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Relationship between Growth of the Body and of Scales in the Atlanto-Scandian Herring

by

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Summary

This paper deals with the testing of the hypothesis of the existence of a rectilinear relationship between growth of the body and of the scales in the Atlanto-Scandian herring, with different growth types and scale formulas. This testing was carried out with the help of the correlation analysis.

In herring the relationship mentioned is rectilinear and it is observed throughout all seasons of the year and all periods of the life history. The curvilinear relationship observed in one-aged group of herring points in some cases to the presence of specimens that have grown up in different ecological conditions.

For the study of the life history of fish it is necessary to know their growth rate not only in the period of observation but also during previous years of their life.

Different methods have been suggested for back calculation of fish growth by scales, bones and otoliths. LEA (1910), who was the first to use the method of back calculation of growth rate of the Norwegian herring by scales, believed that the increase in the size of scale is proportional to the increase in the length of the fish. The relation between the growth of the fish and that of the scales is rectilinear.

The examination of this relation in other fish species showed that along with the rectilinear relation (AVRUTINA, 1929; TYURIN, 1929; LEA, 1910) also a curvilinear relation is observed (KAZANCHEEV, 1955; LUKIN, 1951; RADCHENKO, 1930).

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VOVK (1955) considered that "the mode of relationship between the growth of scales and that of fish is specific for the species", and that this is valid for all populations of the same species, irrespective of where they live.

COOPER (1952) showed that in some isolated populations and sometimes in sexual groups of one and the same population, there may be differences in the mode of relationship between the size of the fish and that of their scales.

That the relation in one and the same fish species is not constant is indicated by data on roach from the Ubinskoe Lake (curvilinear relationship) (RADCHENKO, 1930), and by data on the same species from the Chany Lake (rectilinear relationship) (AVRUTINA, 1929).

BRYUZGIN (1969) considered that "the mode of correlation between fish length and scale size is not a character of a family, genus or even species", but is "an inherent character of a single fish population".

LAPTEV (1953) stated that "growth of scales does not agree with body growth; an agreement may be only random and in different years it may be original".

The present paper deals with testing of the hypothesis of the existence of a rectilinear mode of relation between the growth of the body and that of the scales in Atlanto-Scandian herring with different growth types and scale formulas, and besides the constancy of this relationship was checked for different seasons of the year and periods of their life history (the full correlation analysis).

The full correlation analysis (PLOKHINSKY, 1970) includes calculations of:-

1. Index of rectilinearity of the relation - the suqare of the correlation coefficient. 2. Confidence criterion of the square of the correlation coefficient. 3. Index of curvilinearity of the relation - the square of the correlation ratio. 4. Confidence criterion of the square of the correlation ratio. 5. Curvilinearity criterion.

If the value of the calculated criterion of curvilinearity does not exceed the standard values of FISHER's criterion (defined from the table of three thresholds with appropriate degrees of freedom) the relationship is considered to be rectilinear. The reliability or probability of correct forecasts for biological investigations must be: $\beta_1 = 0.95$.

When the value of the curvilinearity criterion is beyond the existing boundary values which are defined from Tables, then curvilinearity is checked by properties of the correlation ratio (AKSYUTINA, 1968).

1. Correlation ratio cannot be less than the absolute value of the correlation coefficient

$$\bar{\eta} \geq (\bar{r})$$

2. For linear relationship $\eta_{xy} = \eta_{yx}$ and $\eta = (r)$, consequently the difference $\eta^2 - r^2$ can be used as a degree of deviation of the regression relationship from a linear one. Divergence between η and r can be estimated with the help of the criterion

$$\theta = \frac{n - k - 2}{k - 2} \cdot \frac{\bar{\eta}^2_{yx} - \bar{r}^2}{1 - \bar{\eta}^2_{yx}}$$

where k is the number of groups along the x line in the correlation table.

The mean error of the value θ is determined by the equation:

$$\sigma_\theta = \sqrt{\frac{2(n-4)}{(k-2)\cdot(n-k-4)}}$$

3. In case we deal with the inequality $\frac{|\theta - 1|}{\sigma_\theta} < 3$,

the difference between $\bar{\eta}_{yx}$ and $\bar{r}$ is considered to be insignificant (deviation of regression relationship from the linear one can be considered to be negligible). Otherwise the difference between $\bar{\eta}_{yx}$ and $\bar{r}$ is essential (AKSYUTINA, 1968).

Before starting the study of the main question, the relation was checked for herring with different age groups. Two samples taken in October 1953 were examined; they included herring at an age from 2+ to 17+ years (16 age groups, $n = 350$), and the following values were obtained: the correlation coefficient is 0.69; confidence criterion of the square of the correlation coefficient (Fr^2) and of the square of the correlation ratio ($F\,\eta^2$) was higher than $\beta_3 = 0.999$; the curvilinearity criterion was less than $\beta_1 = 0.95$. The relation is linear.

The growth rate of herring that grew up in the Norwegian Sea greatly differs from that of herring inhabiting the Barents Sea during the first years of their life, before they mature (SHUTOVA-KORZH, 1960; SELIVERSTOVA, 1968, 1970). The growth rate is different even in herring that inhabit the Norwegian Sea, but which during the coastal period of their life lived in different areas of that Sea (southern or northern ones). Peculiarities of environmental conditions determined different growth types in the Atlanto-Scandian herring: A, B, B-C, C, D, C-D, (SHUTOVA-KORZH, 1960; OTTESTAD, 1934; SELIVERSTOVA, 1968, 1970).

The A-type is characterized by an annual gradual decrease in increments $t_1 > t_2 > t_3 > t_4$ etc.

The B-type is characterized by an increase in the growth rate during the 3rd year of life, $t_2 < t_3$.

The C-type represents the increase in the growth rate during the 4th year of life, $t_3 < t_4$.

The B-C-type is characterized by an increase in the growth rate during the 3rd and 4th years of life, $t_2 < t_3 < t_4$.

The D-type shows the increase in the growth rate during the 5th year of life, $t_4 < t_5$.

The C-D-type represents an increase in the growth rate during the 4th and 5th years of life, $t_3 < t_4 < t_5$.

Apart from the different types of growth, the Atlanto-Scandian herring have different scale formulas, a ratio of coastal, oceanic and spawning rings (LEA, 1929; RUNNSTRÖM, 1936). Contingents of the Atlanto-Scandian herring in the Barents and Norwegian Seas have defined types of growth and scale formulas (Table 1), and this is a result of the peculiarities of the environmental conditions (SELIVERSTOVA, 1968, 1970).

The existence of such a great number of groups in the Atlanto-Scandian herring makes it possible to test the hypothesis on the constancy of the relation between growth of the body and that of the scales in herring that grew up under different environmental conditions.

The analysis showed that the relation between growth of the body and that of scales in the Atlanto-Scandian herring is rectilinear - it is observed from year to year - during the feeding and wintering periods and also during all periods of their life history. Constancy of the rectilinear mode is also found in herring with other types of growth and scale formulas (Tables 2 and 3).

However, a rectilinear relation between the growth of the body and that of the scales is observed in some cases in groups of herring with different growth types (types A, B, C, D), when the mixed samples are analysed, and in other cases it changes into a curvilinear mode (Table 4).

The thing is that dissociation of herring with different growth types and scale formulas is observed only in the first years of life when young herring during a passive drift are brought to different areas of the coastal zones of Norway and Murman, where they live from two to six years. During the oceanic period of life when the herring migrate from the coastal zone of the Norwegian and Barents Seas to the open part of the Norwegian Sea, a mixing of herring with different growth types and scale formulas is observed. In herring living under very different ecological conditions during the first years of life, the ratio betwenn the growth of the body and that of the scales will be different. Evidently, when herring grow up under identical environmental conditions, they have an identical general pattern of growth, while when they live under different conditions, their pattern of growth will be different.

The analysis of herring of the Barents and Norwegian Seas' contingents with different growth types showed that the linear relation between the growth of the body and that of the scales is observed during the whole life. The analysis of the mixed samples including the Norwegian contingent of the Atlanto-Scandian herring (fish with growth types A, B, and scale formulas S 2+1, N2+1), and the Barents Sea herring (with growth types A, C, and the scale formula N3) showed that the rectilinear relation changed into a curvilinear one (Table 4).

Thus, in many-aged and one-aged groups of the Atlanto-Scandian herring (with different growth types and scale formulas)the relation between the growth of the body and thatof the scales is rectilinear and this is observed during all seasons of the year and periods of their life history. In some cases the curvilinear relation observed in a one-aged group of herring points to the presence of specimens that grew up under different ecological conditions.

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Table 1. Growth types and scale formulas in the Atlanto-Scandian herring.

	Growth Type					
	A	B	C	B-C	D	C-D
Scale formula	N 2+1	N 2+1		N 2+1		
	N 2+2	N 2+2		N 2+2		
	N 3+0		N 3+0		N 4+0	N 4+0
	N 3+1		N 3+1	N 3+1	N 4+1	N 4+1
	N 3+2		N 3+2	N 3+2	N 4+2	N 4+2
	N 6+0		N 6+0		N 6+0	N 6+0
	N 6+1		N 6+1		N 6+1	N 6+1

Note: N 2+1 - N is the northern type of scales; the 2 indicates two coastal rings; 1 indicates one oceanic ring.

N 6+0 - N is the northern type of scales; the 6 indicates six coastal rings; 0 indicates that oceanic rings are not observed, the herring spawn without going through the oceanic stage.

Table 2. The mode of relationship between the growth of the body and that of the scales in the Atlanto-Scandian herring of the C type during different seasons of the year and periods of their life history.

Year Month	Period of Life History	Scale Formula and Number of Fish	Index of rectilinear relation (the square of correlation coefficient) r^2	Index of curvilinear relation (the square of corr. ratio) η^2	Linear Relation: Curvilinearity criterion $F_3 < \beta_1 = 0.95$	Linear Relation: $\eta = (r)$
1961 Sept.	Coastal (Barents Sea)	N 2 / 135	0.14	0.16	less	
1961 Nov.	"	N 2 / 330	0.19	0.20	less	
1962 Summer	Oceanic (Norwegian Sea)	N 3 / 170	0.31	0.32	less	
1962-63 Winter-Spring	Wintering (Norwegian Sea)	N 3 / 93	0.17	0.20	less	
1963 Summer	Feeding (Norwegian Sea)	N 3+1 / 198	0.12	0.13	less	
1963-64 Winter-Spring	Wintering before spawning (Norwegian Sea)	N 3+1 / 418	0.14	0.14		0.37
1964 Winter	Wintering after spawning (Norwegian Sea)	N 3+1+1 / 230	0.10	0.11	less	

Note: in all cases r^2 and η^2 are statistically reliable.

Table 3. The mode of relationship between the growth of the body and that of the scales in the Atlanto-Scandian herring with different growth types and scale formulas during some periods of their life history.

Area	Year Month	Growth Type and Scale Formula and Number of fish	Index of rectilinear relation (the square of correlation coefficient) r^2	Index of curvilinear relation (square of correlation ratio) η^2	Linear relationship		Note
					Curvilinearity criterion $F_{\ell_3} < \beta_1 = 95$	$\eta = (r)$	
Barents Sea	1961 June-Sept.	A N 2 / 355	0.42	0.43	less		coastal
	1962 June-Sept.	D N 3 / 1 019	0.35	0.35		0.59	"
Norwegian Sea	1961 June-Sept.	A N 2 / 75	0.22	0.26	less		oceanic (feeding period before spawning)
		A S 2 / 130	0.16	0.18	less		
	1962 June-Sept.	A N 2+1 / 297	0.23	0.27	less		"
		A S 2+1 / 100	0.12	0.12		0.35	"
		A N 3 / 194	0.63	0.65	less		"
		B N 2+1 / 271	0.12	0.12		0.35	"
		B S 2+1 / 60	0.21	0.21		0.46	"
	1963 June-Sept.	A N2+1 / 126	0.18	0.18		0.42	oceanic(feeding period after spawning)
		D N 4 / 118	0.10	0.14	less		oceanic(feeding period before spawning)

Note: in all cases r^2 and η^2 are statistically reliable.

Table 4. The mode of the relationship between the growth of the body and that of the scales in the Barents and Norwegian Seas contingents of herring.

Area	Year Month	Contingent	Growth Type and Scale Formulas and Number of Fish	Index of rectilinear relation (the square of correlation coefficient) r^2	Index of curvilinear relation (the square of correlation ratio) η^2	Linear Relationship	
						Curvilinearity criterion $F_{\ell} < \beta_1 = 0.95$	$\eta = (r)$
Barents Sea	1961 Jul.-Sep.	Of the Barents Sea	A N 2 / 355	0.42	0.43	lower	
			C N 2 / 136	0.14	0.16	lower	
			A N 2 and C N 2 / 491	0.41	0.41		0.64
Norwegian Sea	1962 Jun.-Sept.	Of the Norwegian Sea	A N 2+1 / 297	0.23	0.27	higher x)	
			A S 2+1 / 100	0.12	0.12		0.35
			B N 2+1 / 271	0.12	0.12		0.35
			B S 2+1 / 60	0.21	0.21		0.46
		Of the Barents Sea	A N 3 / 194	0.63	0.65	lower	
			C N 3 / 170	0.31	0.32	lower	
		Of Norwegian & Barents Seas	All types and formulas / 1 092	0.58	0.61	higher xx)	

Note: In all cases r^2 and η^2 are statistically reliable. x) Curvilinearity criterion proved to be somewhat higher than the first threshold of probability of correct forecasts. The checking of curvilinearity found through the properties of the correlating ratio showed that the difference between $\bar{\eta}_{yx}$ and $\bar{r}$ is unessential, the deviation of regression relationship from the linear one may be considered to be negligible. xx) The checking of curvilinearity found through properties of the correlating ratio showed that the difference between $\bar{\eta}_{yx}$ and $\bar{r}$ is essential.