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GROWTH RATE OF ICELAND AND NORTH SEA BLUE WHITING, *MICROMESISTIUS POUTASSOU* (RISSO, 1810), BACK-CALCULATED FROM OTOLITHS

ODCZYTY WSTECZNE SZYBKOŚCI WZROSTU BŁĘKITKA *MICROMESISTIUS POUTASSOU* (RISSO, 1810) Z REJONU ISLANDII I MORZA PÓŁNOCNEGO PRZY POMOCY OTOLITÓW

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The paper presents blue whiting growth rate back-calculated from otolith broken surface radius. The calculations were corrected using the Rosa Lee method.

INTRODUCTION

Growth rate of blue whiting in various areas of the species distribution was studied by, i.a., Saemundson (1929, after Polonskij, 1969), Matt (1959), Bas and Morales (1966), and Cendrero (1967) – the last three citations after Robles Pariente (1970), Zilanov (1968), Raitt (1968 a, b), Polonskij (1968, 1969), Robles Pariente (1970), Bailey (1970), Kompowski and Sosiński (1976), and Gordon (1977).

Robles Pariente (1970) showed the nearly- rectilinear correlation to exist between the otolith growth and growth of 16.5 – 40 cm long blue whiting. Polonskij (1969) applied the Porcupine Bank blue whiting otoliths to growth rate back-calculations. That author, however, did not study correlation between the fish and otolith lengths.

The present paper aims at using the otolith-based back calculations for studies on growth rate of blue whiting caught in the northern North Sea ad SW of Iceland.

MATERIAL AND METHODS

The individuals to be examined were selected at random from the Polish commercial catches. Fish length and weight were measured to the nearest 1 cm and 1 g, respectively, the individual's sex being determined as well. The growth rate studies involved the use of otoliths. Growth zones are only exceptionally visible on the concave (external) side of those forms without any additional treatment. The author, therefore, employed a technique commonly in use in gadids' age and growth rate studies, the technique involving otolith burning followed by breaking whereby observations and measurements of the broken surface are rendered possible after a vertical positioning of the otolith in question (Christensen, 1964; Gambell and Messtorff, 1963; Trout, 1954; Messtorff, 1964; Blacker, 1964, 1974; Raitt, 1968 b, and others). The author does not share Polonskij's (1969) reservations as to the use of this technique. The lighting having been appropriately adjusted, growth zones on the otolith broken surface are sufficiently well visible. Moreover, the otolith centre (nucleus) can be localised with no difficulty whatsoever on the broken surface at the apex of a V-shaped structure. The structure has its base on the sulcus acusticus on the internal (convex) surface of the otolith (Fig. 1).

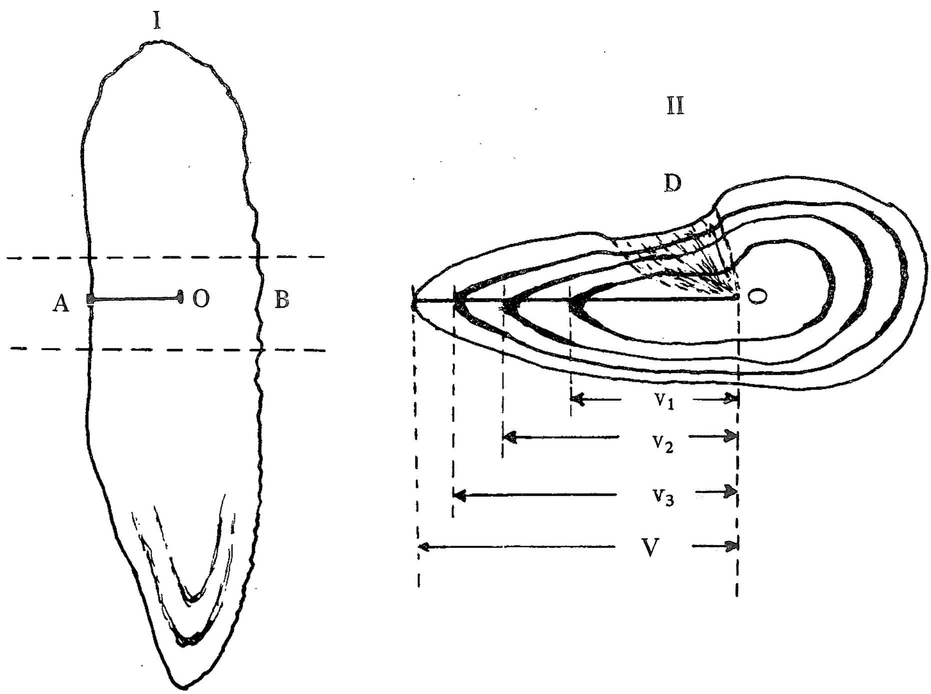

Fig. 1. I External (concave) side of an otolith, breaking marked with a dashed line: II Breaking zone of of an otolith, measuring line marked (AO); D – a V-shaped form, its apex at the otolith centre

The otoliths were measured along the radius as used also by Polonskij (1969), the only difference being his measurements being taken from the intact otoliths (Fig. 1 I, part AO) rather than from the broken surface. The latter as well as a layout of the measurements are presented in Fig. 1, while the complete material examined is summarised in Table 1*.

Table 1

Presentation of the material examined

Area, geographic position, and date of catch	Type of gear	Fish length range (l.t.) cm	No of otoliths		
			Seen	measured	
				for correlation	for back calculations
Iceland 63° 10′ N: 22°00′ W June 11 and 12, 1976	herring bottom trawl	19 -50	299	227	226
North Sea 61° 30′N; 01° 55′ E April 1, 1971	herring trawl	16–43	199	176	134
59° 17′ N; 03° 17′ E March 26, 1973	herring trawl	15–20	100	56	–
59° 20′ N; 02° 14′ E March 28, 1973	herring trawl	23–38	100	80	80
Total	–	–	698	539	440

REMARKS

Bailey (1970) concluded, basing on juvenile blue whiting caught off Scotland, that age determinations made hitherto were erroneous. In his opinion, the 17–22 cm long fishes were more likely to belong to the age group 2 rather than to the 1, the next age groups having been a year older than it had been previously thought.

The present author had no access to otoliths of fishes under 15 cm; he was unable then to follow the process of the first growth zones formation in otoliths. In view of the fact, however, that the most recent studies by Gordon (1977) tend to confirm the earlier opinions on the blue whiting growth rate, the author decided to base his considerations on that tradition.

* The author wishes to express his thanks to Dr. Józef Sosiński of the Sea Fisheries Institute, Gdynia, for making his materials available.

OTOLITH RADIUS LENGTH – FISH TOTAL LÈNGTH RELATIONSHIP

The fundamental question arising when applying back calculations to fish growth rate studies is the determination of a nature of a possible correlation between the organ used in calculations and fish growth.

The results of otolith measurements, presented in Fig. 2, indicate a nearly rectilinear relationship to exist between an otolith radius length and 15–50 cm long blue whiting. The figure also shows clearly that there are no significant differences between the nature of the relationship discussed in the Iceland and northern North Sea fishes. It is still more conspicuous in Fig. 3 presenting mean otolith radii in length classes. Therefore the otolith measurements can be treated jointly for the two regions. Basing on the above-mentioned mean values, a regression equation describing the relationship under consideration was calculated by the least squares method to obtain the following form:

$$V = 0.06959 \text{ l.t.} + 0.18347 \tag{1}$$

where:

V = otolith radius length (mm)
l.t. = fish total length (cm)

The correlation coefficient approaching unity ($r = 0.993$) indicates a fairly close relationship to exist between the two discussed characteristics of blue whiting. However, the regression line passes the y-axis at 0.183 mm from the origin. This shift resulted presumably from an allometric growth of fish and otoliths presented in fishes below the length range studied. Robles Pariente (1970) observed also a rectilinear correlation between growths of blue whiting caught NW of Spain and their otoliths. He measured length and width of otoliths taken from 16–40 cm long fishes. His regression lines run at a considerable distance from the origin. Additionally, the author discussed refers to Bas and Morales (1966) (after Robles Pariente) who found an allometry in growth of total length and otolith length in the western Mediterranean blue whiting. Earlier studies (Kompowski and Sosiński, 1976) showed the blue whiting in their first year of life to be longer than 15–16 cm; starting at this length, the otolith radius-fish length relationship is certainly close to a rectilinear one. Therefore, the Rosa Lee's (1920) correction method should be applied to the back calculations.

When $V = 0$, the equation (1) will be: $0.06959 \text{ l.t.} + 0.183466 = 0$
hence $\text{l.t.} = -2.636$ cm.
The latter value is the correction factor sought.

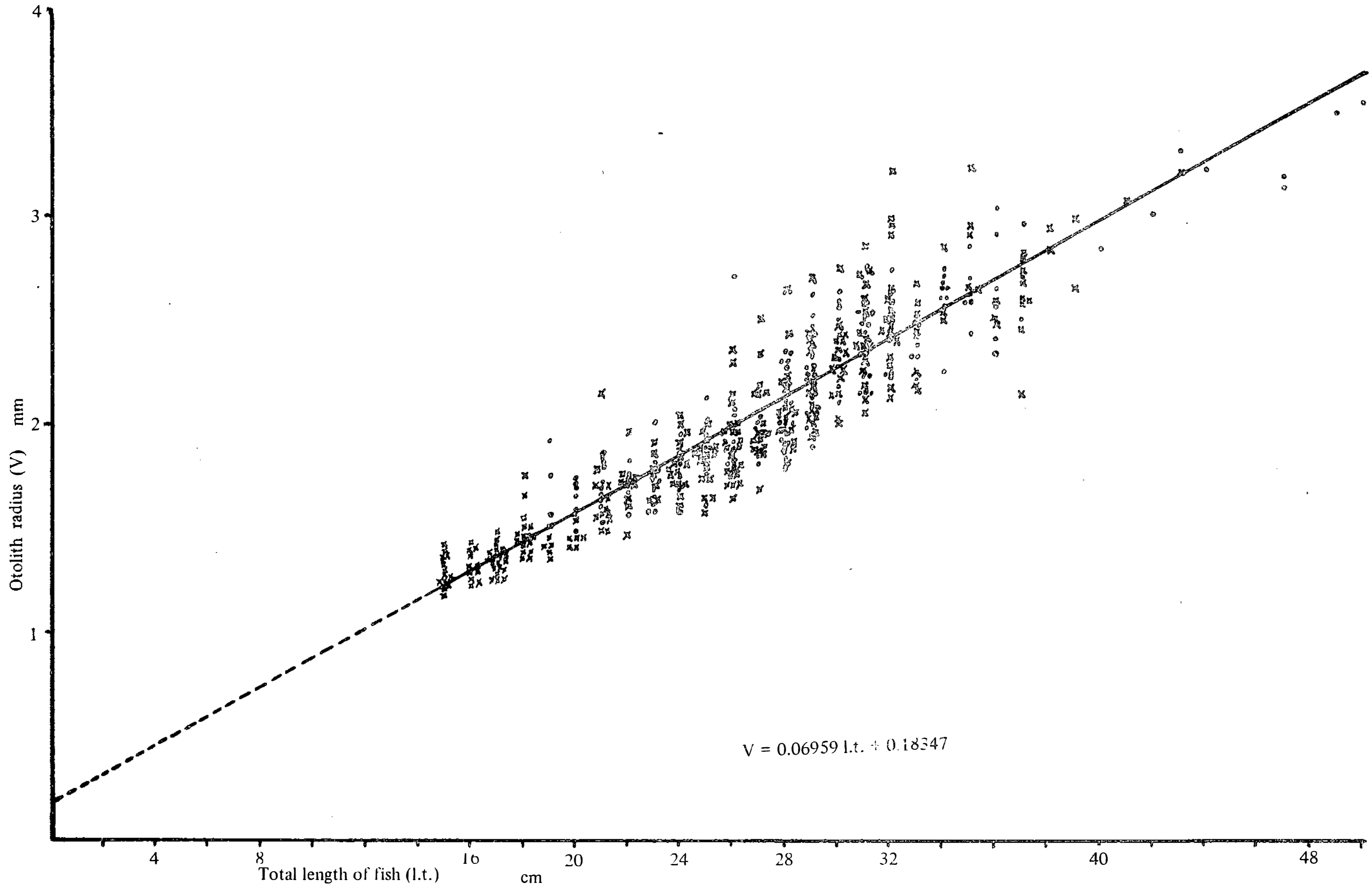

Fig. 2. Total length-otolith radius relationship in Iceland (.) and North Sea (x) blue whiting

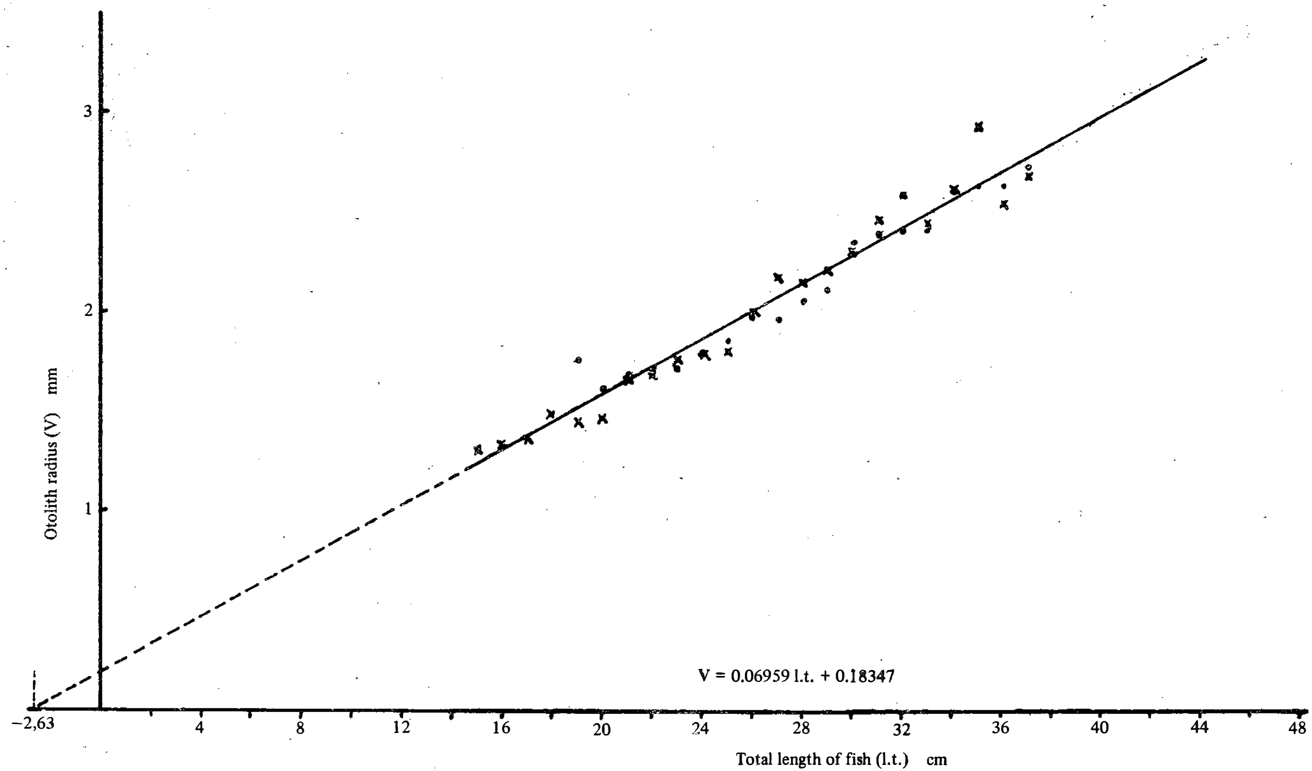

Fig. 3. Total length-otolith radius relationship in Iceland (.) and North Sea (x) blue whiting. Mean otolith radius lengths in length classes

BLUE WHITING GROWTH RATE

Tables 2 and 3 contain the results of corrected back calculations. Edges of otoliths of the North Sea blue whiting caught in March and April were to a great extent made of a hyaline substance, only some of them additionally showing small increments of the opaque zone. On account of that, in order to avoid inaccuracies, the terminal year's increment was always omitted when back-calculating lengths of fishes of the area under consideration.

When the "1_n" values calculated from otoliths of blue whiting of varying age are compared it is seen that the values alter, to some extent, with age of fish. Since the calculations are in a corrected form, the gear selectivity affecting first the faster-growing individuals must be held responsible for the phenomenon.

Table 4 presents growth rates of blue whiting of the discussed or adjacent areas of the Atlantic. Values obtained by direct measurements are usually higher than the back-calculated ones, particularly so in the first few years of life. It results mainly from the higher back-calculated values of fish length read when the hyaline zone has just stopped growing, that is in late March – early April. On the other hand, some direct measurements are made on fishes caught in May and June. Moreover, back calculations nullify to a large degree an effect of trawl selectivity on estimated growth rate. It is also worth mentioning that – owing to a large difference between males and females growth rates (see below) – a sex ratio of a sample considerably influences the final result.

Table 4 shows also that the Iceland blue whiting grow faster than do the individuals of the species in the North Sea.

Basing on data obtained from back calculations, blue whiting growth rates in the two regions considered are presented in a von Bertalanffy growth equation. The equation parameters and theoretical fish lengths calculated for subsequent age classes are presented in Tables 2 and 3 and in Figs. 4 and 5.

An attempt has also been made to express the blue whiting weight growth rate in a von Bertalanffy equation. The fish weight-length relationship is generally expressed as

$$W = a.\, l^n \tag{2}$$

where:

W = fish weight,
l = fish length,
n = power exponent approaching 3,
a = proportionality coefficient.

The relationship can also be expressed as

$$W_t = a.l_t^n \tag{3}$$

where:

W_t = fish weight at the age of t years,
l_t = fish length at the age of t years.

Table 2

Iceland blue whiting growth rate. Back calculations from otoliths
(l.t. in cm)

Age	n	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}
1	54	19.66	–	–	–	–	–	–	–	–	–	–	–
2	51	20.34	25.06	–	–	–	–	–	–	–	–	–	–
3	29	18.65	23.82	27.55	–	–	–	–	–	–	–	–	–
4	22	18.95	23.83	27.49	30.23	–	–	–	–	–	–	–	–
5	27	18.17	22.54	26.23	29.02	31.17	–	–	–	–	–	–	–
6	7	18.37	22.50	25.91	28.40	30.44	32.14	–	–	–	–	–	–
7	10	16.90	21.05	24.50	27.27	29.30	30.88	32.37	–	–	–	–	–
8	9	16.19	21.30	23.88	26.50	28.18	29.62	30.86	31.99	–	–	–	–
9	4	15.50	19.73	22.38	24.73	26.53	28.30	29.53	30.75	31.98	–	–	–
10	2	14.55	19.85	23.85	25.60	27.55	28.80	30.00	30.75	31.60	32.40	–	–
11	1	16.30	23.40	25.90	29.90	31.60	33.10	34.90	36.30	38.10	40.40	41.60	–
12+	7	16.14	21.57	24.83	27.29	29.41	31.63	33.24	34.66	36.10	37.29	38.50	39.63
n	223	223	169	118	89	67	40	33	23	14	10	8	7
Total	$\bar{x}$	18.88	23.40	26.18	28.42	29.85	30.64	31.73	32.67	34.42	36.62	38.89	39.63
	$\pm\sigma$	2.3074	2.4382	2.6794	3.2102	3.3809	3.4494	3.9976	4.6269	5.7640	6.1467	6.7111	7.4106
Theoretical length and growth after von Bertalanffy equation													
Length (cm)		18.64	21.95	24.84	27.36	29.56	31.47	33.14	34.59	35.86	36.97	37.93	38.77
Weight (g)		41.06	65.49	93.26	122.91	153.31	183.34	212.53	240.19	266.26	290.49	312.57	332.76

$W_\infty = 492.217$ g; $L_\infty = 44.463$ cm; K = 0.1374; $t_0 = -2.9538$ roku

Table 3

Northern North Sea blue whiting growth rate. Back calculations from otoliths
(l.t. in cm)

Age	n	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}
2	44	18.77	–	–	–	–	–	–	–	–	–	–
3	66	18.78	23.64	–	–	–	–	–	–	–	–	–
4	18	16.18	22.07	25.96	–	–	–	–	–	–	–	–
5	14	16.01	20.75	24.46	27.29	–	–	–	–	–	–	–
6	11	17.39	21.85	25.16	27.85	29.91	–	–	–	–	–	–
7	10	16.63	20.39	23.47	26.37	28.64	30.52	–	–	–	–	–
8	9	14.90	19.50	22.99	25.34	29.97	28.60	30.29	–	–	–	–
9	11	14.37	18.29	21.50	24.00	25.99	27.47	28.80	30.35	–	–	–
10	9	15.68	19.98	22.49	24.70	26.67	28.16	29.71	30.94	32.09	–	–
11	7	15.01	19.44	22.76	24.76	26.90	28.53	30.26	31.60	33.98	35.37	–
12+	15	13.87	18.39	21.63	24.26	26.03	27.39	28.55	29.74	30.83	32.31	33.30
n	214	214	170	104	86	72	61	51	42	30	19	13
Total	$\bar{x}$	17.22	21.53	23.56	25.62	27.26	28.34	29.35	30.47	31.84	33.27	33.30
	$\pm\sigma$	2.6864	2.7983	2.6144	2.7349	2.8613	2.8382	2.6341	2.8708	3.1836	3.4918	3.7523
Theoretical length and growth after von Bertalanffy equation												
Length (cm)		15.94	19.94	23.09	25.58	27.55	29.10	30.18	31.30	32.06	32.66	33.14
Weight (g)		13.07	28.87	48.51	69.68	90.59	109.95	125.07	142.28	154.88	165.38	174.14

W_∞ = 209,778 g; L_∞ = 34.931 cm; K = 0.2362; t_0 = –1.5808 roku

Table 4

Blue whiting growth rate as estimated by various methods

Area	Season	Reference	Method	Mean total length in age groups (abundance in brackets)											
				l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}
SW of Iceland	May 1927	Saemundson, (after Polonskij, 1969)	direct measurements	18.0 (1)	24.0 (1)	25.59 (27)	29.5 (2)	–	–		–	–	–	–	–
SW of Iceland	May 1962	Raitt, 1968 b	direct measurements	20.56 (9)	23.8 (6)	25.7 (10)	27.0 (18)	28.91 (28)	28.68 (31)	30.8 (9)	33.0 (2)	–	–	–	–
SW of Iceland	June 1971	Kompowski and Sosiński, 1976	direct measurements	22.0 (84)	26.3 (67)	28.77 (41)	30.88 (28)	31.39 (30)	31.3 (12)	32.46 (11)	32.59 (11)	–	–	–	–
SW of Iceland	June 1971	Kompowski (present paper)	back calculations	18.88 (223)	23.40 (169)	26.18 (118)	28.42 (89)	29.85 (67)	30.64 (40)	31.73 (33)	32.67 (23)	34.42 (14)	36.62 (10)	38.89 (8)	39.63 (7)
Faeroes	May-June 1965	Raitt, 1968 a	direct measurements	19.5	23.2	25.4	26.2	28.2	28.6	29.8	30.5	31.8	34.2	–	–
NW North Sea	April 1971	Kompowski and Sosiński, 1976	direct measurements	18.68 (43)	24.42 (29)	27.73 (20)	29.33 (24)	29.39 (10)	31.30 (8)	32.39 (14)	33.32 (13)	31.58 (14)	33.36 (11)	33.0 (7)	35.75 (6)
NW North Sea	April 1971 March 1973	Kompowski (present paper)	back calculations	17.22 (214)	21.53 (170)	23.56 (104)	25.62 (86)	27.26 (72)	28.34 (61)	29.35 (51)	30.47 (42)	31.84 (30)	33.27 (19)	33.3 (13)	–

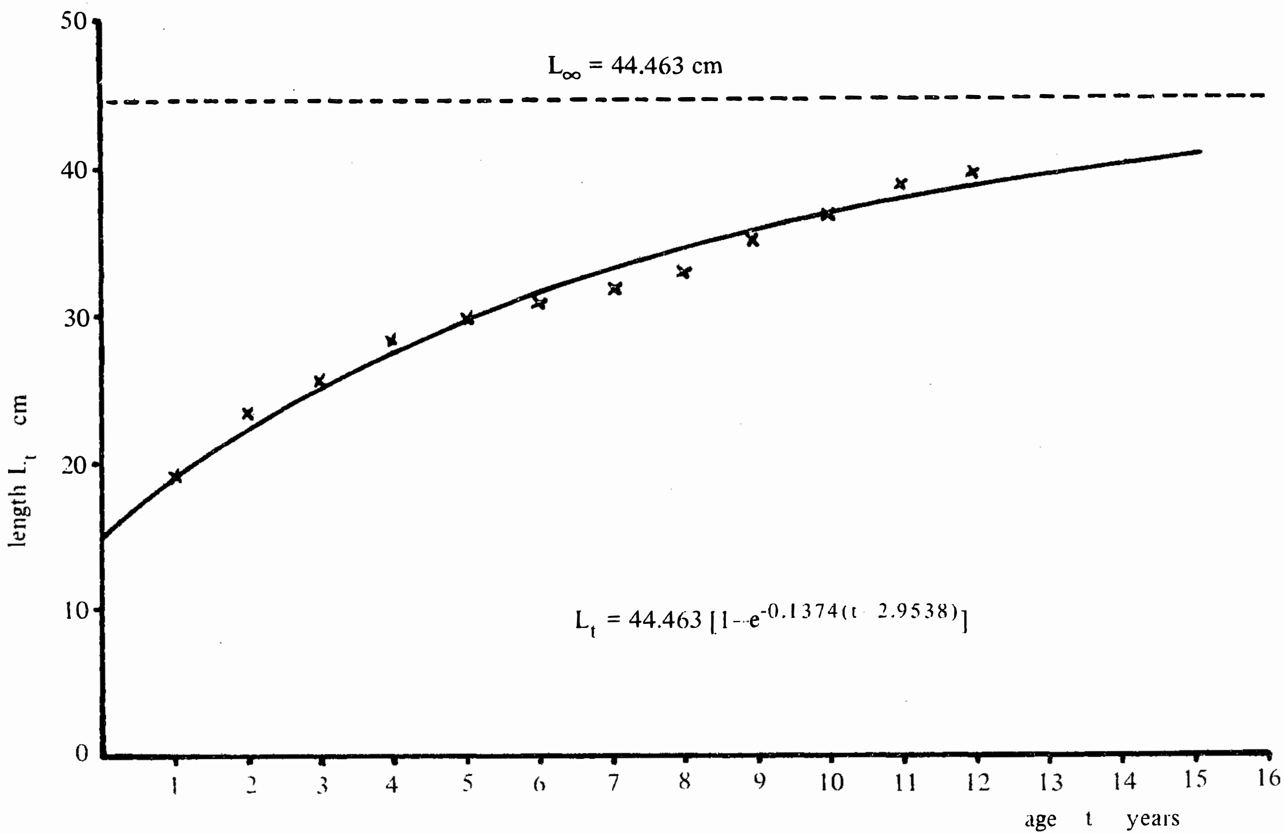

Fig. 4. Length growth rate of Iceland blue whiting. Solid line indicates theoretical growth rate after von Bertalanffy equation; back calculations marked with crosses (x)

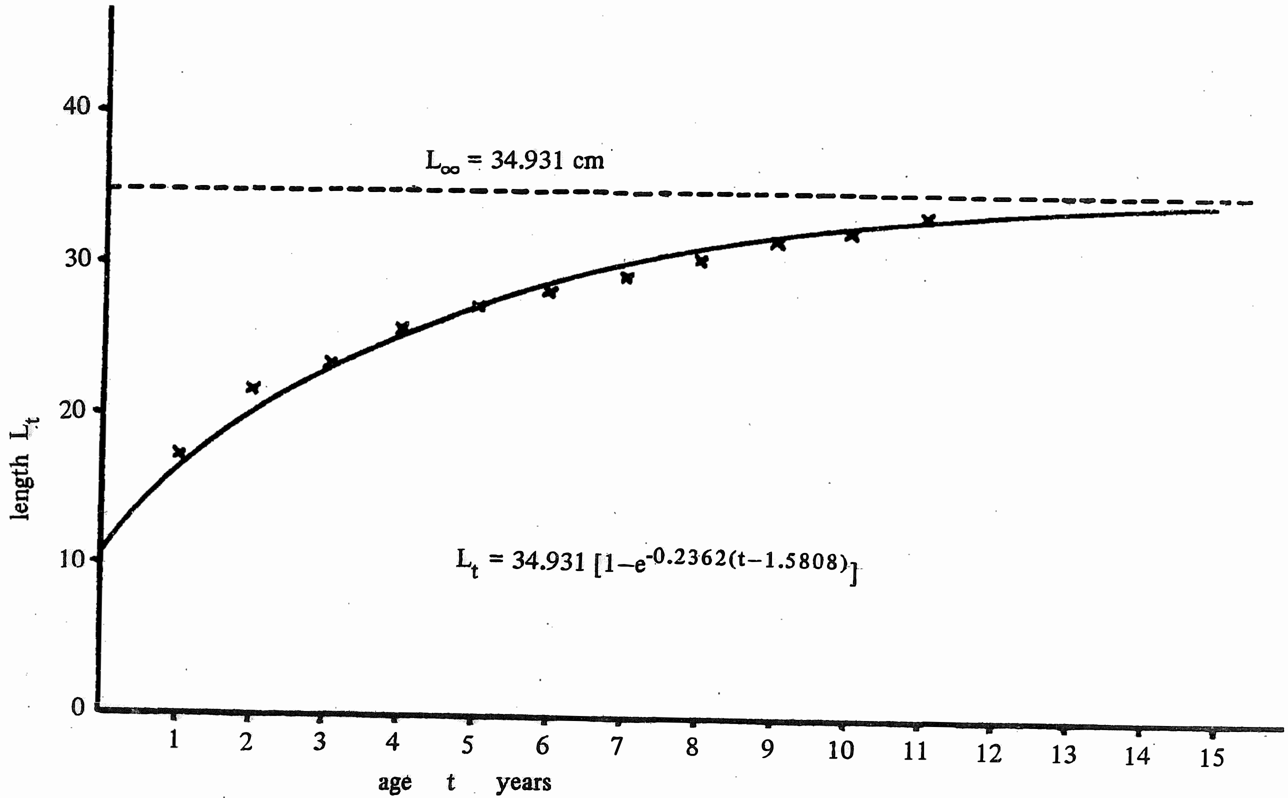

Fig. 5. Length growth rate of northern North Sea blue whiting. Legend as in Fig. 4.

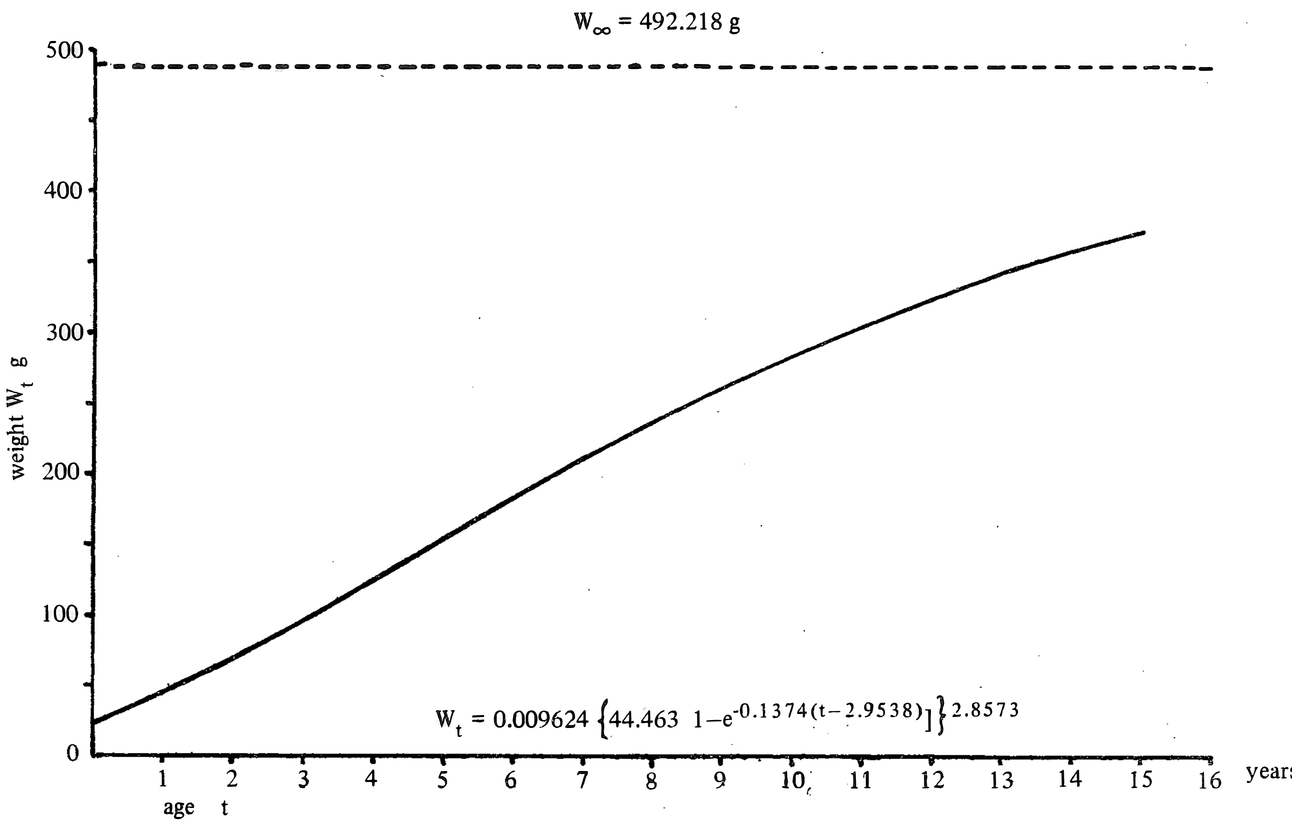

Fig. 6. Weight growth rate of Iceland bluex whiting

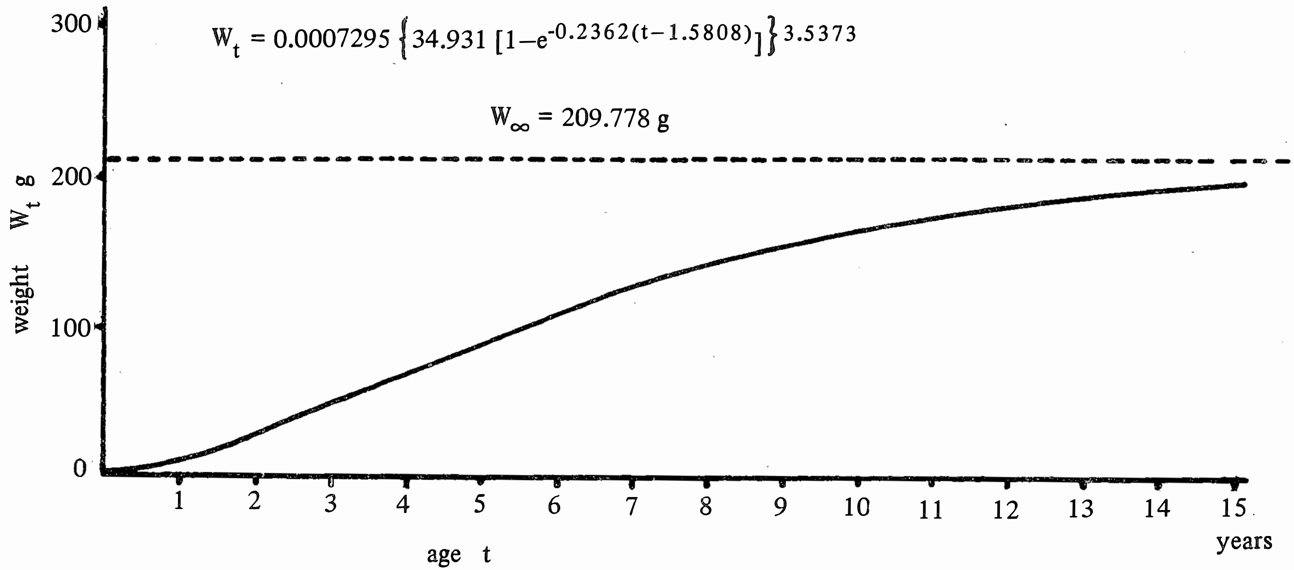

Fig. 7. Weight growth rate of northern North Sea blue whiting

Table 5

Growth rates of blue whiting males and females (l.t. in cm)

Age	length	Iceland		North Sea	
		♂	♀	♂	♀
1	$\bar{x}$ dł.	18.37	19.18	16.84	17.58
	$\pm\sigma$	2.3548	2.1715	2.6301	2.7161
	n	92	134	105	109
2	$\bar{x}$ dł.	22.51	23.85	20.84	22.17
	$\pm\sigma$	2.8187	2.0669	2.4867	2.8733
	n	62	109	79	93
3	$\bar{x}$ dł.	24.44	26.93	22.86	24.29
	$\pm\sigma$	3.1904	2.0075	2.2977	2.4167
	n	38	82	48	76
4	$\bar{x}$ dł.	26.33	29.48	24.90	26.38
	$\pm\sigma$	3.4367	2.3463	2.3916	2.8460
	n	32	59	40	49
5	$\bar{x}$ dł.	27.26	31.23	26.67	28.12
	$\pm\sigma$	3.1074	2.4948	2.5626	3.0573
	n	25	44	32	41
6	$\bar{x}$ dł.	27.68	32.50	26.96	29.30
	$\pm\sigma$	2.3688	2.7511	1.7226	2.9736
	n	16	25	26	37
7	$\bar{x}$ dł.	28.24	34.00	27.92	30.20
	$\pm\sigma$	2.3952	3.0779	1.8105	2.6507
	n	13	20	19	32
8	$\bar{x}$ dł.	28.81	35.63	28.84	31.30
	$\pm\sigma$	2.2867	3.6955	2.0764	2.7883
	n	10	13	16	28
9	$\bar{x}$ dł.	29.02	38.48	30.01	32.51
	$\pm\sigma$	2.1349	3.9601	2.2505	3.1306
	n	6	8	10	22
10	$\bar{x}$ dł.	29.53	39.66	31.25	33.81
	$\pm\sigma$	2.8424	4.4277	3.5004	3.3196
	n	3	7	4	15

At the same time, according to the von Bertalanffy growth model, the length of a fish at the age of t years is given as

$$l_t = L_\infty [1 - e^{-K(t-t_0)}] \tag{4}$$

If l_t of the equation (3) is substituted by the right side of the equation (4), the following formula for calculating the theoretical weight of a t-years old fish is obtained.

$$W_t = a \left\{ L_\infty [1 - e^{-K(t-t_0)}] \right\} n \tag{5}$$

Then, when 1 of the formula (2) is substituted by the asymptotic length L_∞ the result is the asymptotic weight W_∞.

The length-weight relationship estimated by the least squares method for the two sexes jointly are given as the following formulae concerning – respectively – the Icelandic individuals (mostly mature individuals were at the resting gonad stage II, Maier scale) and the northern North Sea ones (gonads mostlyat the pre-spawning stages V and VI):

$$W_t = 0.009624 l_t^{2.8573} \tag{6}$$

$$W_t = 0.0007295 l_t^{3.5373} \tag{7}$$

The theoretical weight growth rates in the two regions, calculated using the above method, are presented in Tables 2 and 3 and Figs. 6 and 7.

Table 5 contains data on growth rates of males and females. It can be clearly seen that in both areas females grow much faster than males. Previous observations recorded by Saemundson (1929, after Polonskij, 1969), Matta (1959, after Robles Pariente, 1970), Raitt (1968 b), Polonskij (1968, 1969), and Robles Pariente (1970) confirm this finding.

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ODCZYTY WSTECZNE SZYBKOŚCI WZROSTU BŁĘKITKA *MICROMESISTIUS POUTASSOU* (RISSO, 1810) Z REJONU ISLANDII I MORZA PÓŁNOCNEGO (PRZY POMOCY OTOLITÓW)

Streszczenie

Celem pracy było zbadanie szybkości wzrostu błękitka – *Micromesistius poutassou* (Risso, 1810) przy pomocy odczytów wstecznych z otolitów.

Zmierzono otolity 227 błękitków z rejonu Islandii i 312 z północnej części M. Północnego (tab. 1). Otolity, uprzednio prażone, mierzono po powierzchni przełomu według schematu podanego na rys. 1.

Stwierdzono, że u błękitków o długości całkowitej 15–50 cm, korelacja między długością całkowitą i długością promienia otolitu jest zbliżona do prostoliniowej i wyraża się wzorem:

$$V = 0{,}06959\ \mathrm{l.t.} + 0{,}183466$$

Nie zaobserwowano istotnych różnic w charakterze korelacji u błękitków z obydwu badanych rejonów (rys. 2 i 3).

Przy obliczeniach szybkości wzrostu stosowano poprawkę metodą Rosa Lee. Szybkość wzrostu błękitków w rejonie Islandii była wyższa niż w północnej części M. Północnego (tab. 2, 3 i 4; rys. 4, 5, 6 i 7). Parametry równania wzrostowego v. Bertalanffy dla rejonu Islandii wynoszą: $L_\infty = 44{,}46$ cm; $K = 0{,}1374$; $t_0 = -2{,}9538$ roku i $W_\infty = 492{,}22$ g, zaś dla północnej części M. Północnego: $L_\infty = 34{,}93$ cm; $K = 0{,}2362$; $t_0 = -1{,}5808$ roku i $W_\infty = 209{,}78$ g.

Zależność długość/ciężar dla rejonu Islandii wyraża się wzorem: $W_t = 0{,}009624\ l_t^{2,8573}$; zaś dla północnej części M. Północnego: $W_t = 0{,}0007295\ l_t^{3,5373}$;

W obydwu badanych rejonach szybkość wzrostu samic była wyższa niż szybkość wzrostu samców (tab. 5).

А. Компоовски

ОБРАТНЫЕ ВЫЧИСЛЕНИЯ СКОРОСТИ РОСТА ПУТАССУ MICROMESISTIUS POUTASSOU (RISSO, 1810), В РАЙОНАХ ИСЛАНДИИ И СЕВЕРНОГО МОРЯ ПО ОТОЛИТАМ

Резюме

Целью работы было исследование скорости роста путассу - Micromesistius poutassou (Risso, 1810) - при помощи обратных вычислений по отолитам.

Измеряли отолиты 227 экз. путассу из района Исландии и 312 экз. из северной части Северного моря (табл. 1). Прокаленные заранее отолиты измеряли на поверхности излома по схеме, представленной на рис. 1.

Установлено, что у путассу, общая длина которых составляла от 15 до 50 см, корреляция между общей длинной и длиной луча отолита приближается к прямолинейной и может быть выражена формулой:

$$V = 0{,}06959\ l.t. + 0{,}183466$$

Не обнаружено существенных различий в характере корреляции у путассу из обоих исследуемых районов (рис. 2 и 3).

При вычислении скорости роста применяли поправку по методу Rosa Lee. Скорость роста путассу в районе Исландии была большей, чем в северной части Северного моря (табл. 2,3 и 4; рис. 4,5,6 и 7). Параметры уравнения роста v.Bertalanffy для района Исландии составляют: $L = 44{,}46$ см; $K = 0{,}1374$; $t_0 = -2{,}9538$ года и $W_\infty = 492{,}22$ г., а для северной части Северного моря: $L_\infty = 34{,}93$ см; $K = 0{,}2362$; $t_0 = -1{,}5808$ года и $W_\infty = 209{,}78$ г.

Зависимость длина/вес для района Исландии может быть выражена формулой:

$$W_t = 0{,}009624\ l_t^{\ 2{,}8573};$$

а для северной части Северного моря:

$$W_t = 0{,}0007295\ l_t^{\ 3{,}5373};$$

В обоих исследуемых районах скорость роста самок была более высокой, чем скорость роста самцов (табл. 5).

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