

GROWTH AND AGE/LENGTH STRUCTURE OF POPULATIONS OF *NOTOTHENIA (LEPIDONOTOTHEN) SQUAMIFRONS (NOTOTHENIIDAE)* IN VARIOUS AREAS OF THE INDIAN SECTOR OF THE SOUTHERN OCEAN

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Abstract

Age, growth and age/length composition of populations of grey rockcod (*Notothenia (Lepidonotothen) squamifrons*), inhabiting areas of the Ob and Lena Banks and the Kerguelen Island Shelf, are presented in this paper. It was found that during the first years of life the linear growth rate is 3 to 5 cm per year. It decreases by a maximum of 1 cm during the last years of life. Maximum annual weight increments of 100 to 120 g at the banks and 153 to 188 g in the Kerguelen Island area were recorded for fish at age 6 to 12. Growth parameters were calculated according to Bertalanffy's equation. The dynamics of age/length composition of catches are also examined in this paper. On the Ob and Lena Banks this composition is fairly stable but on the Kerguelen Shelf there is a tendency towards younger fish being more abundant.

Résumé

L'âge, la croissance et la composition âge/longueur des populations de bocasses grises (*Notothenia (Lepidonotothen) squamifrons*) vivant dans les régions des bancs Ob et Léna et du plateau des îles Kerguelen, sont présentées dans ce document. On a découvert que pendant les premières années de vie, le taux de croissance linéaire est de 3 à 5 cm par an. Il diminue d'un maximum de 1 cm au maximum pendant les dernières années de vie. Une augmentation annuelle maximale de poids de 100 à 120 g sur les bancs et de 153 à 188 g dans la région des îles Kerguelen a été relevée pour les poissons des classes d'âge 6 à 12. Les paramètres de croissance ont été calculés selon l'équation de Bertalanffy. La dynamique de composition âge/longueur des captures est également étudiée dans ce document. Sur les bancs Ob et Léna, cette composition est relativement stable, mais sur le plateau de Kerguelen, les poissons plus jeunes ont tendance à être plus abondants.

Резюме

В настоящем документе представлена информация о возрасте, темпах роста и размерно-возрастной структуре популяций серой нототении (*Notothenia (Lepidonotothen) squamifrons*), обитающих в районе банок Обь и Лена, а также шельфа Кергелена. Было установлено, что на протяжении первых лет жизни темп линейного роста входящих в эти популяции особей составляет 3-5 см в год. В течение последних лет жизни он снижается на не более, чем 1 см за год. Максимальный ежегодный прирост веса в пределах 100-120 г и 153-188 г в районе банок и Кергелена соответственно, был отмечен среди особей в возрасте

6-12 лет. Параметры роста были вычислены по уравнению Бергаланффи. В данной работе также рассматривается динамика размерно-возрастного состава уловов. Состав уловов, полученных в районе банок Обь и Лена, довольно стабилен, в то время как в составе уловов, полученных на шельфе Кергелена, наблюдается тенденция к омоложению.

Resumen

En este documento se presenta la edad, crecimiento y composición de edad/longitud de las poblaciones de tramas grises (*Notothenia (Lepidonotothen) squamifrons*), que habitan las áreas de los Bancos de Ob y de Lena y la plataforma de la Isla Kerguelen. Se observó que durante los primeros años de vida el índice lineal de crecimiento es de 3 a 5 cm al año, disminuyendo a un máximo de 1 cm durante los últimos años de vida. Se registraron aumentos máximos de peso anual de 100 a 120 g en los bancos y de 153 a 188 g en el área de la Isla Kerguelen en peces de edad 6 a 12. Parámetros de crecimiento se calcularon de acuerdo a la ecuación de Bertalanffy. Las dinámicas de composición de edad/longitud de las capturas también se examina en este documento. En los Bancos de Ob y de Lena esta composición es bastante estable pero en la Plataforma Kerguelen los peces más jóvenes tienden a ser más abundantes.

1. INTRODUCTION

The grey rockcod (*Notothenia (Lepidonotothen) squamifrons*) is widely distributed in sub-Antarctic waters of the Southern Ocean. There are numerous populations of the Indian Ocean sub-species of this species (*Notothenia squamifrons* Günther, 1880) which inhabits island shelves (Crozet, Prince Edward and Kerguelen Islands) as well as seamounts (Ob, Lena and Skif Banks) (Duhamel, Hureau, Ozouf-Costaz, 1983; Duhamel, Ozouf-Costaz, 1985).

It has been demonstrated that *N. squamifrons* populations of the Ob and Lena Banks are discrete (Zaitsev, 1987 and 1989). Utilization of available resources of this species on these banks must therefore be carried out carefully and all biological features of the species should be taken into account.

Since the impact of fishing has recently become constant, it is increasingly important to examine age, growth rates and the dynamics of age/length composition of each population separately. Research on age structure of the Atlantic sub-species of this species (*N. squamifrons atlantica*, Permitin and Sazonov, 1974) in the South Georgia area was undertaken by Shust and Pinskaya (1978), while a similar study of Indian Ocean sub-species has been carried out by Duhamel and Ozouf-Costaz (Duhamel, 1981; Duhamel, Ozouf-Costaz, 1985). This paper results from the analyses of a large range of material. It supplements to a considerable degree, earlier data on the biology of the Indian Ocean sub-species.

2. MATERIALS AND METHODS

The material was collected by research vessels from the AzCherNIRO Institute and Yugrybpromrazvedka (Southern Fishery Survey Authority) from around the Ob and Lena Banks and the Kerguelen Islands from 1969 to 1987.

The age of fish was determined using standard methods (Chugunova, 1959). To this end, fish scales were used as an age reading structure. Preparations of scales were analyzed with the help of microfiche reading equipment "Microphot 5-PO-1" (materials from the Ob and Lena Banks) and "Microphot-3" AChM-22 (material from the Kerguelen Islands) with 1x20 magnification. Both permanent and temporary preparations were used with "Microphot-3" AChM-22. In the latter case a microfiche frame was used as a slide to speed up the process of preparing and analyzing preparations at least twice.

Altogether 536 preparations from the Ob and Lena Banks and 987 from the Kerguelen Islands were studied. Standard length was measured (standard length is from the tip of the snout to the end of the urostyle). Fish weight was determined to the nearest gram. In total, 94 354 specimens of *N. squamifrons* were weighed and measured.

In order to avoid errors in determining the age of *N. squamifrons*, sclerites were counted up to the edge of each annual ring, (i.e. to the point at which the sclerites begin to merge). The results of the count were processed on a computer using a BMDP program package. The hypothesis of normal distribution of sclerite up to the edge of annual rings was tested. Based on the Kolmogorov test, the distributions observed were considered normal at $P=0.2$. Moreover, single variable statistics of distribution of sclerites in each annual ring were calculated. A polymodal curve was drawn on the basis of these calculations, allowing for a more accurate determination of the age of fish in case of faint annual rings on their scales (Figure 1). A similar curve was used by Boronin and Frolkina (1976) in determining the age of *N. gibberifrons* (Lönnberg) from the South-West Atlantic.

Age composition of catches over the period under study was determined according to the Morozov-Mayorova method using size composition as a starting point

(Chugunova, 1959). Bertalanffy's growth equation was used to calculate parameters of linear and weight growth (Hohendorf, 1966). All calculations were performed on an EC 1035 mainframe computer.

3. LENGTH AND WEIGHT

The equation $W=aL^b$ was used in analyzing the relationship between length and weight where W - weight of fish; L - length; "a" and "b" - parameters statistically calculated from actual data (Ricker, 1979). This equation was calculated for each study area and for male and female specimens separately. A significant positive correlation between length and weight ($r>0.9$) was observed in each instance.

Sexual dimorphism was not apparent within the parameters under examination. The value of coefficient "a", however, varies from area to area (Table 2). Irrespective of the sample, the value of coefficient "b" is close to 3, which enables consideration of the growth of *N. squamifrons* in the areas under investigation as isometric. It also allows the use of these parameters for calculation of growth rates by means of Bertalanffy's equation.

It is worth noting the change in the length-weight ratio of fish in the Kerguelen Islands area from 1969 to 1986. There is a tendency towards weight increase per-unit-length among large fish (more than 25 cm) (Figure 2). These changes are most likely the result of intensive commercial fishing in the area. According to the catch data (Studenetskaya, 1983), the annual catch of *N. squamifrons* has exceeded 50 000 tonnes in some years. It is probable that this substantial yield has improved conditions for feeding and consequently led to a change in the length-weight ratio.

Data obtained from the Kerguelen Island area (1980 to 1986) correspond with those obtained earlier by Duhamel (1981), however it should be noted that Duhamel used total length (L) for calculating the ratio while in our work standard length (SL) was applied.

When comparing the data of different scientists who used either total or standard length, a ratio between these values for *N. squamifrons* was calculated as follows:

$$SL = 0.85L + 7 \text{ (mm)}$$
$$(r = 0.97)$$

4. LINEAR AND WEIGHT GROWTH

Data on growth rate of *N. squamifrons* were obtained from processing age data. This species is characterized by a long life cycle; 15 year old specimens were recorded in our samples. Both sexes of *N. squamifrons* have high linear and weight growth rates while sexual dimorphism was not observed (Table 1). Fish grow at a faster rate in the first half of their life cycle - up to 6 to 8 years (i.e. up until sexual maturity). During this period linear growth is 3 to 5 cm per year. Linear growth decreases by a maximum of 2 cm in mature fish aged 8 to 10 and towards the end of life by a maximum of 1 cm. Maximum increase in weight occurs at age 6 to 10 around the Ob and Lena Banks (100 to 120 g/year) and at age 7 to 12 in the Kerguelen Island area (155 to 188 g/year). It must be noted that retardation of the weight growth rate on the Lena Bank begins at an earlier age than in other areas (Table 1). Weight gain values for the Ob and Lena Bank populations are similar to those obtained for the Atlantic sub-species of *N. squamifrons* in the South Georgia area (Shust, Pinskaya, 1978).

Parameters of linear and weight growth equations (Bertalanffy's equation) were calculated for each area using the data obtained from observations (Table 2).

When comparing the data obtained it can be seen that while the growth rate for all three areas is fairly similar, the calculated values for length and weight of specimens of the same age group are minimal on the Ob Bank and maximal in the Kerguelen Islands area (data for 1980 to 1986) (Table 1). Relative growth rate coefficients (K), calculated using Bertalanffy's equation, are also different (Table 2).

Growth characteristics of *N. squamifrons* in the Kerguelen waters deserve special attention. Material collected before the commencement of exploitation of resources on the Kerguelen Shelf (1969 to 1972), and during the period reflecting the current state of the exploited population (1980 to 1988), has been analyzed. Both empirical and calculated values of length and weight by age for these periods practically coincide. The differences in growth rate coefficients are not significant and are more likely caused by the varied quality of materials than by physiological changes of fish. The results of this research demonstrate, therefore, that despite the impact of the fishery and the slight tendency of the length-weight ratio to change, the general growth pattern of fish in this area has remained virtually constant.

Analysis of the data shows that *N. squamifrons* reaches two-thirds of its theoretical maximum length and one-third of its maximum body weight at the age of 9 years on the Lena Bank, 10 years on the Ob Bank and 11 years in the Kerguelen area.

5. AGE/LENGTH CATCH COMPOSITION

The dynamics of age/length composition of catches may serve as an indicator of the state of exploited populations. Our material makes it possible to assess the age/length catch composition of *N. squamifrons* in each of the areas studied over different years and to note changes that may be occurring.

N. squamifrons taken on the Ob Bank consisted of specimens 8 to 46 cm in length, 4 to 1 400 g in weight and 1 to 15 years old. Specimens of the younger and older age/length groups generally appeared in small numbers. The bulk of the exploited part of the population comprised specimens 20 to 36 cm in length and 4 to 12 years old, the proportion of which varied from 83.8 to 97.6% in different years (Figure 3). The mean age in this area is about 8 years. Earlier it was established that on the Ob and Lena Banks, *N. squamifrons* reaches maturity at the age of 6 to 7 (Zaitsev, 1989), which indicates that primarily mature specimens were fished. Age/length catch composition on the banks is relatively stable, although with the fairly constant mean age of the population over the last two years, the proportion of fish with a mode of 28 to 32 cm aged 8 in catches has increased markedly while the proportion of older specimens has declined (Figure 3). These changes are associated with a concentration in these years of fishing on pre-spawning and spawning aggregations which contain specimens of the above age/length groups.

Age/length catch composition of *N. squamifrons* on the Lena Bank is slightly different from that on the Ob Bank. With similar values for maximum length and age, the mean values of these parameters were lower. The mode was usually 22 to 32 cm and 5 to 8 years while the mean age was approximately 7 years. In recent years there have been no significant changes in age/length structure (Figure 4).

Specimens 8 to 50 cm in length and 7 to 2 200 g in weight were found in trawl catches around the Kerguelen Islands. The age of these fish varied from 1 to 15 years. In the first years of the fishery (1969 to 1972) primarily older aged fish were taken (8 to 13 years), comprising from 67.8 to 92.6% of the total (Figure 5). In the 1980s there was a tendency towards a younger fish in catches with 6 to 7 year old specimens predominating. From 1969 to 1987 the mean age of fish in catches dropped by almost four years. This can be illustrated by the nature of changes in mean length and the range of variation in modal values during the periods being compared. Figure 6 shows a sharp decrease in these

parameters from 1969 to 1983 with some stabilization in recent years. Since the majority of fish in the Kerguelen Islands area reach maturity at the age of 7 to 8 and the bulk of the catch for 1985 to 1987 comprised 6 to 7 year olds, it is clear that mainly immature or maturing specimens were targeted by the fishery.

The general trend towards change in the age/length catch composition and a younger population indicates that the fishery in the Kerguelen Islands area must be regulated and managed on the basis of scientific recommendations, made as a result of joint Franco-Soviet research projects.

6. CONCLUSIONS

- (i) Growth of *N. squamifrons* in the areas under study is close to isometric since the coefficient "b" of the length-weight ratio is close to 3.0 for both males and females. The relationship between total length (L) and standard length (SL) is expressed by the following equation: $SL=0.85L + 7 \text{ mm}$.
- (ii) Linear growth rate is from 3 to 5 cm per year in the first years of life to 1 cm in the last years, dependent upon the area. Maximum increase in weight occurs at 6 to 10 years of age in the Ob and Lena Bank areas (100 to 120 g) and 7 to 12 years in the Kerguelen Islands area (153 to 188 g).
- (iii) Specimens aged 1 to 15 are taken in trawl catches. The bulk of the exploited part of the population on the Ob bank comprised fish 20 to 36 cm in length, aged 4 to 12 ($\bar{T}=8$ years) and on the Lena Bank - 22 to 32 cm in length, aged 5 to 8 ($\bar{T}=7$ years). At the beginning of exploitation in the Kerguelen Islands area the bulk of the catch consisted of 8 to 13 year old specimens, while in the 1980s, 6 to 7 year olds began to predominate. The mean age of fish in catches dropped by about four years.
- (iv) Between-year dynamics of age/length catch composition demonstrated that while *N. squamifrons* populations in the Ob and Lena Bank areas are in a fairly stable condition, the Kerguelen population is experiencing the impact of the fishery which ought to be regulated in this area.

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Table 1: Linear (cm) and weight (g) growth of *N. squamifrons* (calculated according to Bertalanffy's equation).

Area	Sex	Age in years														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Linear growth														
Ob Bank	Females	-	9.3	13.4	17.1	20.5	23.5	26.2	28.7	30.9	32.9	34.8	36.4	37.9	39.2	
	Males	-	8.7	13.3	17.4	20.9	24.1	26.9	29.4	31.6	33.5	35.3	36.8	38.1	39.3	
	Both sexes	-	9.3	13.5	17.3	20.7	23.8	26.6	29.0	31.2	33.2	35.0	36.5	37.9	39.2	
Lena Bank	Females	6.1	10.9	15.2	18.9	22.3	25.3	28.0	30.3	32.5	34.3	36.0				-
	Males	5.0	10.6	15.4	19.5	23.0	26.0	28.6	30.7	32.6	34.2	35.6				(38.6)
	Both sexes	5.8	10.9	15.3	19.2	22.6	25.5	28.2	30.5	32.5	34.3	35.9				(39.5)
Kerguelen Islands (1980-1986)	Females	7.5	12.2	16.5	20.3	23.7	26.8	29.6	32.0	34.2	36.2	38.0	39.6	41.0		(42.7)
	Males	6.2	11.6	16.3	20.4	24.0	27.1	29.9	32.3	34.4	36.3	37.9	39.3	-	-	
	Both sexes	7.1	12.1	16.5	20.4	23.9	27.0	29.7	32.2	34.3	36.2	37.9	39.4	40.8		(42.7)
(1969-1972)	Both sexes				20.1	23.3	26.3	29.1	31.7	34.0	36.2	38.3	40.1	41.9	43.5	44.9

Area	Sex	Age in years														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Weight growth														
Ob Bank	Females		12	41	92	163	251	354	468	587	711	835	957	1076	1214	
	Males		12	43	98	176	273	384	506	633	761	888	1012	1130	1242	
	Both sexes		13	44	96	170	262	368	485	609	736	863	989	1111	1228	
Lena Bank	Females	2	18	57	123	210	316	432	556	678	799	914				-
	Males	1	16	65	146	247	359	472	580	679	767	844				(1028)
	Both sexes	2	18	61	131	223	330	446	564	679	788	891				(1180)
Kerguelen Islands (1980-1986)	Females	5	23	64	129	220	336	474	630	800	981	1169	1361	1554		(2001)
	Males	4	22	64	132	227	346	484	637	800	969	1140	1310	-	-	
	Both sexes	5	24	65	132	225	341	478	631	796	970	1148	1329	1508		(2001)
(1969-1972)	Both sexes				129	221	337	472	625	792	969	1152	1338	1526	1713	1897

Table 2: Parameters of length-weight equation and Bertalanffy's growth equation for *N. squamifrons*.

Area	Sex	Parameters						
		a	b	L_{∞}	W_{∞}	K	t_0	n
Ob Bank	Females	0.01466	3.0831	51.83	2487	0.1015	0.0591	115
	Males	0.00947	3.2209	48.28	2317	0.1235	0.3917	130
	Both sexes	0.01147	3.1600	49.89	2524	0.1115	0.1781	245
Lena Bank	Females	0.00647	3.3250	49.53	1933	0.1166	-0.1350	168
	Males	0.00887	3.2285	43.55	1233	0.1573	0.2182	123
	Both sexes	0.00735	3.2880	47.24	1632	0.1290	-0.0302	291
Lena Bank (Duhamel, Ozouf-Costaz, 1985)	Both sexes	-	-	43.0	1003	0.117	1.0593	
Kerguelen Is (1969-1972)	Both sexes	0.01244	3.1315	63.29	4830	0.0779	-0.9075	309
Kerguelen Is (1980-1986)	Females	0.00293	3.3198	53.59	4755	0.1087	0.3788	281
	Males	0.00262	3.3401	49.39	3547	0.1325	0.0150	295
	Both sexes	0.00314	3.3089	51.31	4157	0.1196	0.2426	576
Kerguelen Is (Duhamel, Ozouf-Costaz, 1985)	Females	0.0025	3.4359	-	-	-	-	627
	Males	0.0032	3.3686	-	-	-	-	683
	Both sexes	-	-	67.0	4470	0.078	0.1075	-

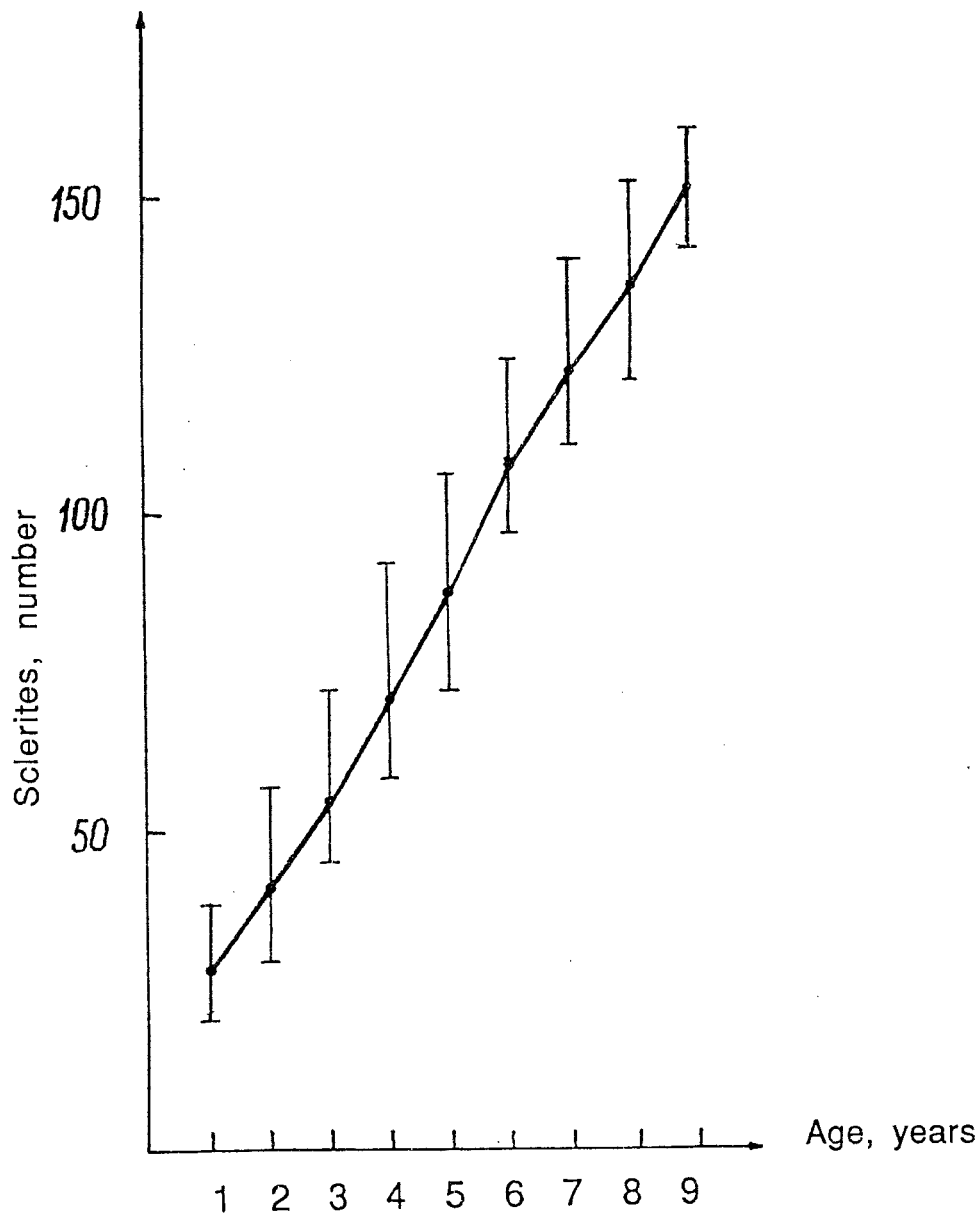


Figure 1: Change in the number of sclerites of *N. squamifrons* of different age.

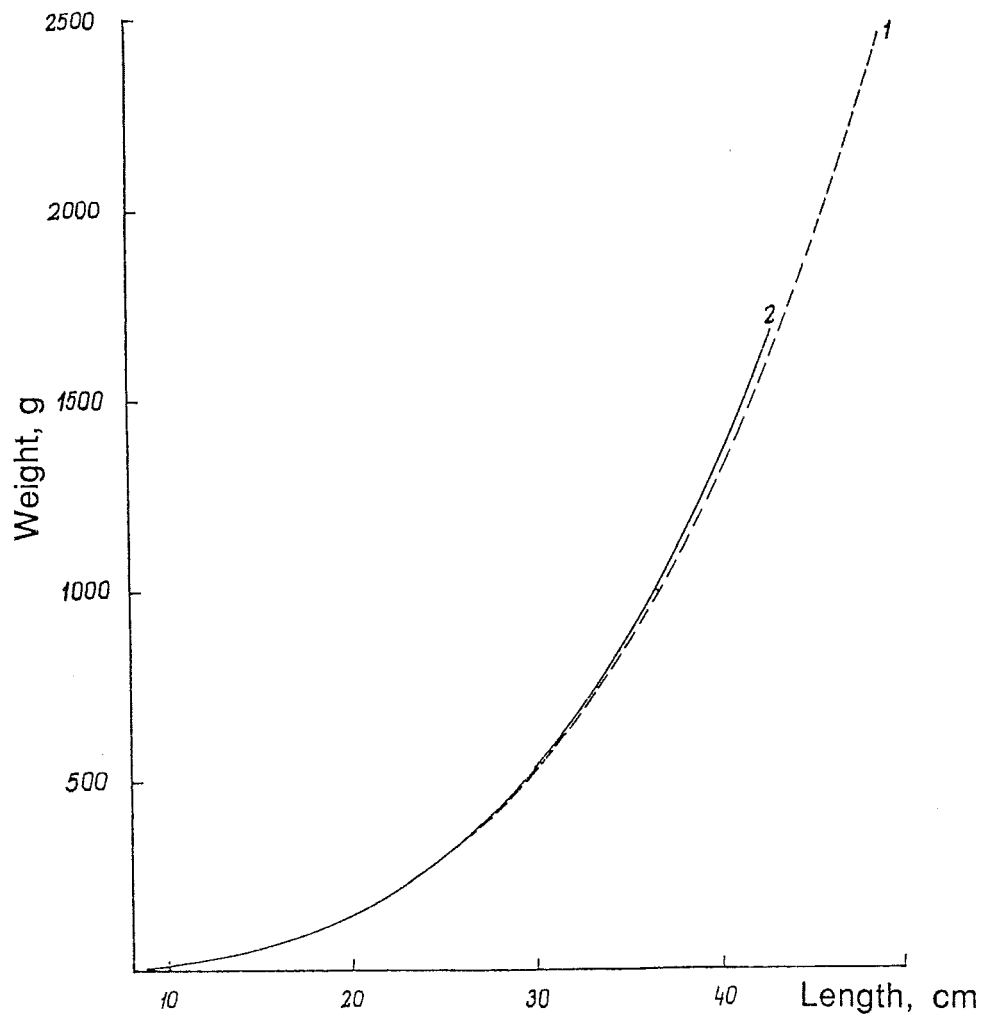


Figure 2: Length-weight ratio of *N. squamifrons* from the Kerguelen Island area:
1=1969 to 1972; 2=1980 to 1986.

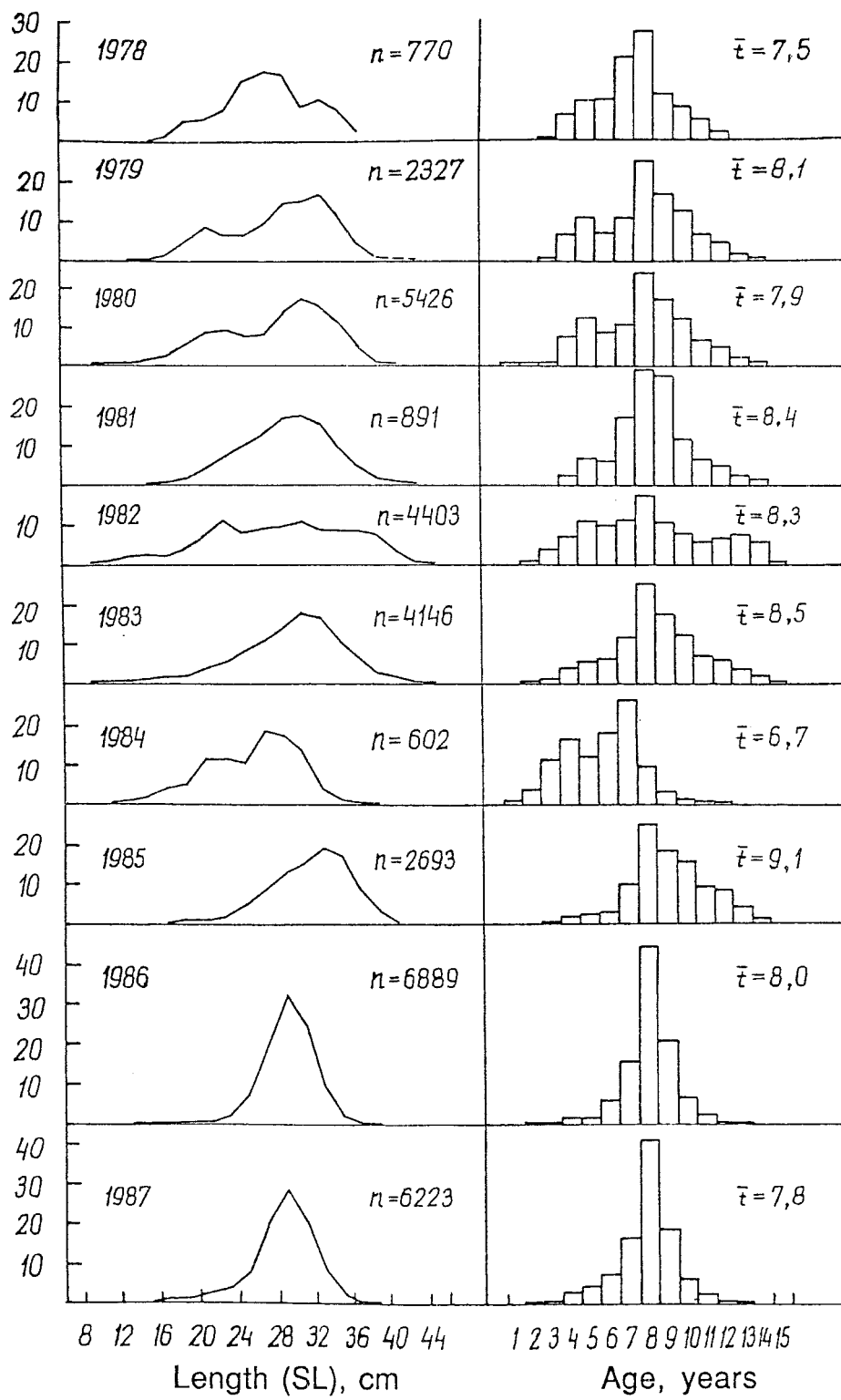


Figure 3: Age/length composition of *N. squamifrons* in the Ob Bank area.

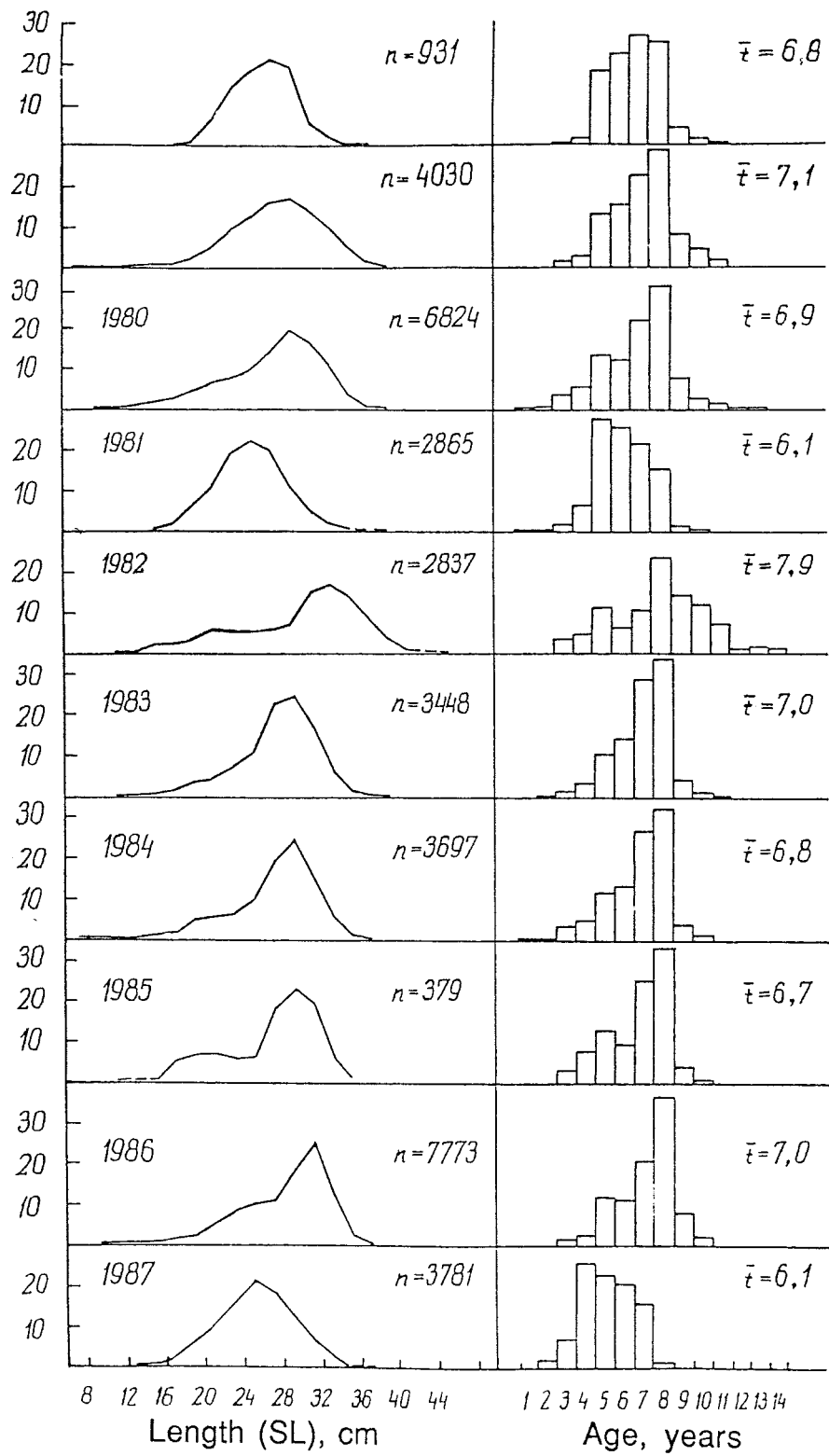


Figure 4: Age/length composition of *N. squamifrons* in the Lena Bank area.

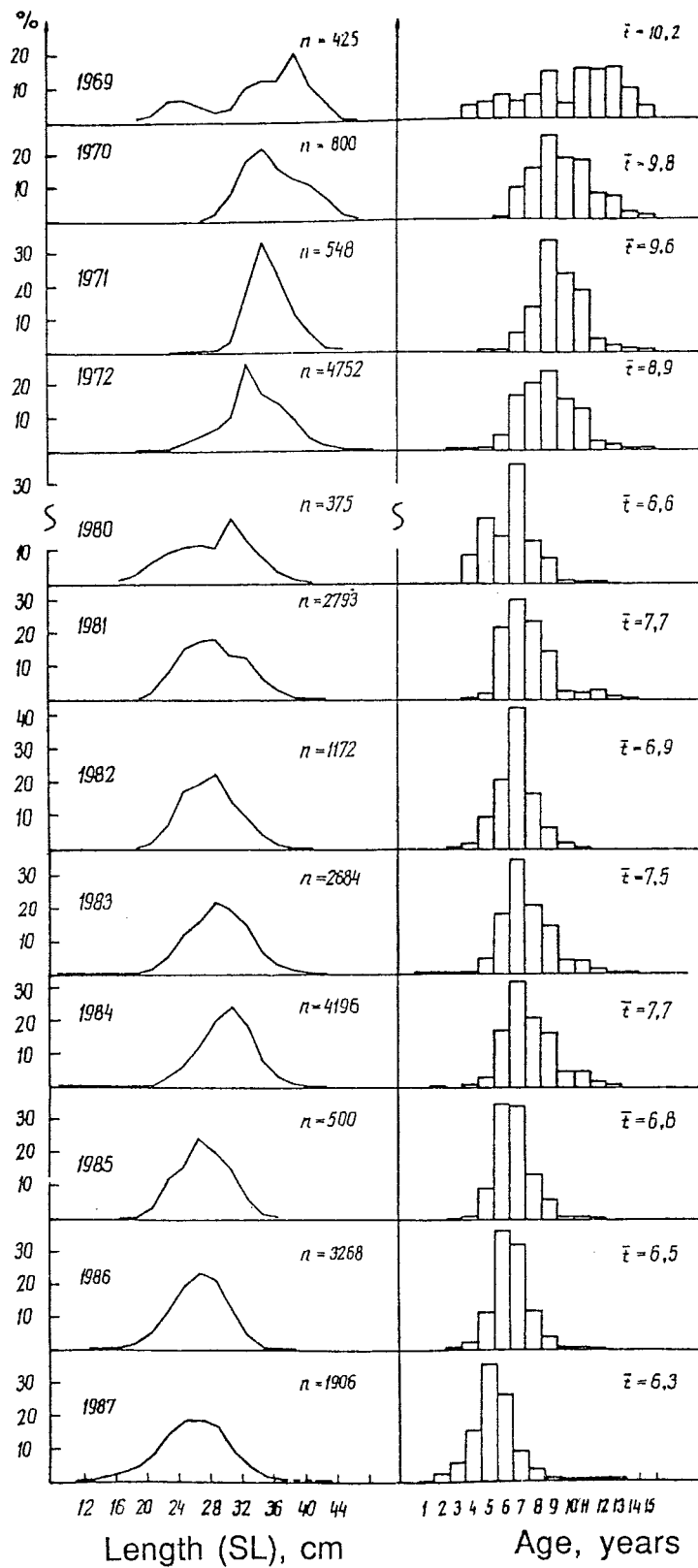


Figure 5: Age/length composition of *N. squamifrons* in the Kerguelen Island area.

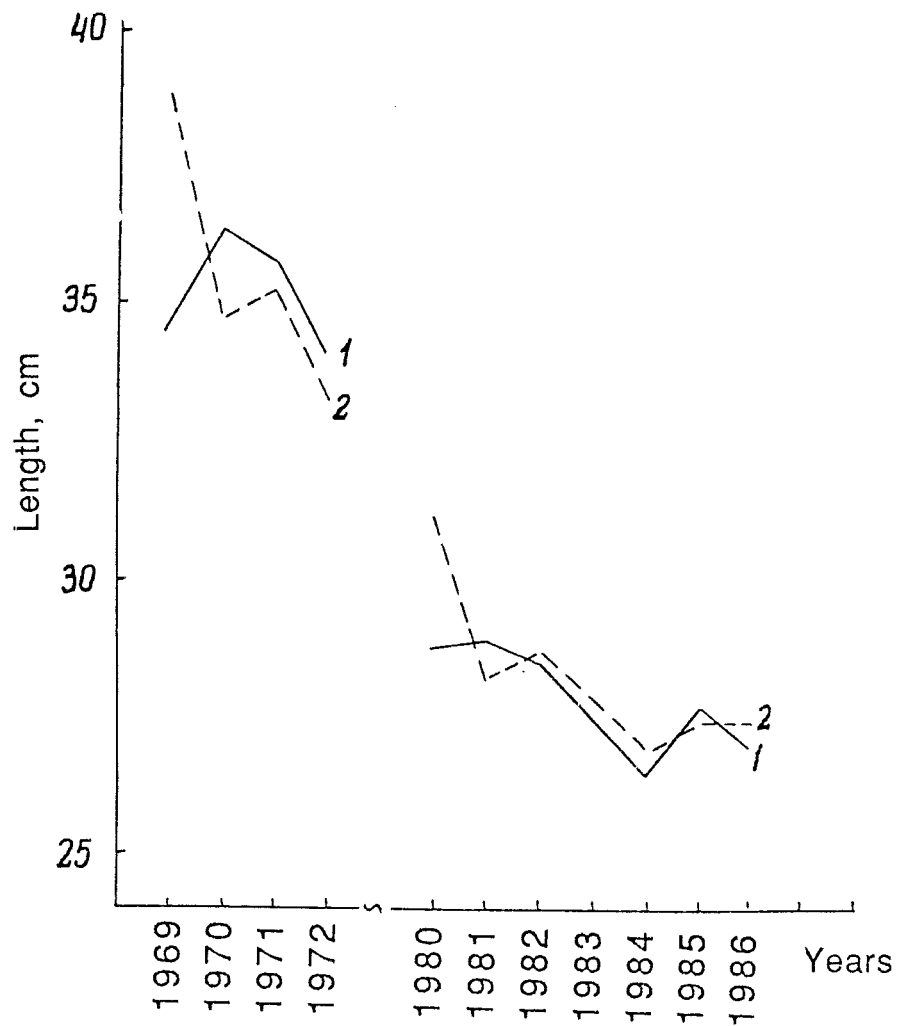


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1 - mean length; 2 - modal length

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