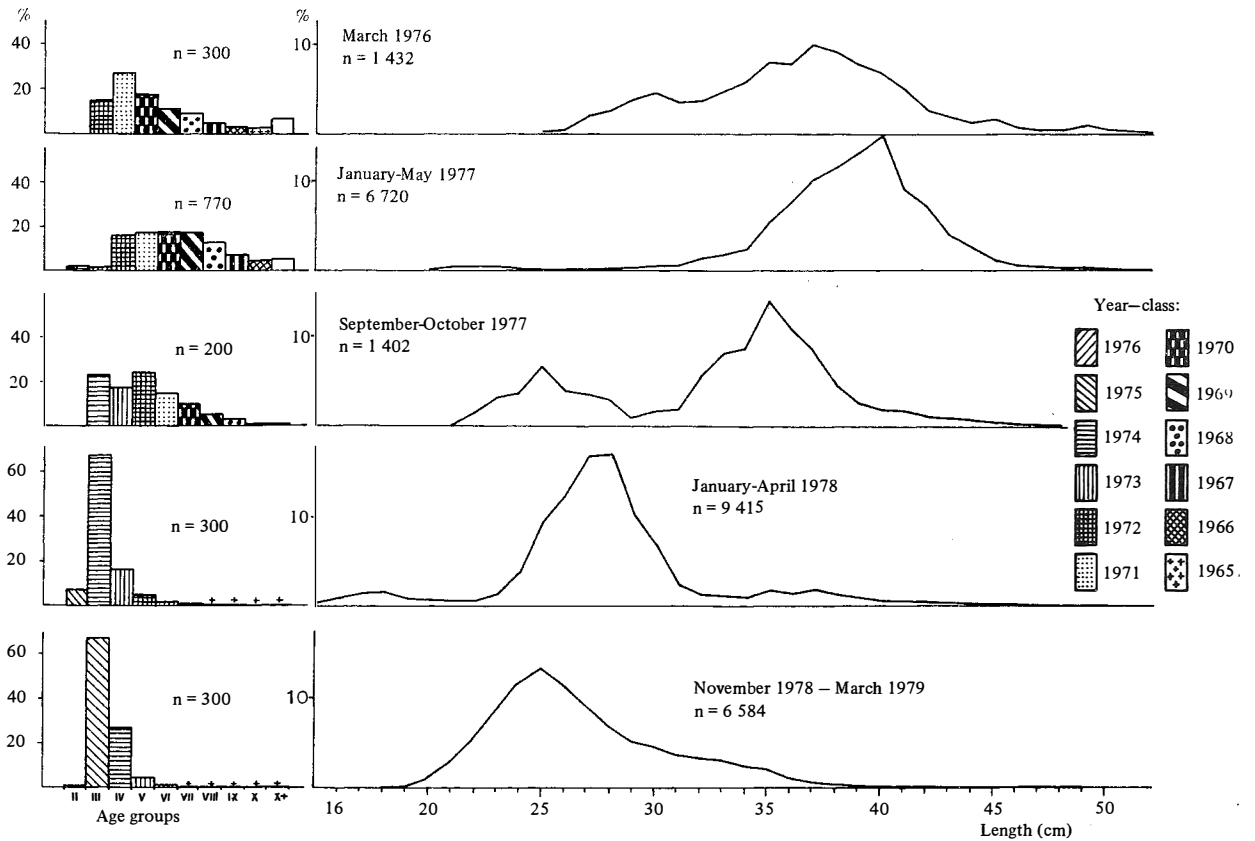

Fig. 14. Length distribution and age composition of *Ch. gunnari* caught off South Georgia within 1976–1979

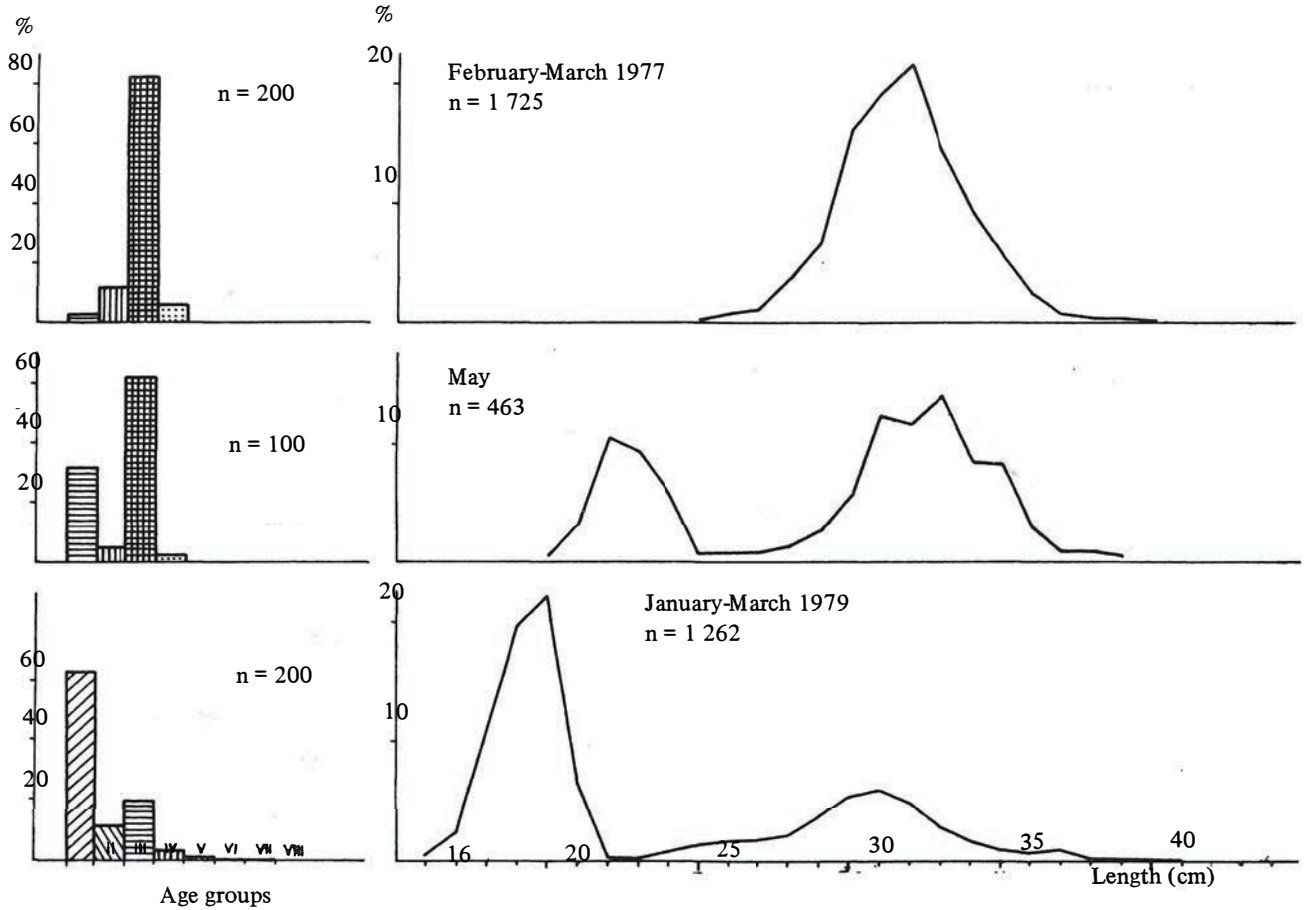

Fig. 15. Length distribution and age composition of *Ch. gunnari* caught off Shag Rocks in 1977 and 1979 (generations denoted as in Fig. 14)

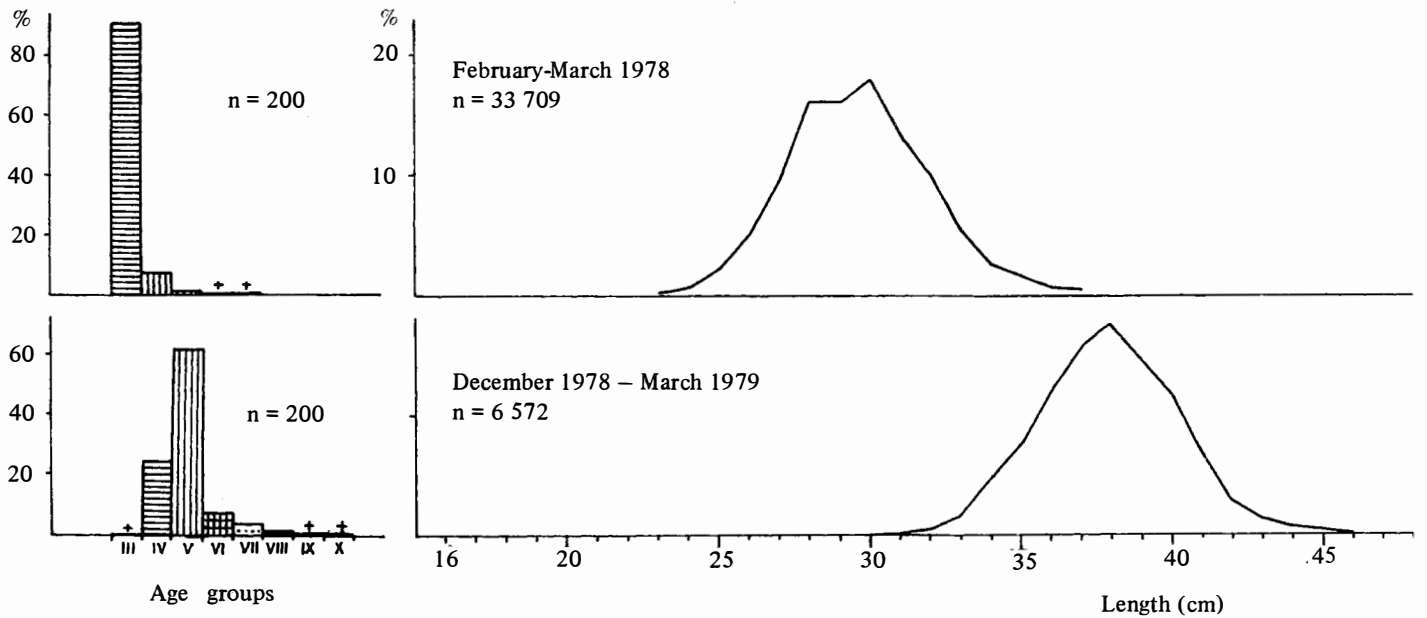

Fig. 16. Length distribution and age composition of *Ch. gunnari* in 1976 and 1979 caught off South Orkneys (generations denoted as in Fig. 14)

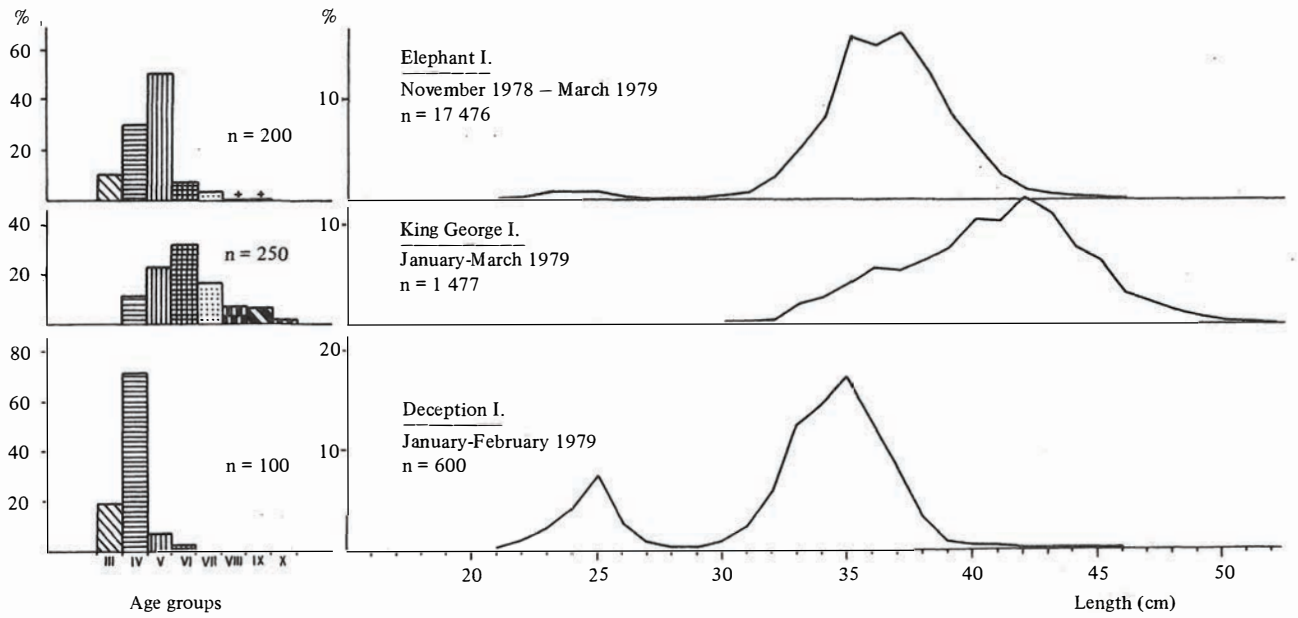

Fig. 17. Length distribution and age composition of *Ch. gunnari* caught off South Shetlands in 1978/79 (generations denoted as in Fig. 14)

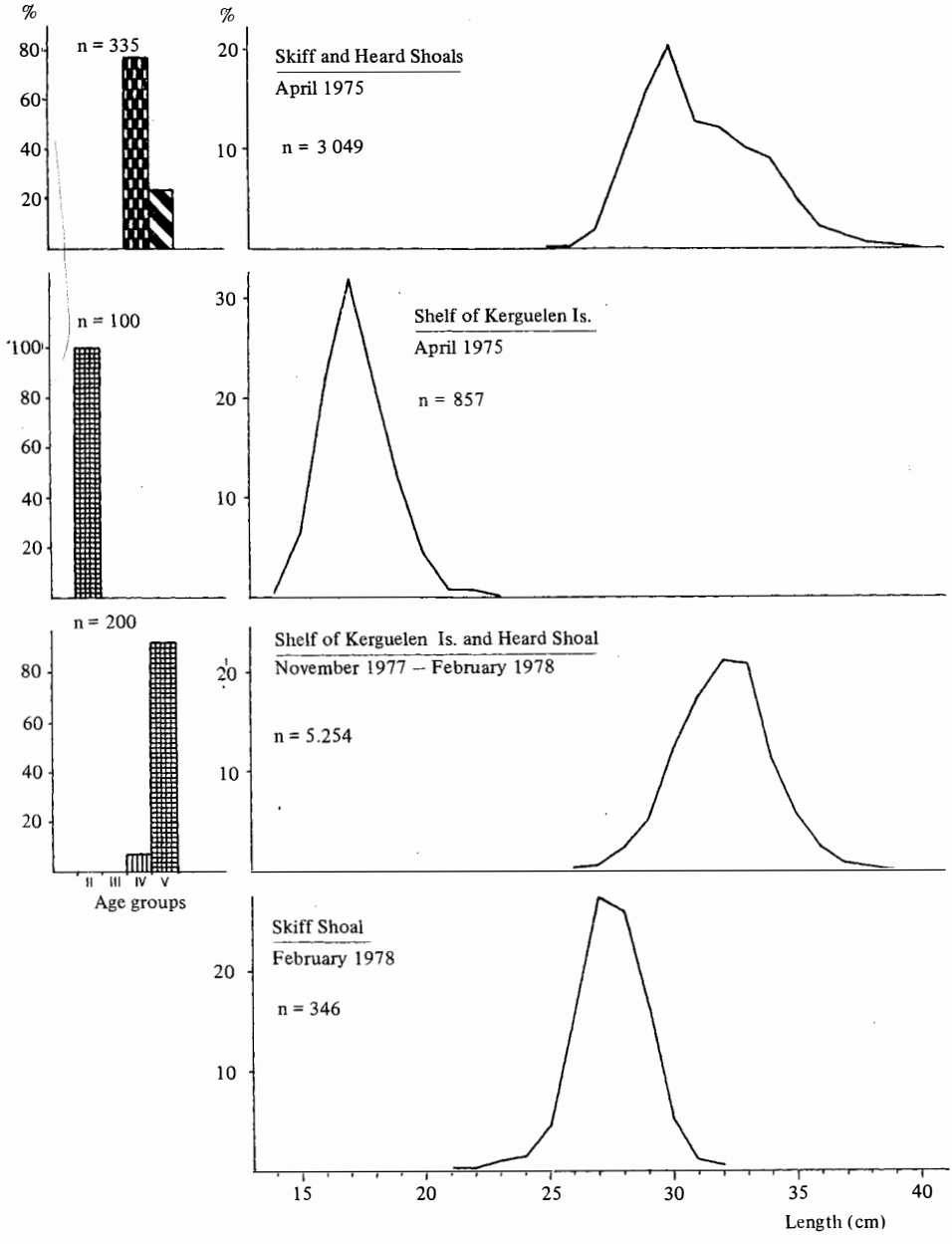

Fig. 18. Length distribution and age composition of *Ch. gunnari* caught off Kerguelen Islands in 1975 and 1977/78 (generations denoted as in Fig. 14)

Fig. 18 presents length and age distributions of *Ch gunnari* caught in the Indian Ocean sector of the Antarctica, off Kerguelen Islands. The stock composition shows between-regions and between-seasons differences.

Summing-up

Champsocephalus gunnari Lönnberg, 1905 is one of the more important white-blood fish species in the Antarctica. Studies carried out in 1975–1979 proved the species presence in the following fishing grounds:

– in the Indian Ocean sector of the Antarctica, off Kerguelen Islands;
  a) on the Kerguelen Islands shelf,
  b) on Skif Shoal, W of Kerguelen Islands,
  c) on Heard Shoal, S of Kerguelen Islands,
– in the Atlantic sector of the Antarctica:
  a) on the NE shelf of South Georgia,
  b) off Shag Rocks, W of South Georgia,
  c) off South Orkneys,
  d) off Elephant Island,
  e) off South Shetlands.

Palmer Archipelago, located W of the Antarctic Peninsula, was the southernmost limit of *Ch. gunnari* distribution in the Atlantic sector. The fish were being caught at depths down to 600 m; the best catches were made at about 300 m dept.

To analyse in detail stocks from various fishing grounds, two meristics characters: verterbrae count and fin ray count were studied.

Analysis of the first character showed the Kerguelen Islands individuals to have the lowest vertebrae counts. Higher counts are typical of the Atlantic sector individuals, those caught in the southern grounds of the sector showing the highest counts.

The fin ray count analysis (D_2 and A are most suitable for the purpose) showed the Kerguelen Islands *Ch. gunnari* to differ significantly from those of the Atlantic sector, while in the latter no significant differences existed between northern and southern fishing grounds in this respect.

A number of biological features of the Antarctic icefish was studied, Growth analysis was started from the description of otolith growth. A clear-cut relationship between otolith size and fish total length was found. Otoliths of the Indian Ocean sector individuals were usually larger than otoliths collected from the Atlantic sector individuals of the same size.

Moreover, in the Atlantic sector, otoliths collected off South Georgia and Shag Rocks were larger than those obtained from the southern fishing grounds. A linear equation fits the otolith sizefish length relationship pretty well, but logarithmic and parabolic curves describe the relationship more precisely.

There are no between-sexes differences in body length growth. Up to age group III, the fish grow relatively fast (about 7 cm a year); subsequently the growth rate slows down to

1 cm year in age group X. The lowest growth rate was found in the Antarctic icefish off Kerguelen Islands. Individuals from off South Georgia and Shag Rocks grow faster, while the highest growth rate is typical of those individuals caught from the southern grounds of the Atlantic sector.

No between-sexes differences in weight were found between individuals of the same size. On the other hand, differences were found between individuals of the same length classes from various regions: the Kerguelen Islands individuals were lighter than those from the Atlantic sector.

Ch. gunnari spawns in fjords and on shelves adjacent to islands, from March through May. Northern stocks attain maturity earlier in the year than southern stocks. Usually the first maturity is reached at body length of 23–27 cm. The smallest maturing individual measured 20 cm. The usual age at the first maturity is 4 years, although mature 3-yr-old individuals were being found as well. The gonad maturity analysis shows that adults do not spawn every year. Individual fecundity was found to range from 1700 to 17,338 eggs. Correlations were found to exist between individual fecundity and fish length and weight. The highest fecundity was typical of the individuals caught off South Georgia and Kerguelen Islands, while the fish caught in southern fishing grounds were less fecund.

The Antarctic icefish feed with the highest intensity during the austral summer; the most intensive feeding coincides in time with gonad maturation.

The materials examined encompassed individuals measuring 12–68 cm whose age ranged from group II to XIX, most fishes belonging to groups II–VIII. Length and age of the individuals caught in various fishing grounds differed; moreover, the parameters changed from season to season in the same fishing ground. Intensive fishery was found to bring about the rejuvenation of the *Ch. gunnari* stocks.

To conclude, the analysis of meristic characters allows to separate three groups of the Antarctic icefish stocks:

1) from off Kerguelen Islands (the Indian Ocean sector of the Antarctica),
2) from northern fishing grounds of the Atlantic sector (South Georgia, Shag Rocks),
3) from southern fishing grounds of the Atlantic sector (South Orkneys, Elephant Island, South Shetlands).

Most biological features differ between the regions, too.

Using the commonly accepted criteria of the biological concept of the species (3) one can assume, based on the significance of differences in meristic characters and variations in biological ones, that *Ch. gunnari* is a polytypic species composed of a number of allopatric populations. The populations occurring in the Atlantic sector differ from those of the Indian Ocean sector enough to treat them as separate subspecies. The Atlantic sector subspecies can be subdivided into two ecological races, northern and southern, with local stocks.

The three groups of populations can be characterised by the following features:

1. *Ch. gunnari* subspecies from the Indian Ocean sector (Kerguelen Islands):
   mean vertebrae count 59.53;
   mean fin ray counts: D_1 9.16, D_2 36.42, P 27.00, A. 35.87;

Otoliths (relative to fish length) larger than in other areas; slowest length growth; mean length of 26.90 cm attained in the fourth year of life;
body weight relative to length somewhat lower than in the Atlantic sector;
spawning from March through May; in April 1975, individuals larger than 26 cm were ready to spawn;
individual fecundity from 2000 to 10,645 eggs.

2. *Ch. gunnari* subspecies of the Atlantic sector
   a) northern race (South Georgia, Shag Rocks)
   mean vertebrae count 61.27;
   mean fin ray counts: D_1 9.14, D_2 38.28, P 26.95, A 37.52;
   otoliths (relative to fish length) somewhat larger than in southern fishing grounds and smaller than off Kerguelen Islands;
   length growth rate higher than off Kerguelen Islands; mean length of 27.97 cm attained in the fourth year of life;
   smallest individuals measured 20 cm;
   individual fecundity from 1700 to 17,338 eggs.
   b) southern race (South Orkneys, Elephant Island, South Shetlands) mean vertebrae count 62.01;
   mean fin ray count: D_1 9.50, D_2 38.77, P 26.95, A 37.39;
   otoliths (relative to fish length) somewhat smaller than in other regions;
   fastest growth rate; mean length of 29.80 cm in the fourth year of life;
   body weight relative to length similar to that in northern fishing grounds of the Atlantic sector;
   spawning from March through May, slightly delayed from that in northern fishing grounds;
   about 50% of all individuals reach first maturity at 32 cm length;
   individual fecundity from 5169 to 11.753 eggs.

CONCLUSIONS

1. *Champsocephalus gunnari* Lönnberg, 1905 is a polytypis species. Populations inhabiting the Indian Ocean and Atlantic sectors of the Antarctica form two separate subspecies. The Atlantic sector subspecies can be subdivided into two ecological races, northern and southern. The races consist of local stocks migrating from one fishing ground to another.
2. Within 1976–1979, fisheries affected the *Ch. gunnari* resources in the Atlantic sector by reducing the abundance of older individuals.
3. The minimum length of exploited *Ch. gunnari,* as one of the protective measures, equal to the length at which about 50% of all individuals attain the first maturity, should be set in the Atlantic sector at:

– 24 cm in northern fishing grounds (South Georgia, Shag Rocks)
– 32 cm in southern fishing grounds (South Orkneys, Elephant Island, South Shetlands).

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Translated: Dr. Teresa Radziejewska

Józef Sosiński

PEWNE DANE Z TAKSONOMII I BIOLOGII KERGULENY (*CHAMPSOCEPHALUS GUNNARI*, LÖNNBERG 1905)

STRESZCZENIE

W wyniku przeprowadzonych badań w latach 1975–1979 zlokalizowano stada kerguleny w indyjskim sektorze Antarktyki w rejonie Wysp Kerguelena oraz w atlantyckim sektorze Antarktyki w

rejonach Georgii Południowej, Orkadów Południowych i Szetlandów Południowych. Na podstawie analizy istotności różnic zbadanych cech merystycznych (liczba kręgów i liczba promieni płetw) oraz zróżnicowania cech biologicznych przyjęto, że kergulena jest gatunkiem politypowym. Populacje występujące w atlantyckim sektorze Antarktyki wykazują wystarczające różnice w stosunku do populacji występujących w indyjskim sektorze Antarktyki aby je wyodrębnić jako dwa osobne podgatunki.

W obrębie podgatunku z atlantyckiego sektora Antarktyki można wyorębnić dwie rasy ekologiczne (północną i południową) z lokalnymi stadami.

Te trzy wyodrębnione grupy populacji kerguleny charakteryzują się następującymi cechami:

1. Podgatunek kerguleny z indyjskiego sektora Antarktyki (Wyspy Kerguelena)

Ryby charakteryzują się średnią liczbą kręgów wynoszącą 59,53 oraz średnią liczbą promieni w płetwach: D_1 – 9,16; D_2 – 36,42; P – 27,00; A – 35,87.

Otolity ich w stosunku do długości ciała są nieco większe od otolitów kergulen z innych rejonów. Wzrost długości ciała jest stosunkowo najwolniejszy. W czwartym roku życia wynosi średnio 26,90 cm. Ciężar ryb w odniesieniu do długości ciała jest nieco mniejszy aniżeli u kergulen z atlantyckiego sektora Antarktyki. Tarło odbywają od marca do maja. Płodność zbadanych ryb wynosiła od 2 tys. do 10,6 tys. ziaren ikry.

2. Podgatunek kerguleny z atlantyckiego sektora Antarktyki

a) rasa północna (Georgia Południowa, Skały Shag)

Kerguleny z północnych łowisk atlantyckiego sektora Antarktyki charakteryzują się średnią liczbą kręgów wynoszącą 61,27, oraz średnią liczbą promieni w płetwach: D_1 – 9,14; D_2 – 38,28; P – 26,95; A – 37,52.

Otolity w stosunku do wielkości ryby są nieco większe od otolitów kergulen z łowisk południowych, zaś mniejsze od otolitów kergulen z Wysp Kerguelena. Tempo wzrostu długości ryb jest większe od tempa wzrostu kergulen z Wysp Kerguelena. W czwartym roku życia osiągają średnio 27,97 cm. Ciężar ryb w odniesieniu do długości ciała jest nieco większy aniżeli u kergulen z Wysp Kerguelena. Tarło odbywają od marca do maja. Pierwszy raz przystępują do tarła przy długości około 24 cm. Najmniejsze dojrzałe osobniki miały długość 20 cm. Płodność zbadanych ryb wynosiła od 1,7 tys. do 17,3 tys. ziaren ikry.

b) rasa południowa (Orkady Południowe, Wyspa Elephant, Szetlandy Południowe).

Ryby charakteryzują się średnią liczbą kręgów wynoszącą 62,01, oraz średnią liczbą promieni w płetwach: D_1 – 9,50; D_2 – 38,77; P – 26,95; A – 37,39.

Otolity w stosunku do wielkości ryb są nieco mniejsze od otolitów kergulen z innych rejonów. Tempo wzrostu jest najszybsze. W czwartym roku życia ryby osiągają średnio 29,80 cm długości. Ciężar ryb w odniesieniu do długości ciała jest podobny jak u kergulen z północnych łowisk. Tarło odbywają od marca do maja z tym, że odbywają się one nieco później niż u kergulen z łowisk bardziej północnych. Około 50% ryb osiąga pierwszą dojrzałość płciową przy długości ciała 32 cm. Płodność zbadanych ryb wynosiła od 5,2 tys. do 11,7 tys. ziaren ikry.

Na łowiskach występowały osobniki długości 12–68 cm. Rozpiętość wieku wynosiła od II do XIX grupy wieku. Większość zbadanych ryb należała od II do VIII grupy. Długość i wiek kergulen łowionych na poszczególnych łowiskach były różne. Również na danym łowisku zmieniały się w kolejnych latach badań. Stwierdzono, że intensywne rybołówstwo wpłynęło na odmłodzenie stad kergulen.

Józef Sosiński

ДАННЫЕ О ТАКСОНОМИИ И БИОЛОГИИ ЛЕДЯНОЙ РЫБЫ (CHAMPSOCEPHALUS GUNNARI, LÖNNBERG 1905)

Р е з ю м е

В результате исследований, проводимых в 1975--1979 гг. определены места скоплений стад ледяной рыбы в индийском секторе Антарктики в районе островов Кергелен, а также в атлантическом секторе Антарктики в районе Южной Георгии, Южных Оркнеев и Южных Шетландов. На основе анализа существенных различий исследуемых меристических черт (количество позвонков, количество лучей), а также неоднородности черт биологических, принято считать ледяную рыбу видом политиповым. Популяции, обитающие в атлантическом секторе Антарктики обнаруживают достаточное количество различий по отношению к популяциям индийского сектора Антарктики для того, чтобы их выделить как два самостоятельных подвида.

У подвида атлантического сектора Антарктиды можно в свою очередь выделить две экологические расы (северную и южную) с локальными стадами.

Эти три выделенные группы популяций ледяной рыбы характеризуются следующими чертами:

1. Подвид ледяной рыбы из индийского сектора Антарктики (острова Кергелен).

Рыбы характеризуются средним количеством позвонков, составляющим 59,53, а также средним количеством лучей плавников: D_1 - 9,16; D_2 -36,42; P - 27,00; A - 35,87.

Их отолиты по отношению к длине тела больше отолитов ледяной рыбы других районов. Рост длины тела относительно медленный. В возрасте 4 лет составляет в среднем 26,90 см. Вес рыб по отношению к длине тела меньший чем у ледяной рыбы атлантического сектора Антарктики. Нерест с марта по май. Плодовитость исследованных рыб составляла от 2 тыс. до 10,6 тыс. икринок.

2. Подвид ледяной рыбы атлантического сектора Антарктики

а) северная раса

(Южная Георгия, Скалы Шаг).

Леденая рыба северных районов промысла атлантического сектора Антарктики характеризуется средним количеством позвонков - 61,27, а также средним количеством лучей в плавниках:

D_1 - 9,14; D_2 - 38,28; P - 26,95; A - 37,52.

Отолиты по отношению к величине рыб больше чем у отолитов ледяной рыбы южных районов промысла, но меньше отолитов ледяной рыбы с островов Кергелен.

Темп роста длины рыб больше темпа роста ледяной рыбы с островов Кергелен. В возрасте 4 лет достигают средней длины 27,97 см. Отношение веса тела к длине больше, чем у леденой рыбы с островов Кергелен. Нерест с марта по май. Первый нерест при длине около 24 см. Длина наименьших половозрелых особей составляет 20 см. Плодовитость исследованных рыб составила 1,7 тыс. до 17,3 тыс. икринок.

б) южная раса

(Южные Оркнеи, о-в Элефан, Южные Шетланды).

Рыбы характеризовались средним количеством позвонков - 62,01, а также средним количеством лучей в плавниках:

D_1 - 9,50; D_2 - 38,77; P - 26,95; A - 37,39.

Отолиты по отношению к величине рыбы меньше, чем отолиты ледяной рыбы других районов. Темп роста самый высокий. В возрасте 4 лет достигают средней длины 29,80 см. Отношение веса тела к длине - такое же как и у ледяной рыбы северных районов промысла. Нерест с марта по май, с тем только, что он происходит несколько позднее, чем у ледяной рыбы с более северных районов промысла. Около 50% рыб достигает половозрелости при длине тела 32 см. Плодовитость исследуемых рыб - от 5,2 тыс. до 11,7 тыс. икринок.

На местах промысла встречались особи длиной 12--68 см. По возрасту распределялись от II до XIX возрастных групп. Большинство исследованных рыб принадлежало II - VIII возрастным группам. Длина и возраст ледяной рыбы, выловленной на вышеуказанных местах промысла были разными. Эти же параметры менялись в определённых районах промысла в течение указанных лет. Доказано, что интенсивность рыболовства повлияла на омолаживание стад ледяной рыбы.

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