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METHODS OF AGE DETERMINATION FOR MACKEREL ICEFISH (*CHAMPSOCEPHALUS GUNNARI* LÖNNBERG 1905) FROM THE SOUTH GEORGIA ISLAND SHELF

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Abstract

Radii of annual elements of otoliths of mackerel icefish (*Champsocephalus gunnari*) from the South Georgia shelf were determined by analyzing data on length frequency distribution of fish in catches simultaneously with otolith radii of fish taken in the period July to September. The latter was done using specimens from strictly defined age groups. It is suggested that the determined radii of annual elements of otolith could be used to adjust age assessments of fish longer than 30 cm having an enlarged otolith centre. An age/length key for the third quarter of the year was also calculated.

Résumé

Le rayon des éléments annuels des otolithes de poisson des glaces (*Champsocephalus gunnari*) du plateau de la Géorgie du Sud ont été déterminés par analyse simultanée des données de distribution des fréquences de poissons dans les captures et des rayons d'otolithes de poissons échantillonnés de juillet à septembre. Ces derniers ont été mesurés à partir de spécimens provenant de classes d'âge définies avec précision. L'utilisation des rayons déterminés des éléments annuels des otolithes a été suggérée pour ajuster les évaluations de l'âge des poissons d'une longueur supérieure à 30 cm dont l'otolithe est dilaté en son centre. Une clef âges-longueurs a également été calculée pour le troisième trimestre de l'année.

Резюме

Радиусы годовых колец отолитов ледяной рыбы (*Champsocephalus gunnari*) в районе шельфа Южной Георгии были рассчитаны на основе изучения частотного распределения длины особей в уловах, проводимого одновременно с измерением радиусов отолитов рыб, выловленных за период с июля по сентябрь. При измерении радиусов отолитов использовались экземпляры точно определенных возрастных групп. Было предложено использовать рассчитанные радиусы годовых колец отолитов для оценки возраста особей, длина которых превышает 30 см, с увеличенным центром отолита. Также был рассчитан размерно-возрастной ключ для третьего квартала.

Resumen

Los radios formados por los elementos anuales en los otolitos del draco rayado (*Champocephalus gunnari*) de la plataforma de Georgia del Sur fueron determinados analizando los datos de distribución talla-frecuencia de los peces capturados, simultáneamente con radios de otolitos de peces pescados en el período de julio a septiembre. Esto último fue hecho usando especímenes de grupos de edad estrictamente definidos. Se sugiere que los radios de elementos anuales de otolitos puede ser utilizados para ajustar la evaluación de peces de longitud mayor de 30 cm que tengan el centro del otolito agrandado. También se calculó una clave de edad/longitud para el tercer trimestre del año.

1. INTRODUCTION

The mackerel icefish (*Champsocephalus gunnari*), is a member of the *Channichthyidae* family and is widely distributed in the Antarctic and sub-Antarctic waters of the Atlantic Ocean. The study of its various ecological characteristics has received a great deal of attention from Soviet and foreign researchers. (Andriyashev, 1969; Efremenko,1979; Kochkin, 1979; Lisovenko, 1982; Permitin,1972-3; Bellisio, Tomo 1970; Kock, 1975, 1979, 1980; Kompowski, 1980; Olsen 1955; Rudd, 1954; Rembiszewski, Krzeptowski 1978, Sosinski, 1983). To the present, however, agreement upon the correct method of age determination has not been reached. Therefore insufficient investigation has been undertaken regarding growth rate, natural mortality, age at maturation and, consequently, patterns of population dynamics.

At the Workshop on Age Determination of Antarctic Fish held in Moscow in 1986, it was decided that it was necessary to continue development of age determination techniques for *C. gunnari.*

Methods of age determination of fish are quite well detailed by Chugunova (1959). Age assessment, however, is somewhat subjective and much depends on the experience of the scientist. Thus, experienced scientists achieved a 95% agreement rate in a cross-checking of 101 cases of age determination and a rate of 89% for age determination in the case of older specimens while those of little experience managed rates of 78% and 36% respectively (Clark, 1958, cited in Shentyakova, 1971). Hence it is essential to develop more objective ways of interpreting results of scale "reading". A technique for verification and clarification of age assessments has been suggested by Mina (1973).

This technique has been applied in this work for age determination of a range of Antarctic fish. This technique has proven to be beneficial in decreasing the possibility of errors in age determination when used by different scientists.

2. MATERIALS AND METHODS

Research material was collected aboard research vessels *Gizhiga*, *Pioner Latvii*, *Slavgorod*, *Evrika* and others from 1984 to 1986. This material is comprised of otoliths representing all major size groups of fish which were sampled monthly.

Approximately 2.5 thousand pairs of otoliths were examined for age determination. These age reading structures are very small and fragile. First dry otoliths were used, which were further treated with glycerine to make them transparent when required. Using these otoliths a second time is impossible, however, because the process of their discolouration is irreversible. Good results were achieved by the method of preserving otoliths in alcohol vapour and then allowing them to air for 30 minutes. They were then placed in camphor-oil and examined under a microscope (magnification 2 x 8) in direct light (a black block-dish with oblique light).

Since alternation of hyaline and opaque elements is most distinct on the dorsal side of the otolith, its radius was measured on this side. The data thus obtained were used to identify growth rate. Zoological total length of fish is used in all calculations.

3. RESULTS

Researchers applied several approaches in developing methods of age determination. Using a device he had constructed himself, Kochkin (1982, 1985) prepared a sagittal otolith section, dyed it and examined it at 130-500 x magnification. Daily and weekly growth increments were in this way identified. This method is very time consuming and cannot be applied to the processing of large quantities of material.

In respect of the difficulty of examining individual specimens, the West German scientist, Kock, (Kock, 1981) conducted a graphic analysis of fish length distribution frequency (the Petersen method). In Kock's opinion, this method can only be successfully applied to the first age classes (i.e. fish up to 32 cm long). At the same time he examined otolith ring structures. By superimposing age distribution on a length frequency curve, he obtained a more accurate age assessment for specimens of the first four age classes. Even after cleansing, the centre of otoliths of older specimens remains too opaque to clearly identify first annual elements (AE)* .

Our first task was to establish the periods over which AE were formed. To this end 20 pairs of otoliths were analysed every month for the period 1984 to 1988. Data obtained from this analysis showed that the formation of AE occurs from June to September (i.e. austral winter). Moreover, depending on year-to-year fluctuations in environmental conditions, the periods of AE formation and the number of specimens with AE around the edges may vary from year to year. According to our observations, the formation of AE generally ends in June for 10%, in July for 40%, in August for 95% and in September for 100% of specimens. Fish otoliths consist mainly of crystals of inorganic calcium carbonate (aragonite) which is impregnated into the organic matrix (wavy protein, known as otolin). The difference in the proportion of organic and inorganic components leads to the alternation of concentric hyaline and opaque areas of the otolith. Opaque areas appear during periods of rapid growth when larger amount of aragonite forms on the otolith surface, while hyaline areas consisting of less aragonite appear during periods of slow growth. The formation of hyaline areas is generally associated with spending of energy for spawning, worsening feeding conditions and decreased metabolic rates due to a drop in water temperature. All of the above are important factors during the formation of AE for *C. gunnari* and may impact on this process. Fluctuations in the periods of AE formation by year were noted. In order to identify the factor having the most influence upon the changes in growth rate of *C. gunnari* and hence on the formation of AE, data on the monthly change in modal length of fish, obtained from numerous measurements taken in 1985, 1986, 1987 were summarized.

The growth rate curves for two adjacent year-classes differ significantly (Figure 1a). The growth period in 1985 to 1986 can be divided into periods of slackened growth (July to November 1985 and July to September 1986) and accelerated growth (December to June 1985). A gradual increase in length was observed throughout 1987 with a slight decrease only in September to November.

During the study period from 1985 to 1987, maximum density of krill was observed in 1987, when krill remained available to *C. gunnari* even in the autumn. Minimum density of krill on the South Georgia shelf was noted in 1985. An analogous tendency was also observed in the index of stomach fullness of *C. gunnari* over these years (Figure 1b).

A difference in AE formation was noted on otoliths of fish caught in July, October and November 1987. In July 1986, 50% of specimens had a broad hyaline area around the edges, comparable with the width for the previous annual area while only 5% of specimens taken in July 1987 had this hyaline area. One hundred percent of fish taken in November 1986 showed a slight increase in growth, whereas in November 1987 only a narrow hyaline area around the edges was observed and later, in January 1988 only, the growth increments became clearly visible. This may be explained by the fact that the cessation of growth and

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* We consider the term "element as a part of an age reading structure which differs from its other parts by one or another characteristic" (suggested by Mina and Klevezal, 1971) to be more appropriate than the term "ring", since it may be of any shape.

consequently, the formation of AE in 1987 probably occurred two months later than usual. The much narrower hyaline area in 1987 when compared to 1985 and 1986 is apparently associated with the shorter period of decreased intensity of metabolism.

Growth rate of *C. gunnari* is evidently influenced by the density and availability of krill swarms. The periods when krill ceases to be available to fish generally coincide with periods of AE formation which makes it highly likely that these processes are interlinked. A comparison of Figures 1a and 1b demonstrates that a slackening in growth occurred when the index of stomach fullness decreased, and the onset of intense growth was timed to the period of increasing stomach fullness.

Shcherbich (1975) suggested that for age determination of *Notothenia rossii*, the beginning of the reference year should be 1 July and not 1 January as is the practice for fish in the Northern Hemisphere. The concept of the beginning of the year is a formal one. The formation of AE does not occur simultaneously in various specimens of the same population over the year. There are also year-to-year variations in the dates of its formation.

Study of population dynamics, however, especially with a view to ecosystem modelling using multispecies models, demands standard in the choice of the beginning of the reference year. Since the beginning of the year for many Southern Ocean fish is taken to be 1 July, this date is proposed here for *C. gunnari.*

As in Kock (1981), length frequency distribution of *C. gunnari* in catches was used for developing this method. Analyzing data on numerous fish measurements taken from catches in May, July and August 1985 and from trawl census surveys in April/May 1984, facilitates division of fish into distinct size groups related to adjacent age classes. By comparing our material with Kock's data the similarity is evident. We can now determine to which age groups these data refer.

The research of both Soviet and foreign scientists (Efremenko, 1979; Kochkin, 1985; Olsen, 1955; Rembiszewski, 1978; Kock, 1980), in addition to our data from a trawl census survey of the zero age class, clearly demonstrates fish growth in the first year of life (Figure 2). Consequently, towards the end of the first year a length of 9 to 10 cm is reached and the radius of the element formed during this period for a fish of the above length should correspond to the size of the first AE. Therefore, the first group before 1 July (Table 1) refers to the zero age class, the next group refers to the first age class and so on.

According to the length distribution frequency in catches, the fish lengths in July are as follows: first year, 9 to 10 cm; second year, 17 to 18 cm; third year, 24 to 25 cm; fourth year, 29 to 30 cm. Therefore, choosing otoliths of fish taken in July to September and measuring radii from the centre to the edge of otolith gives the most likely position of the first four annual elements (Table 2). This finding will assist in more accurate age determination of cases in doubt.

Taking into consideration the existence of annual fluctuations in the growth rate of *C. gunnari*, radii of otoliths from 1984 to 1988 were measured and the data are presented in Table 2.

A large volume of age data for 1983 to 1985 was used to verify the reliability of our methods. An age/length key was calculated for the third quarter of the calendar year (i.e. beginning of the reference year) with the help of these data. Using material covering these three years enabled the differences in growth rate for various years to be averaged. For this reason the derived age/length key may not be used in the future for stock assessment of *C. gunnari*.

In accordance with our method, these annual quarterly keys were calculated using the large amount of materials. In this way mean lengths by age for the South Georgia population were obtained. By comparing these mean lengths with the modal lengths derived from extensive measurements taken annually in the third quarter, the close agreement between these values is evident. The growth of the strong 1983 year class was also monitored by measuring the modal lengths of a large number of specimens (Figure 3). A comparison of mean lengths obtained when determining age with the modal lengths of this year class demonstrates that they are practically identical. Therefore the proposed method can be used for age determination since those elements taken as annual are precisely that.

Differences in mean lengths described in this work and by other authors (Kochkin, 1985; Kock, 1981; Sosinski, 1983) obviously occur due to the fact that intensive fishing in the area is primarily conducted in the fourth quarter, the period in which extensive age data is primarily collected. The modal length of *C. gunnari* in this period is 26 to 28 cm.

An extensive amount of age determination material is presently being processed by means of the proposed method. The study of age composition of *C. gunnari* from the South Georgia Shelf demonstrated that the predominant fish in this area have a length of 35 to 40 cm and are aged 5 to 7, while individual specimens aged 8 to 9 attain a length of 51 to 53 cm. The largest specimens taken in May 1984 had the following characteristics:

female - length, 66 cm; weight, 2 400 g; age - 16
male - length, 62 cm; weight, 2 000 g; age - 14

4. CONCLUSIONS

(i) Otoliths can be preserved for age determination by means of treating them in the field and storing in alcohol vapour.

(ii) Since formation of annual elements occurs during July/August and fry are hatched in August/September, the formal date of birth for *C. gunnari* can be considered as 1 July.

(iii) Towards the end of the first year of life the majority of fish reaches 9 to 10 cm in length and the radius of the first annual element is 9 to 15 points of an ocular micrometre. Towards the end of the second year these figures are 17 to 19 cm and 17 to 23 points, for the third year, 23 to 25 cm and 23 to 28 points and for the fourth year, 30 cm and 27 to 35 points.

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Table 1: Comparison of Kock's (1981) and our data (1984, 1985) on modal lengths of various linear (age) groups.

Kock		Our Data			
1981		1984		1985	
December	March-April	April	May	July	August
5.6	-	9.5	-	9.4	-
15.4	18.2	18.0	-	17.0	17.0
22.6	25.5	25.0	22.0	24.0	24.0
			23.0	25.0	25.0

Table 2: Radii of fish otoliths having annual rings around the edges and sizes of annual elements of the first four age groups.

Age-groups	1	2	3	4
Size groups (cm)	9-11	17-19	23-25	30
Otolith radii (oc. micr. points)	9-12	18-22	25-27	32-34
Radii of elements taken to be annual (oc. micr. points)	9-15	17-23	23-28	27-35

Table 3: Age/length keys for *C. gunnari* from the South Georgia Shelf (July to September).

Length (cm)	Age in years							
	1	2	3	4	5	6	7	8
7	8							
8	16							
9	54							
10	39							
11	31							
12	26							
13	5							
14		1						
15		8						
16		19						
17		44						
18		50						
19		48						
20		36	4					
21		20	22					
22		11	37					
23		7	41					
24		3	46	2				
25			52	2				
26			36	16				
27			22	27				
28			14	30				
29			7	44				
30			1	59	1			
31				31	3			
32				5	10			
33				2	35			
34					35			
35					31			
36					31	2		
37					21	4		
38					10	7		
39					1	9		
40						2		
41						2		
42						1	1	
43							2	
44							4	
45							1	1
46							1	3
47								2
48								1
n	179	247	282	218	178	27	9	7
$\bar{L}$	9.98	18.73	24.37	29.02	34.80	38.61	43.94	46.48

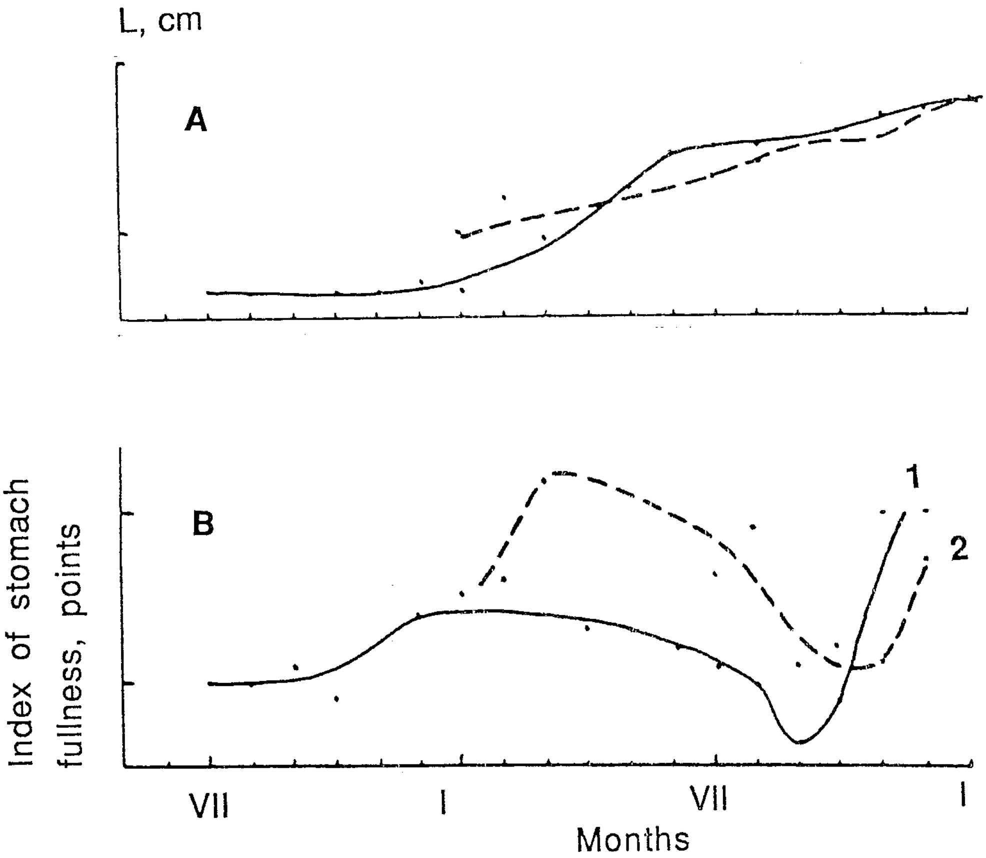

Figure 1: Growth rate of *C. gunnari*. Data obtained from extensive measurements in 1985, 1986 and 1987 (a).

Level of stomach contents for the same period (b).

- - - 1985-1986
- - - 1987

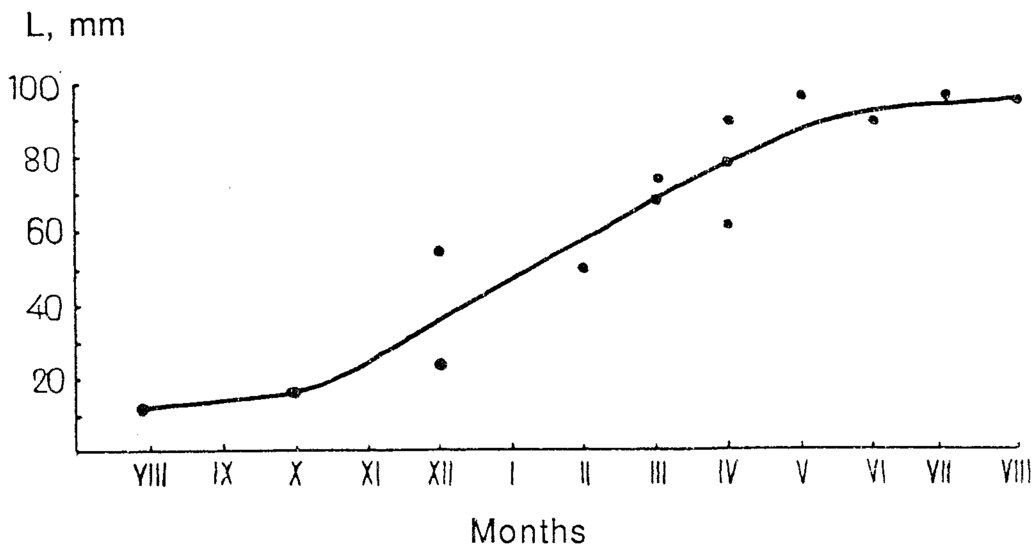

Figure 2: Growth rate of *C. gunnari* during the first year of life. Data from various sources.

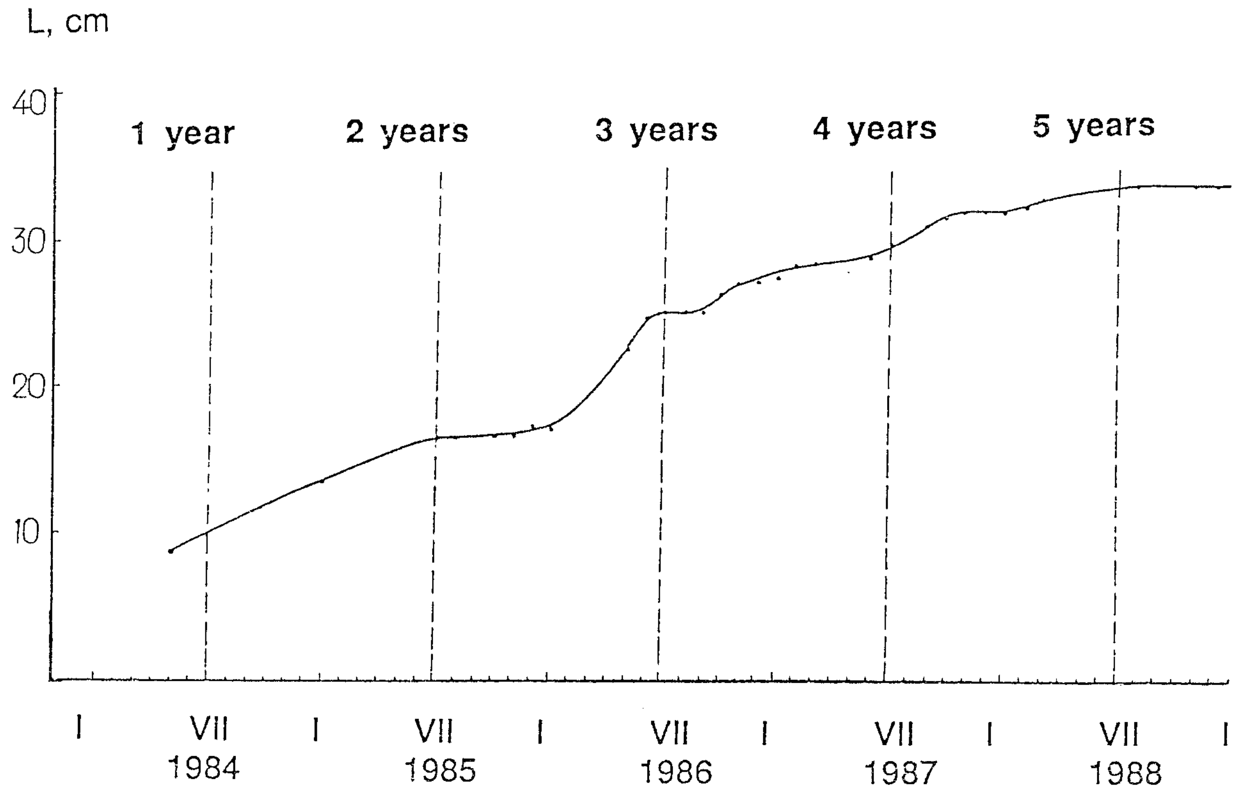

Figure 3: Growth of 1983 year-class using length frequency distribution data from catches.

Liste des tableaux

Tableau 1: Comparaison entre les données de Kock (1981) et les nôtres (1984, 1985) sur les longueurs modales de diverses classes (d'âge) linéaires.

Tableau 2: Rayon des otolithes de poissons cerclés d'anneaux annuels et taille des éléments annuels des quatre premières classes d'âge.

Tableau 3: Clefs âges-longueurs pour *C. gunnari* du plateau de la Géorgie du Sud (de juillet à septembre).

Liste des figures

Figure 1: Taux de croissance de *C. gunnari.* Données obtenues à partir de mesurages approfondis en 1985, 1986 et 1987 (a).

Niveau des contenus stomacaux pendant la même période (b).

--- 1985-1986
- - - 1987

Figure 2: Taux de croissance de *C. gunnari* pendant la première année de vie. Données provenant de sources diverses.

Figure 3: Croissance de la classe d'âge de 1983, utilisant les données sur la distribution des fréquences des longueurs provenant des captures.

Список таблиц

Таблица 1: Сравнение данных Кока (1981 г.) и наших данных (1984,1985 гг.) по модальной длине различных линейных (возрастных) групп.

Таблица 2: Радиусы отолитов рыбы с внешними годовыми кольцами и размеры годовых колец у первых четырех возрастных групп.

Таблица 3: Размерно-возрастные ключи для *C. gunnari* на шельфе Южной Георгии (июль-сентябрь).

Список рисунков

Рисунок 1: Темп роста *C. gunnari.* Данные, полученные на основе обширных измерений в 1985, 1986, и 1987 гг. (a).

Уровень содержимого желудка за тот же период (b).

--- 1985-1986 г.
- - - 1987 г.

Рисунок 2: Темп роста *C. gunnari* в течение первого года жизни. Данные из разных источников.

Рисунок 3: Рост годового класса 1983 г. при использовании полученных данных по частотному распределению длин в уловах.

Lista de las tablas

Tabla 1: Comparación entre los datos de Kock (1981) y los nuestros (1984, 1985) sobre longitudes modales de varios grupos lineales (edad).

Tabla 2: Radios de otolitos de peces que tienen anillos anuales alrededor de los bordes y longitudes de elementos anuales de los primeros cuatro grupos de edades.

Tabla 3: Claves de edad/longitud para *C. gunnari* de la plataforma de Georgia del Sur (julio a septiembre)

Lista de las figuras

Figura 1: Indice de crecimiento de *C. gunnari*. Datos obtenidos de mediciones exhaustivas realizadas en 1985, 1986 y 1987 (a).

Nivel de los contenidos estomacales para el mismo período (b)

--- 1985-1986
- - - 1987

Figura 2: Indice de crecimiento de *C. gunnari* durante el primer año de vida. Datos procedentes de varias fuentes.

Figura 3: Crecimiento de la clase del año 1983 usando información de distribución de frecuencia de longitud de las capturas.