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REGULARITIES OF SPOTTED WOLFFISH (ANARHICHAS MINOR OLAFSEN) GROWTH

by

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ABSTRACT

Analysis for the author's materials and for data from literature using the methods of variational stitistics has allowed to establish an age dynamics of linear and weight growth, seasonal and geographical differences in growth rate and condition factor of spotted wolffish dwelling in the North-Atlantic waters.

In spite of the growth allometry of spotted wolffish from each of age groups, their grouping growth in population is closed to isometric one, what allows to apply the Bertalanffy equation to estimate the parameters of the mathematical model of population within maturity stage (at the age of 7-16). The obtained growth indices including maximum theoretical length and age - $L_\infty = 145.9$ cm; $t_\infty > 28$ years - are close to those observed under natural conditions maximum lengths and ages of spotted wolffish and corresponds well to Fulton's regularity (1906) connecting minimum length of maturation with the maximumlength of fish. Biological aspect of the revealed regularities of spotted wolffish growth allows to use them in fisheries investigations.

INTRODUCTION

Little is known on growth of spotted wolffish (Anarhichas minor Olafsen). Usually, studies on growth were limited by empirical data on age, length and weight of fish (Maslov, 1944; Barsukov, 1959; Lundbeck, 1951; Hansen, 1958). Beese and Kandler (1969), and later on Smidt (1980) approximated empirical data on ratio between length and weight of spotted wolffish by the equation of the exponent function. Some authors (Ostvedt, 1963; Beese and Kandler, 1969; Kruger, 1970), using different methods including the Bertalanffy equation, calculated growth indices of North-Atlantic wolffish, and maximum theoretical length in particular (L_∞). The results are very different. The authors did not discuss the biological content of the obtained indices. Therefore, it is impossible to use any published results to work out a mathematical model of the commercial stock of the spotted wolffish. More over, the published data concern different areas and seasons, and different methods were used to collect tham and proceed.

That is why the paper includes analysis of data both from literature and the own ones on growth of spotted wolffish in order to reveal the regularities of growth and to obtain parameters of wolffish growth for further usage in a mathematical model of a population.

MATERIALS AND METHODS

The growth of spotted wolffish of the Barents Sea was studied by age samples (724 spec.) collected in October-December, 1984, in a research cruise. The absolute lengths of fish were measured with accuracy to 1 cm, and weight - to 50 g. The age was determined by otoliths with the use of stereoscoping microscope and a method worked out by the author. Empirical data on length and weight of wolffish (Table 1) were approximated by the equation of exponent function, which expresses well the growth allometry (Ricker, 1979): $y = ax^B$, where y - weight of ungutted wolffish (g) and x - absolute length (cm). To calculate parameters of the regressional equation, mean values of length and weight by 5-cm groups are used. Coefficients of regressional equations are obtained using a method of the least squares. Linear growth of wolffish was studied by the Bertalanffy equation (Ricker, 1979; Bertalangffy, 1938).

DISCUSSION OF RESULTS

To our data, equations of linear-weight growth of spotted wolffish of the Barents Sea are as follows:

males $y = 0.004803\ x^{3.1830}$ (1)
females $y = 0.006115\ x^{3.1230}$ (2)
both sexes together (Fig. 1) $y = 0.005859\ x^{3.1355}$ (3)

Sexual differences between weight increments with the increase of wolffish length influence first of all the factor of a degree determining the slope of a curve. Differences are small and do not exceed an error of fish weighing by an absolute value. When comparing the curves, we have revealed that weight of small fish females exceeded weight of same length males, whereas big fish females had less weight than males. Therefore, curves of linear-weight correlation between males and females cross each other in points of 56 cm length and 1760 g weight, i.e. when wolffish females begin to maturate (7 year old) (Shevelev, 1988). Factor "a", characterizing condition of males and females by Fulton (Ricker, 1979) constituted 1.0032 % in that case.

Linear-weight growth of spotted wolffish without dividing by sex expressed by data of other authors is as follows:

$y = 0.0085\ x^{3.0380}$ (Beese and Kandler, 1969) (4)
$y = 0.0040$ x 3.1882 (Smidt, 1980) (5)

Besides, an equation of regression is calculated for the Barents Sea wolffish by data of Barsukov and Sakhno (Shevelev,1988):

$$y = 0.0166\ x^{2.8940} \qquad (6)$$

In the last case, mean length and weight of fish by ages are used because of the absence of mean length of wolffish specimens by length classes. As we have revealed, this leads to small discrepancies in parameters of the correspondent equations.

Parameters of equations 3-6 differ from each other sufficiently. Minimum factor of a degree (2.8940) and, consequently, the slowest growth of weight and condition of wolffish with the increase of length are present in the equation of regression (6), calculated by data of Sakhno and Barsukov. The highest value of this parameter (3.1882) belongs to Smidt's equation (5) calculated by data collected in the West-Greenland waters. Parameters of Beese's and Kandler's equation (4) obtained by materials collected in waters of the West Greenland, Iceland and the Barents Sea, as well as parameters of the regression equation for the Barents Sea wolffish (3) have imnermediate values.

Graphs of dependence between weight logarithm and length logarithm (Fig. 2) show that linear-weight growth of spotted wolffish from the West Greenland (5) differs sufficiently from growth of wolffish from the Barents Sea (3, 4, 6). Weight logarithm of same-size fish near the western shores of Greenland is much lower than that in the Barents Sea and close to the latter one only in specimens with maximum length, i.e. these logarithmic straight lines do not coincide and do not cross each other. At the same time, graphs of weight logarithms of the Barents Sea wolffish (3, 4, 6) are directed along a middle axis, which a logarithmic straight line (4) obtained by equation of Beese and Kandler is the most close to. Common character of this group of straight lines is evident and can be explained by the fact that all fish belong to the same population. A reason of the difference between Smidt's equation (5) and others is in characteristic features of growth of spotted wolffish from the Greenland waters.

Due to Barsukov (1953) and Templeman (1986), weight of same-size immature specimens or, to say more accurately, condition of wolffish both spotted and Atlantic ones increase steadili during a year and reaches maximum at the end of a year. Condition of mature specimens decreases to the year minimum in July-September (in the spawning season) and after it increases again. This event, widely spread among fish (Shatunovsky, 1980; etc.), proves the usage by spawners of reserve matters of the body tissues (albumen and lipids) for reproduction. It also explains the observed differences in linear-weight growth of the Barents Sea wolffish. Sakhno and Barsukov collected their materials predominantly in the third and partly in the second quaters of the year (Maslov, 1944; Barsukov, 1959), i.e. in a period close to the spawning season or coinciding with it. Therefore, the logarithm of weight and, consequently, the condition of the largest specimens were the lowest ones for fish of the same size from the analyzed samples.

Wolffish from samples of Beese and Kandler were caught in September-November, when condition of mature fish increases after spawning. Therefore, values of parameters of the exponential function 4 and the location of the straight line of the weight logarithm have intermediate significance.

Our materials were mainly obtained in November-December, when condition of mature wolffish restors in the result of feeding. It promoted the maximum value of a factor of degree from equation 3, as well as the upper location of the logarithmic straight line for large specimens.

The right side of the length-weight series, the most changeable component of which are mature females, influences strongly the values of equational parameters and, consequently, the running of functions. Running of functions on the low parts of graphs for immature fish changes correspondingly to changes of the right side of series and first of all to changes of condition of mature females. This results in crossing of all three logarithmic lines of the Barents Sea wolffish weight in one point, the absciss of which corresponds to the wolffish length of 74.6 cm, and ordinate - to weight of 4365 g. It was revealed (Shevelev, 1988) that about 50 % of females mature at this length corresponding to the age of 9. Apparently, the crossing of logarithmic functions of length-age relations reflecting the seasonal changes of condition, characterizes the mean length and age of females participating in the spawning.

Thus, differences in parameters of equations 3, 4 and 6 arecaused by the seasonal changes of condition, which are determined by the characteristic features of females maturation. The common characters of this group of functions and differences between them allow to compose an equation of regression of a function averaged by seasons for wolffish from the Barents Sea population:

$$y = 0.009845\ x^{3.0153} \qquad (7)$$

This equation does not differ much of the equation of isometric growth. It means that in spite of the growth allometry of wolffish of each age group, their group growth in the population in general is close to the isometric one, and weight of a mean statistical specimen is proportional to a cube of its length.

Isometric growth of a mean statistical specimens of spotted wolffish allow to use the Bertalanffi equation (Ricker, 1979) for calculation of growth factors in order to use them in a theoretical model of a population.

Parameters of linear and weight growth.

It is known that the Bertalanffi equation reflects the biological essence of processes of growth best of all beginning from a moment, when the initial stage of physiological formation of fish, coinciding with the period of immaturation, comes to an end

(Ricker, 1979). Theoretical values of parameters of linear growth at stages of immature and mature organisms were calculated taking the mentioned above into account (Table 2). Fig. 3 presents curves of linear growth of wolffish at the immature (1) and mature (2) ages, the mutual running of which proves the enforcement of growth in the immature period and gradual slowing of growth in the mature one. In the part, corresponding to the age of the maturation beginning (7 years old), each of the curves has a point of bend, where they joint into one sigmoid asymmetric curve characterizing growth of wolffish during the major part of the life. Data of observations, corresponding to each other, mark this common curve. Sufficient deviations of empiric data from the growth curve are peculiar for older fish, the number of length and weight measurements of which is not big enough. The upper part of a common curve, showing the growth of mature wolffish, asymptotically comes to the length (L_∞ = 145,88 cm), which they might have reach if would live infinitely, with the increase of the age. Growth factor of mature fish (k) constituted 0.1060, and age, at which wolffish would have body length equal to zero (t_0), - 1.4188 years.

Beese and Kandler have obtained the following parameters of growth of spotted wolffish during the analysis including 4-19 age groups:

L_∞ = 181.0 cm; t_0 = 1.596; k = 0.0614.

Calculation by our data for 3-14 age groups of wolffish corresponding to samples of Beese and Kandler (Shevelev, 1988) gave parameters of growth close to their results (Table 3).

Maximum theoretical length calculated by Kruger with the use of data of Beese and Kandler constituted 258.5 cm.. Ostvedt has obtained maximum theoretical length of wolffish equal to 155.0 cm by the graphic method of Wallford.

Analysis of changeability of parameters from Bertalanffi equation in dependence on the composition and value of the analyzed sample (Table 3) has shown that minimal factors of growth and maximum lengths are obtained when including the youngest age groups into a sample. Excluding gradually young ages from the sample, growth factors increase and maximum lengths decrease quickly and within wider range during the change of sample size at the expense of immature fish. It is explained by the strong changeability of growth rate during development of the organism.

Changes of low and upper borders of a sample at the stage of mature organism (at the age of 7-16) influence the value of parameters of growth much less, that proves the steady growth of spotted wolffish within the range of the stage of maturation. However, the including of next (the 16th) age group, which belongs to the stage of old age, into a sample decreases the growth factor and increases the maximum theoretical length, that is a sign of the appearance of a new natural phenomenon of growth. Orientation to the obtaining of parameters of the commercial stock of spotted wolffish, in which specimens at the stage of old age do not play a great role because of small number, shows that maximum theoretical length should be calculated on the basis of data belonging to the stage of maturation.

Maximum lengths of spotted wolffish obtained by different authors can be estimated biologically on the basis of a regularity revealed by Fulton (1906) and proved by some researchers (Dryagin, 1934; Nikolsky, 1965; Pravdin, 1966 et al.). Its main point is that the largest sizes of males and females in the spawning stock exceed usually minimum lengths two times. Results obtained by us and Ostvedt are close to each other and corresponds well both to maximum lengths observed in the nature and the mentioned regularity. It is explained by a fact that the graphic method of Wallford used by Ostvedt excludes from a sample those ages which lay even slightly lower than a logarithmic straight line designed for older fish (Ricker, 1979). Therefore, in spite of the usage by this author of a sample including young age groups as well their influence on L_∞ was excluded.

Maximum theoretical length of spotted wolffish obtained by Beese and Kandler exceeds sufficiently the length, calculated by us and Ostvedt, and corresponds worse to both maximum fish lengths occurring in catches and the Fulton regularity.

To our opinion, the reason of such discrepancy is underestimation by the authors of staging of fish development and a willing to describe wolffish growth through the whole fish life with the use of one common equation of growth, that is impossible due to opinion of many researchers (Nikolsky, 1965; Mina and Klevezal, 1976; Ricker, 1979).

Interpreting their results, Beese and Kandler used unreliable to our opinion maximum lengths of wild wolffish (180-200 cm), that is well seen in Table 4. We think that results of Kruger (1970) are also unreliable, that gives rise to doubt in his equation of growth.

Analysis of running of curves proves the presence of weak sexual differences among wolffish of the same age. However, males with lower factor of growth reach larger maximum length (150.6 cm) than females (138.9 cm) (Table 2) and, correspondingly, live longer than the latters. A great difference in maximum theoretical lengths of males and females (11.7) is caused by the methodic simplicity supposing that fish live infinitively long.

Since we are interested in parameters of commercial stock, let consider the age of specimens with maximum lengths occurring in catches (135 cm) as the maximum age, which wolffish live to (Shevelev, 1988). Apparently, larger fish play unsufficient role in fisheries, therefore we can ignor them in calculations. Due to the curve of the linear growth (Fig. 3), wolffish reach the length of 135 cm, that is 92 % of the maximum length, at the age of 28.

CONCLUSIONS

Thus, studies of length-weight correlation of wolffish have shown that the group growth of fish in a population is close to the isometric one, that allow us to use the Bertalanffi equation for calculation of growth factors. High sensitivity of the Bertalanffi equation to changes of fish growth character features allow to use it to determine the borders between stages of development. Calculation of factors of fish growth on the basis of this equation should be done with the account of development stages. Growth factors, calculated for wolffish specimens at the stage of maturity (at the age of 7-16) $L_\infty = 145.9$; $t_0 = 1.4188$ years; $t_\infty > 28$ years, corresponds satisfactory to the know Fulton's regularity and values observed in nature.

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Table 1. Mean length and weight of spotted wolffish at different ages and sexes in November-December, 1984.

Age gr.	Males			Females			Total		
	No. spec	middle length: cm	middle weight: g	No. spec	middle length: cm	middle weight: g	No. spec	middle length: cm	middle weight: g
0				4	15.2	34	4	15.2	34
1	7	19.4	69	6	19.8	70	14	19.4	66
2	20	23.5	113	20	23.1	106	40	23.3	109
3	22	30.5	229	31	30.7	241	53	30.6	236
4	27	37.8	505	23	40.1	594	50	38.8	546
5	35	46.5	956	25	46.3	1031	60	46.4	987
6	55	56.2	1787	47	55.7	1768	102	56.0	1778
7	69	65.2	2905	57	65.2	2859	126	65.2	2884
8	29	73.2	4405	26	73.0	4086	55	73.1	4254
9	23	80.9	5764	18	79.3	5268	41	80.2	5546
10	22	87.3	7381	27	87.3	6657	49	87.3	6982
11	22	93.3	8591	20	93.3	9212	42	93.3	8887
12	18	99.0	10479	14	100.0	10678	32	99.5	10566
13	11	103.1	12845	13	101.2	12300	24	102.1	12550
14	10	107.3	13920	6	107.0	14925	16	107.2	14297
15	5	112.3	17460	4	110.5	15912	9	111.5	16772
16	4	115.0	19225	1	119.0	16200	5	115.7	18620
17	1	125.0	19200				1	125.0	19200
18									
19	1	123.0	22000				1	123.0	22000
Middle		64.9	4304		62.8	3917		63.8	4115
Total	381			342			724		

Table 2. Theoretical values of parameters of the linear growth of wolffish at different stages of development.

Sex *	Age group	Parameters of Bertalanffi eq.: L_∞, cm	t_0, years	k	Error of equat.
M	1 - 6	-9.2	-5.6	-0.1685	0.40
	6 -15	150.6	1.2	0.0987	0.34
F	0 - 6	-20.1	-4.2	-0.1301	1.10
	6 -15	138.9	1.7	0.1195	0.93
M + F	0 - 6	-11.8	-5.2	-0.1564	0.66
	6 -15	145.9	1.4	0.1060	0.55

* M - males, F - females

Table 3. Changeability of parameters of linear growth in dependence on growth of analyzed wolffish.

Age group (No. of groups)	Parameters of the Bertalanffi equation:			Error of equat.
	L_∞, cm	t_0, years	k	
0 - 16 (17)	357.4	- 0.3	0.0235	3.02
1 - 15 (15)	280.2	- 0.8	0.0333	2.34
3 - 14 (12)	180.8	1.3	0.0670	1.18
6 - 15 (10)	145.9	1.4	0.1060	0.55
6 - 16 (11)	150.0	1.3	0.0993	0.58
6 - 10 (5)	155.6	1.2	0.0936	0.19
6 - 11 (6)	152.1	1.3	0.0980	0.17
10 - 15 (6)	142.5	1.6	0.1128	0.69
10 - 16 (7)	251.7	-2.1	0.0327	0.64

Table 4. Biological and mathematical estimations of maximum theoretical length of wolffish due to data of various authors.

Sex*	Minimum length of fish maturing for the first time, cm	Maximum theoretical length, cm		Author
		calculated: by Fulton	calculated: by growth equations	
M + F	65	130	155	Ostvedt, 1963
M + F	48	96	181	Beese, Kandler, 1969
M	66	132	151	our data
F	53	106	139	
M + F	53	106	146	

* M - males, F - females

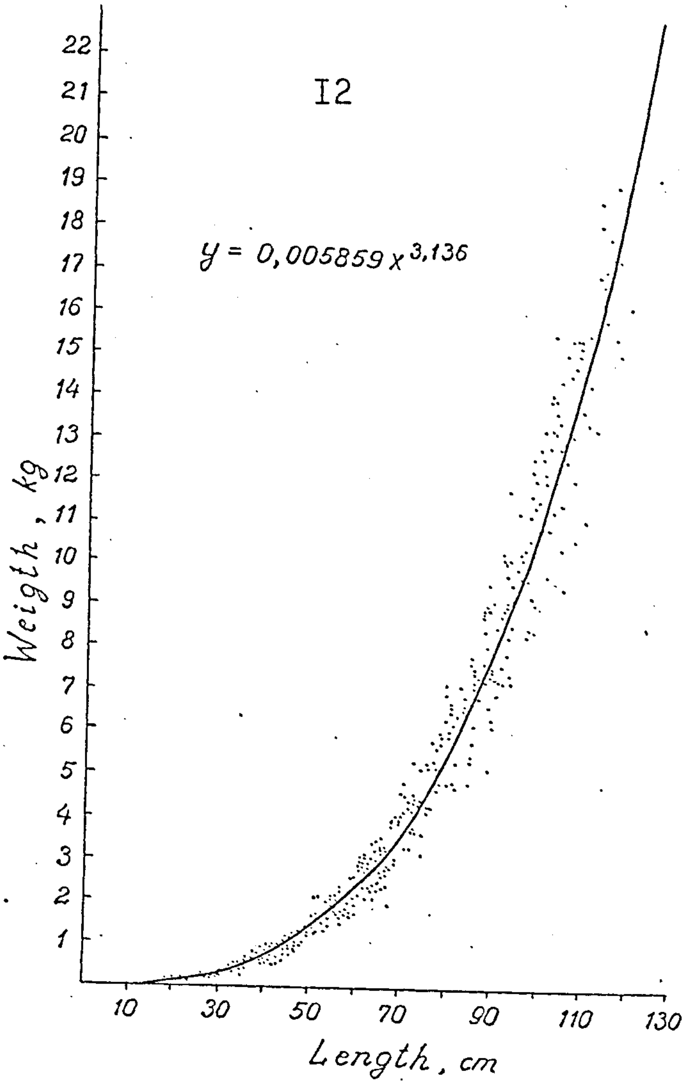

Fig. 1. Dependence of spotted wolffish weight on length by the equation 3.

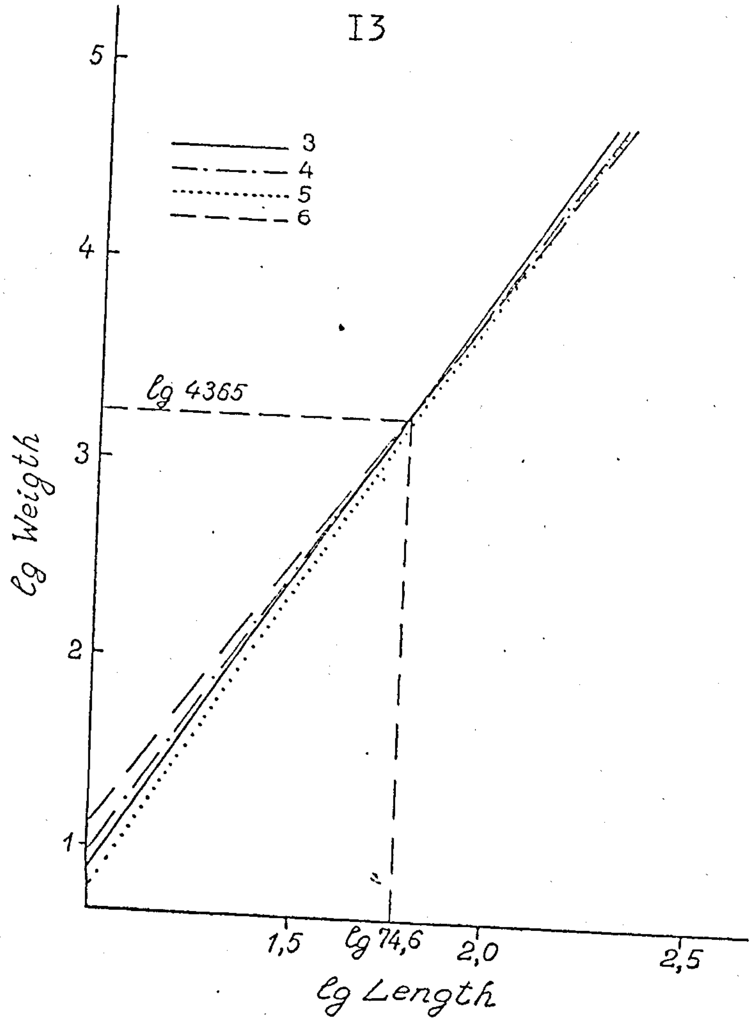

Fig. 2. Dependence of a logarithm of spotted wolffish weight on the logarithm of length due to data of various authors: 3 - our data; 4 - Beese and Kandler (1969); 5 - Smidt (1980); 6 - Sakhno, Barsukov (1959). Figures correspond to No. of equations in t text.

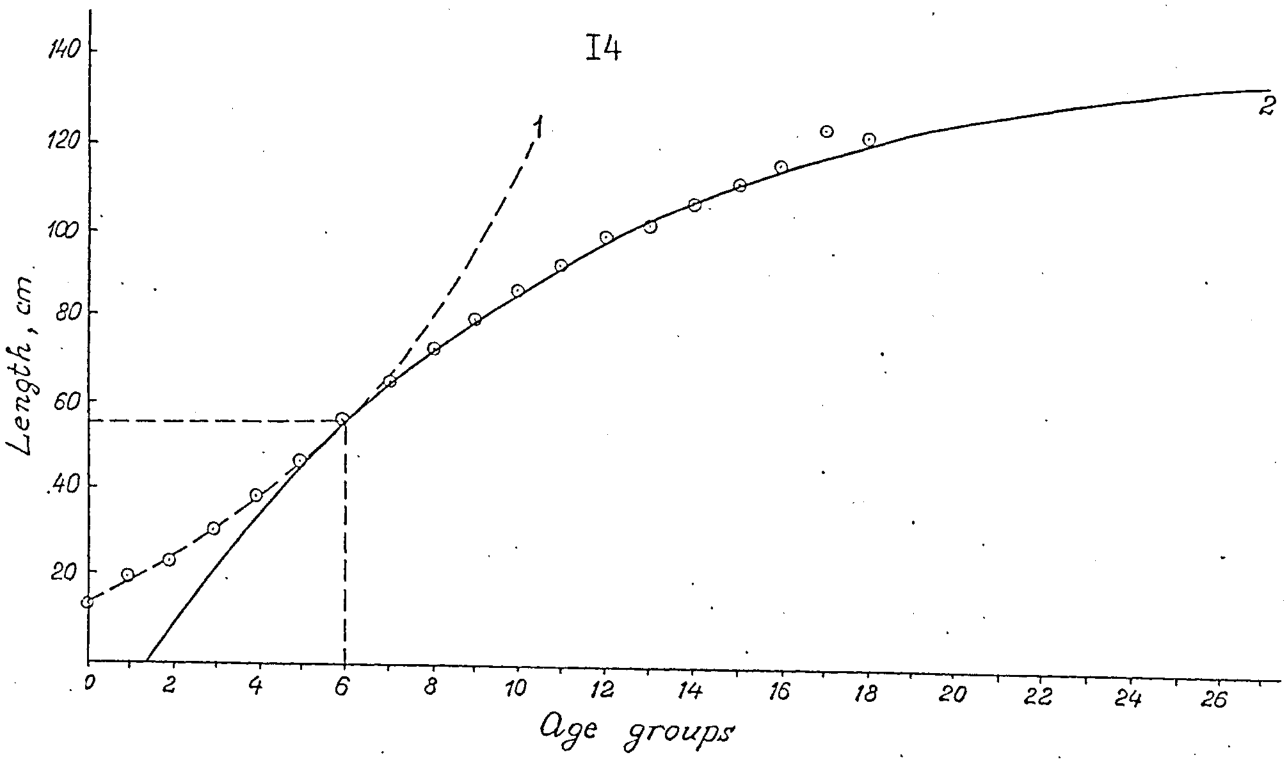

Fig. 3. Linear growth of spotted wolffish by the Bertalanffy equation without dividing by sex:
1 - for 0-6 age groups $L_t = -11.759 [1 - e^{0.1564(t+5.2085)}]$; 2 - for 6-15 age groups $L_t=145.8808 [1-e^{-0.1060(t-1.4188)}]$.
Circles mean the observed data.