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Fish biology

COMPARISON OF GROWTH RATES OF CAPE HAKE (*MERLUCCIUS CAPENSIS*)  
AND DEEP-WATER HAKE (*MERLUCCIUS PARADOXUS*) OFF NAMIBIA  
PORÓWNANIE TEMPA WZROSTU MORSZCZUKA PRZYŁĄDKOWEGO  
(*MERLUCCIUS CAPENSIS*) I MORSZCZUKA GŁĘBOKOWODNEGO  
(*MERLUCCIUS PARADOXUS*) Z ŁOWISK NAMIBII

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Growth rates of Cape hake (*Merluccius capensis*) and deep-water hake (*Merluccius paradoxus*) off Namibia are compared in terms of length and weight growth of both sexes of each species. The von Bertalanffy growth equation parameters are given; principles of otolith age reading and interpretation are discussed and illustrated with photographs.

#### INTRODUCTION

Two species of hake are encountered in the Namibian fishing grounds (South-West Africa): Cape hake (*Merluccius capensis*) and deep-water hake (*Merluccius paradoxus*), both species contributing substantially to fisheries in the area.

The two species differ in their thermal requirements; they, however, co-exist within a

rather extensive depth range. Long-term observations (Chłapowski, 1978) allowed to conclude on the domination of one species over the other at the depth contour of about 350 m. Above this depth Cape hake prevails, deep-water hake predominating below it. Owing to a frequent co-occurrence of the two species in hauls and their considerable external similarity, the fishes caught are not separated into species and in consequence are treated as one stock of a more or less uniform growth rate.

The Polish literature dealing with hake biology contains a single study discussing investigations of growth rates of the two hake species (Kolender, 1975), the investigations being, however, based on age back readings and disregarding the age-dependent weight growth.

The data presented here are assumed to extend the existing knowledge on the problem; it will be noted that a particular attention is paid to principles of age reading and interpretation, the issues being illustrated by photographs.

## MATERIALS AND METHODS

Materials to be used in the South-West African age and growth rate characteristics constitute a homogenous sample as they were collected exclusively during the first quarter of the year. The data were collected in the Namibian fishing ground /off Oranje and Cross, up to 27° S/ in 1972, 1974, and 1976. Cape and deep-water hakes yielded 3082 and 1291 otoliths, respectively.

The fishes were measured to the nearest cm. According to the ICSEAF Working Group's recommendations, 1 January was assumed to be the fishes' birth date, in spite of the fact that the day of 1 October could be taken as the actual birth date (Botha, 1971) due to the peak of hake spawning occurring over September – November.

Before reading, the otoliths were soaked in fresh water in order to improve their legibility, and then placed – against a black background – in a vessel filled with water. The readings were made in the incident light under a 4–6 x magnification binocular microscope. Hyaline rings were counted.

The length growth was characterised by the van Bertalanffy growth equation, while the growth of weight was described by the same equation as modified by Gulland (1969).

## PRINCIPLES OF AGE READING AND INTERPRETATION

A correct interpretation of growth zones visible on an otolith in order to determine fish age poses a basic problem when both growth rate and age distribution determinations are attempted. Among the others, actual hyaline rings corresponding to annual increments should be correctly distinguished and separated from other similar zones termed usually "additional rings"; the latter are sometimes mistaken for the annual zones.

In a number of cases, when interpreting growth zones visible on an otolith, some difficulties were encountered that may be summarised as follows:

1. Difficulties in identifying a hyaline ring corresponding to the end of the first year of life,
2. the presence of additional or double hyaline rings,
3. difficulties in an objective identification of the number of annual hyaline zones in older fishes.

These problems are usually solved more or less correctly depending on the examiner's expertise, their resolution being by and large affected by the latter's subjective judgment, which is the major cause of discrepancies encountered when the same otoliths are examined by different experts. In order to rule out these interpretational differences and in consequence to unify the age readings, some basic criteria should be adopted.

The criteria used to solve the above-mentioned problems and resulting from the author's long-term experience in the hake otolith analysis are presented below.

The issue is illustrated with photographs of otoliths of Cape hake caught off Oranje in the first quarter of 1976 (Fig. 1, Photos 1–22). The photographs show the otoliths taken from fishes of various age. Both the otoliths of a typical appearance, i.e., those with the hyaline rings proper only, taken into account when reading the age (in the figure caption they are termed "annual hyaline rings") and those with hyaline zones disregarded in age reading are presented. A concise description of the photographs is given in explanation of Fig. 1.

The examination of the otoliths of small hakes (body length of 12 cm and above) demonstrated a frequent presence of a poorly-visible hyaline ring close to the otolith centre (Photo 1). In some cases, instead of a homogenous zone a number of thin layers of a substance filling the opaque zone between the centre and the first winter ring were observed. The zone in question, frequently invisible in the 1-yr-old individuals, was considered to correspond to the pelagic phase in fish life and was disregarded when counting the annual rings.

Unfortunately, the author failed to collect individuals smaller than 12 cm; thus it is impossible to state the actual length at which the zone in question forms. Assuming the formation of a pelagic zone to be associated with a change in feeding habits caused by the fish switching over from a pelagic to demersal phase (Gambell and Messtorf, 1964; Nichy, 1969), it can be supposed that the zone begins at the age of 1.5–2.5 months since, as shown by previous observations, this is the time of a switch to the demersal mode of life. (O'Toole, 1977).

The presence of the zone discussed may result in its being mistaken for an annual hyaline ring, particularly when – owing to a late birth of a fish – the first winter ring is placed close to the otolith centre (Photo 2). In such cases, the author considered the width and conspicuousness of the rings assuming that the actual hyaline ring is usually more conspicuous than any other one.

Until the third – fourth year of hake life, additional hyaline rings are frequently observed; together with the actual winter ring they form a zone of a slow growth. In



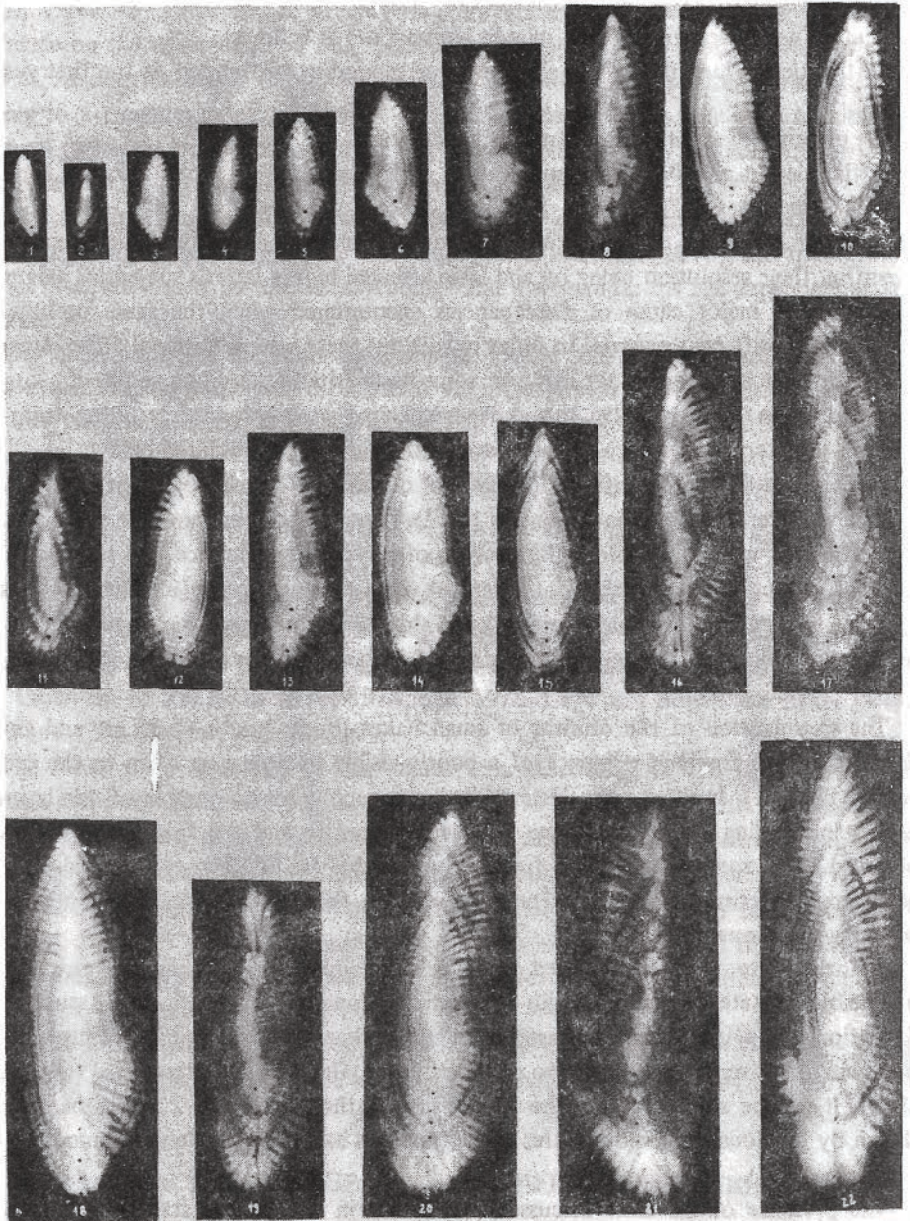


Fig. 1. Otoliths of Cape hake (*Merluccius capensis*) caught within January – March 1976 off Oranje (Area 1.5). (Explanation of photographs Fig. 1)

Description of otoliths of Cape hake caught off Oranje within January-March 1976.  
Explanation of Fig. 1.

Photo No.	Fish length (cm)	Years of life	Age group	Remarks
1	13	1	II	First hyaline ring pelagic, second annual
2	11	1	II	Annual hyaline ring close to centre
3	15	1	II	Hyaline ring on otolith margin
4	16	1	II	Hyaline ring far off from centre
5	19	2	III	Typical example of 2-yr-old fish otolith
6	24	2	III	Additional hyaline zone visible between annual hyaline rings
7	30	2	III	Poorly-visible outlines of additional ring between annual ones
8	38	3	IV	Typical example of 3-yr-old fish otolith
9	34	3	IV	First hyaline ring additional because opaque zone between it and next rings narrower than that between second and third hyaline rings
10	39	3	IV	Second annual hyaline ring double
11	32	3	IV	Third annual hyaline ring consisting of several hyaline zones
12	32	3	IV	First and second annual rings double
13	38	4	V	Typical example of 4-yr-old fish otolith
14	36	4	V	Two additional hyaline rings between first and second ones, and between second and third ones
15	41	5	V	First annual hyaline ring poorly visible
16	52	5	VI	Second annual ring double; third, although not equally clearly seen on its entire perimeter, regarded as annual because opaque ring between second and third visible hyaline rings, in caudal section, very wide
17	68	5	VI	Several additional zones between first and second annual hyaline rings; third annual ring double
18	71	6	VII	Additional ring visible between third and fourth annual ones
19	57	6	VII	First annual hyaline ring poorly visible; additional ring between second and third annual ones
20	74	8	IX	Additional ring between first and second annual ones
21	77	9	X	Terminal annual hyaline rings not equally well visible on their entire perimeters
22	91	10	XI	Several additional rings between second and fourth annual ones. Terminal annual rings poorly visible.

order to avoid counting all those zones, one should bear in mind that additional rings are usually less well outlined than the actual winter ones (e.g., Photo 6) and they frequently do not form rings entirely closed (Photo 18 – an additional ring between the third and fourth annual hyaline rings); sometimes they converge with the actual hyaline zones. Helpful may be also the fact that the opaque ring separating the ring proper and an additional one is much narrower here than between the next winter rings (e.g., Photos 9 and 11). In older individuals additional hyaline rings formed earlier become obliterated on the otolith picture.

A separate and difficult problem in age interpretation is posed by otoliths collected from older (aged 6–7 years) individuals. Owing to a thickened central part of an otolith, the first annual hyaline ring can be poorly visible (Photo 19). An additional difficulty is presented by heavily concentrated annual hyaline rings on the otolith margins in those fishes. In such cases it seems that the only practical solution is to determine annual increments by interpolation, considering the width of an opaque zone and outlines of a hyaline one.

Apart from the problems presented above, another question is a correct allocation of an individual to an age group. To assess the resources it is not enough to determine the fish age at capture; it is additionally necessary to place the individual into a correctly identified age class. The principles governing such allocation are discussed in detail by Wysokiński and Chłapowski (1978).

## RESULTS AND DISCUSSION

The comparison of lengths in each age group of the two hake species for the years 1972, 1974, and 1976 demonstrated the numerical values to be similar in each calendar year considered. Both this finding and the statement by Pšeničnyj and Assorov (1969) that life processes of the South-West African hakes, repeated from year to year, only slightly deviated from multi-annual means, made it justifiable to regard the length values obtained as the multi-annual means.

The means for Cape hake and deep-water hake are presented in Tables 1 and 2, respectively. The data contained therein served to determine growth characteristics of the two species by means of the von Bertalanffy equation. The values of each equation parameter are given in Table 3. Based on the calculated values, theoretical lengths corresponding to each age group were determined, presented in Table 4 and illustrated in Figs. 2–4.

When analysing Table 4 it should be borne in mind that – according to the actual birth date of the fishes (1 October), their theoretical birth date (1 January), and the time of capture (January – March) – the actual age was, e.g., 15–17 months for the age group II, 23–29 months for the group III, etc. Those fishes caught in the first quarter of the year were, according to Botha (1971), just beginning their phase of the maximum growth.



**Table 1**

Mean lengths of Cape hake (*Merluccius capensis*) in age groups ds)

First quarter of 1972, 1974, 1976 (Namibian fishing grounds)

Sex	Age group										No. of fishes
	II	III	IV	V	VI	VII	VIII	IX	X	XI	
Males	15.30	27.82	34.6	42.70	51.57	57.66	65.00	71.91	79.00	80.50	1326
Females	15.50	28.31	34.97	43.70	52.54	59.74	65.80	74.17	80.26	82.92	1756
Males and females	15.43	28.02	34.57	43.30	52.12	58.89	65.47	73.23	79.96	82.61	3082

growth *Merluccius capensis* and *M. paradoxus*

Table 2

Mean lengths of deep-water hake (*Merluccius paradoxus*)  
in age groups a First quarter of 1972, 1974, 1976 (Namibian fishing grounds)

Sex	Age group							No. of fishes
	II	III	IV	V	VI	VII	VIII	
Males	22.33	27.7	34.54	40.82	44.38			327
Females	23.94	28.09	35.39	41.76	49.27	55.18	56.25	964
Males and females	23.52	27.99	35.14	41.51	48.4	55.18	56.25	1291

Table 3

Von Bertalanffy growth equation parameters for Cape hake and deep-water hake

Species	Sex	$L_{\infty}$	k	$t_0$
Cape hake	♂♂	120.22	0.108	0.705
	♀♀	126.27	0.104	0.728
	♂♀	129.07	0.099	0.707
Deep-water hake	♂♂	86.06	0.106	-0.839
	♀♀	100.28	0.092	-1.022
	♂♀	103.14	0.088	-0.974

It will be seen from the mean lengths and annual increments presented in Table 4 that the growth of length proceeded in a rather different way in the two hake species. In Cape hake, lower mean lengths are observed in the initial period of life compared to the corresponding lengths in deep-water hake. The growth rates, however, alter with age, the mean lengths in older age groups becoming higher in deep-water hake than in Cape hake. In both species annual increments tend to decrease with age; they, however, remain fairly high.

In Cape hake small differences between males and females in terms of the mean lengths in age groups were found. On the other hand, the differences are significant in deep-water hake. Similar statements of a small difference between Cape hake males' and females' lengths are put forward by Ritzhaupt (1969), Kolender (1975), and Preński (1978). It was only Botha (1971) who showed marked differences in this respect.

Noteworthy is a lower number of age groups in deep-water hake males than in females of the species. A similar conclusion was drawn by Botha (1971), which could be taken as an evidence of the males of the species having a shorter life span than the females.



Table 4

Theoretical lengths in age groups of Cape hake and deep-water hake (Namibian fishing grounds)

Age group	Cape hake						Deep-water hake					
	Males		Females		Males+females		Males		Females		Males+females	
	Length	Increment	Length	Increment	Length	Increment	Length	Increment	Length	Increment	Length	Increment
II	15.68		15.66		15.55		22.41		24.32		23.83	
		10.69		10.94		10.73		6.41		6.66		6.71
III	26.37		26.60		26.28		28.82		30.98		30.54	
		9.6		9.87		9.72		5.77		6.08		6.14
IV	35.97		36.47		36.0		34.59		37.06		36.68	
		8.62		8.88		8.8		5.18		5.55		5.62
V	44.59		45.35		44.8		39.77		42.61		42.3	
		7.73		8.01		7.96		4.67		5.07		5.14
VI	52.32		53.36		52.76		44.44		47.68		47.44	
		6.95		7.21		7.22				4.62		4.71
VII	59.27		60.57		59.98				52.3		52.15	
		6.23		6.5		6.53				4.21		4.31
VIII	65.5		67.07		66.51				56.51		56.46	
		5.6		5.86		5.91						
IX	71.10		72.93		72.42							
		5.02		5.28		5.36						
X	76.12		78.21		77.78							
		4.51		4.75		4.85						
XI	80.63		82.96		82.63							

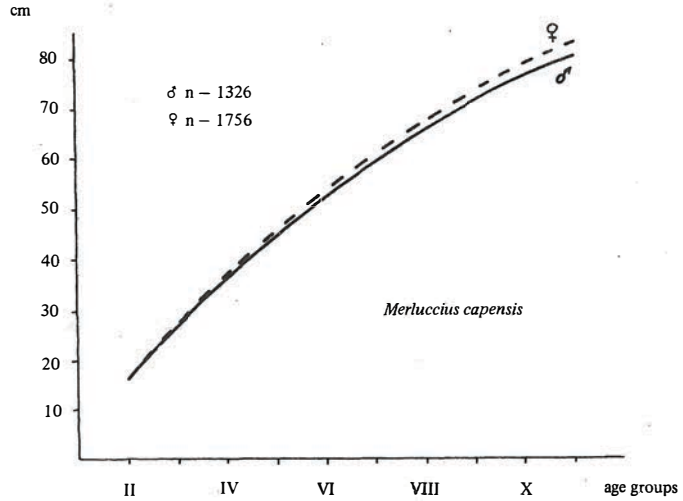


Fig. 2. Theoretical length growth curves for Cape hake (*Merluccius capensis*)

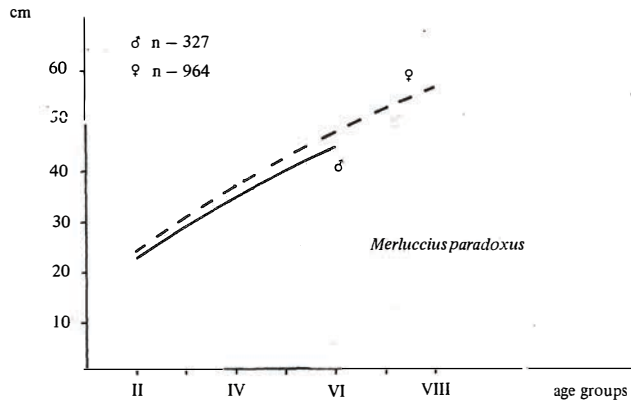


Fig. 3. Theoretical length growth curves for deep - water hake (*Merluccius paradoxus*)

A number of authors determined age of the two species. Data on the von Bertalanffy equation parameters are therefore summarised in Table 5 for comparative purposes.

It will be seen from the Table that marked differences exist between the parameters values as determined by various authors for a given hake species. The asymptotic lengths ranged within 100.2–179.8 cm and 103.1–172 cm for Cape hake and deep-water hake, respectively.

Considerable discrepancies between the results reported by various authors seem to have resulted from differences in age interpretation from otoliths.

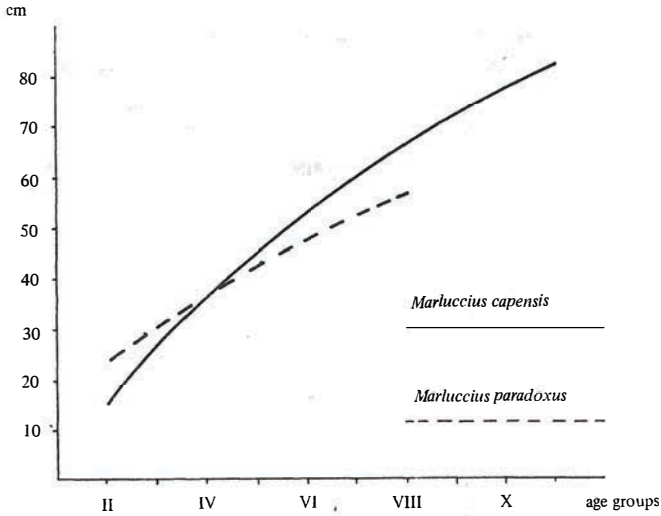


Fig. 4. Comparison between theoretical length growth curves of Cape hake (*Merluccius capensis*) and deep-water hake (*M. paradoxus*)

Table 5

Growth parameters of Cape hake and deep-water hake (after various authors)

Author	Area*	Growth parameters		
		$L_{\infty}$	k	$t_0$
Cape hake				
Botha (1971)	1.5–1.6	141.3	0.091	0.473
Mombeck (1971)	1.4–1.5	179.8	-0.059	-0.677
Kolender (1975)	1.4–1.6	174.8	0.063	0.365
Mac Pherson (1975)	1.4	100.2	0.139	-1.05
Pozo (1976)	1.3–1.4	111.1	0.12	-0.24
Preński (1978)	1.4–1.5	125.2	0.106	0.211
Author's own data	1.4–1.5	129.07	0.099	0.707
Deep-water hake				
Botha (1971)	1.5–1.6	107.1	0.137	0.53
Mombeck (1971)	1.4–1.5	172.0	-0.065	-0.59
Kolender (1975)	1.5–1.6	130.3	0.077	-0.601
Author's own data	1.5	103.1	0.088	-0.974

\* Cunene 1.3 (15°S–20°S)  
 Cross 1.4 (20°S–25°S)  
 Oranje 1.5 (25°S–30°S)  
 Cape of Good Hope 1.6 (30°S–40°S)

Table 6

Weight of Cape hake and deep-water hake in age groups  
as calculated with modified von Bertalanffy equation

Age group	Weight (g)	
	Cape hake	Deep-water hake
II	24	97
III	118	208
IV	304	364
V	587	564
VI	964	803
VII	1419	1073
VIII	1938	1369
IX	2507	
X	3110	
XI	3733	

In order to present the weight growth in each age group, the "n" coefficient of the length-weight relationship was determined first. The mean coefficient values, obtained from materials covering the years 1972–1976 in the Cross-Oranje area, amounted to 3.016 (at  $k = 0.0061$ ) and 3.065 (at  $k = 0.0059$ ) for Cape hake and deep-water hake (off Oranje), respectively.

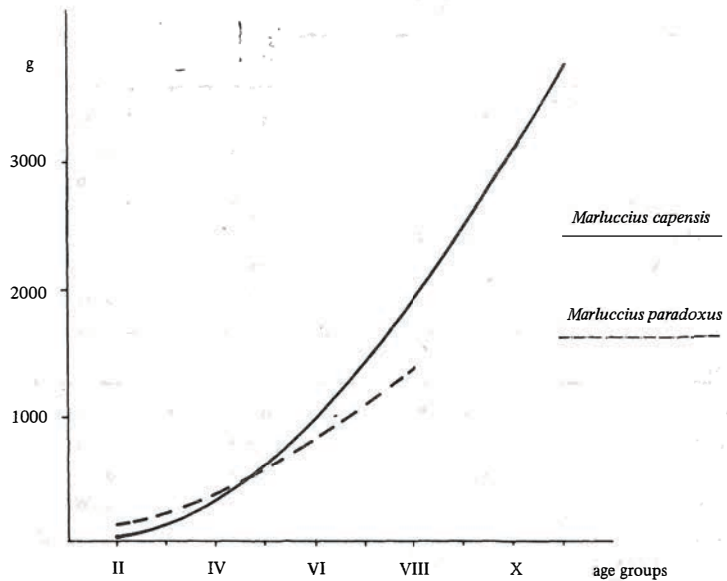


Fig. 5. Comparison between theoretical weight growth curves of Cape hake (*Merluccius capensis*) and deep-water hake (*M. paradoxus*)



The theoretical weights in each age group of the two species (males and females together) are presented in Table 6 and illustrated in Fig. 5. The  $W_{\infty}$  weights corresponding to the asymptotic lengths of Cape hake and deep-water hake were found to amount to 14409 g and 8750 g, respectively.

## CONCLUSIONS

1. Length growth parameters (females and males pooled together) are as follows:  
Cape hake  
 $L_{\infty} = 129.07$  cm;  $K = 0.099$ ;  $t_0 = 0.707$   
deep-water hake  
 $L_{\infty} = 103.14$  cm;  $k = 0.088$ ;  $t_0 = -0.974$
2. Relatively small differences in mean length between males and females, at the same age group, were found in the two species, the differences being more pronounced in deep-water hake.
3. Cape hake shows lower mean lengths in the initial period of life compared to the corresponding lengths of deep-water hake, the means becoming higher with age in Cape hake.
4. The  $W_{\infty}$  weights corresponding to the asymptotic lengths amount to 14409 g and 8750 g in Cape hake and deep-water hake, respectively.
5. Due to the differences found between the two species in terms of their growth rates and length-weight relationships, the species should be treated separately at any attempt to calculate hake biomass rather than be pooled together, still the usual procedure.

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PORÓWNANIE TEMPA WZROSTU MORSZCZUKA PRZYŁĄDKOWEGO  
(*MERLUCCIUS CAPENSIS*)  
I MORSZCZUKA GŁĘBOKOWODNEGO (*MERLUCCIUS PARADOXUS*)  
Z ŁOWISK NAMIBII

Streszczenie

Omówiono, w oparciu o dokumentację zdjęciową, sposób interpretacji wyglądu otolitów morszczuków. Na podstawie materiałów zbieranych w latach 1972, 1974, 1976 w rejonie Namibii, obliczono parametry wzrostu morszczuka przyławkowego (*Merluccius capensis*) i morszczuka głębokowodnego (*Merluccius paradoxus*). Parametry te przedstawiają się następująco:

morszczuk przyławkowy

$$L_{\infty} = 129,07 \text{ cm} \quad k = 0,099 \quad t_0 = 0,707$$

morszczuk głębokowodny

$$L_{\infty} = 103,14 \text{ cm} \quad k = 0,088 \quad t_0 = -0,974$$

Wykazano dość odmienny wzrost długości u obu gatunków. W miarę upływu lat średnie długości grup wiekowych są wyższe u morszczuka przyławkowego niż u morszczuka głębokowodnego. Z uwagi na stwierdzone wyżej różnice należałoby przy wszelkich wyliczeniach biomasy morszczuków oba te gatunki traktować osobno, a nie razem jak to się stosuje do tej pory.

К. Хлаповски

СРАВНЕНИЕ ТЕМПА РОСТА КАПСКОЙ МЕРЛУЗЫ (*MERLUCCIVS CAPENSIS*)  
И НАМИБИЙСКОЙ МЕРЛУЗЫ (*MERLUCCIVS PARADOXUS*) ИЗ ПРОМЫСЛОВОГО  
РАЙОНА НАМИБИИ

Р е з ю м е

В работе представлен способ интерпретации формы отолитов мерлузы на основе фотографической документации. В результате анализа материалов собранных в 1972, 1974, 1976 гг. в районе Намибии определили параметры роста капской мерлузы (*Merluccius capensis*) и намибийской мерлузы (*Merluccius paradoxus*). Параметры эти имеют следующий вид:

- капская мерлуза

$$L_{\infty} = 129,07 \text{ см} \quad k = 0,099 \quad t_0 = 0,707$$

- намибийская мерлуза

$$L_{\infty} = 103,14 \text{ см} \quad k = 0,088 \quad t_0 = - 0,974$$

Показан довольно отличающийся характер роста длины этих видов. С течением лет средние длины возрастных групп выше у капской мерлузы чем у намибийской мерлузы. Принимая во внимание приведенные выше различия необходимо при подсчетах биомассы мерлузы оба эти вида рассматривать раздельно а не вместе, как это делали до сих пор.

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