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Conversion formulae and nomograms for various measurements of length in the peled (*Coregonus peled* Gmel.)

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Abstract — In the present paper, the relationships between three measurements of length (standard length, total length, Smitt's length) were described for the age classes 0+ to 3+ in *Coregonus peled* (Gmel.). Nomograms were constructed for particular age groups, facilitating rapid interconversion of these measurements. The statistical verification of regression equations revealed that the conversion formulae for particular classes differ, hence common equations may be used for only some of them.

Key words: conversion relationship, fish, *Coregonus peled*, body length measurements.

1. Introduction

In ichthyology several methods of measuring the length of fish are applied. The differences between particular measurements result from the choice of different points of reference on the body of the fish, and also from the use of various measuring instruments. Three methods of measurement are most frequently employed, each specially defined. The total length (longitudo totalis), also known as the absolute length, is taken from the anterior with jaws closed, along the axis of the fish's body, to its intersection with a perpendicular from the longest ray of the caudal fin. For most fish, standard body length (longitudo corporis) signifies the length from the anterior end of the body to the base of caudal fin, or to where the scale cover ends. For *Salmonidae* and *Coregonidae*, Smitt's length is used, which is a modification of tail length (longitudo caudalis). This is the length from the anterior end of the body to the end of the medial rays of the caudal fin (in coregonids, measured from the beginning of the maxilla).

Routine measurements, frequently taken on abundant material in the field, require unification in the way of expressing length, so as to reduce manipulation time to a minimum. In practice, however, arbitrary methods of measurement are used, this leading to problems in comparing results presented by different authors. To date, there is no agreement as to which measurement is the best (Carlander, Smith 1945, Hile 1948, Chugunova 1955, 1963, Lagler 1956). Therefore, wherever possible, it is advisable to use conversion coefficients which should allow interconversion of different measurements. The aim of the present work was to investigate the relationship between three measurements of length in the peled (*Coregonus peled* Gmel.), originating from controlled rearing conditions (cages).

2. Material and method

The study material was taken from illuminated cages in Lake Legińskie, in which the peled were kept in the period 1977—1980 (Mamcarz, Szczerbowski 1984). Specimens of various sizes, belonging to successive age groups from 0+ to 3+, were taken for measurement (Table I). In order to obtain a true picture of changes in the length of these fish during growth, control samples were taken monthly over the four year rearing period. Altogether, 1274 specimens were measured.

Table I. Characteristics of the material

Age group	Range of length in mm			Number of specimens
	total length	standard length	Smitt's length	
0+	15.4 - 114.0	13.9 - 99.0	15.2 - 105.0	373
1+	85.0 - 188.0	74.0 - 158.0	79.0 - 170.0	442
2+	130.0 - 265.0	111.0 - 227.0	119.0 - 244.0	233
3+	154.0 - 328.0	177.0 - 290.0	164.0 - 308.0	226

In order to describe the relationships between the three measurements (standard length, total length, Smitt's length), the equations $y=a+bx$ and $x=a+by$ of simple regression were computed for these measurements in particular age classes. These equations were then verified statistically, using the method of comparing several regression lines (Elandt 1964).

This method consists in testing the hypotheses that the regression lines are parallel ($H_0 : B_1 = B_2$) and identical ($H_0 : A_1 = A_2$). The testing was carried out at a significance level $\alpha = 0.05$ with F_{tab} for $d_1 = 1$ and for $d_2 = n_1 + n_2 - 4$ for the first hypothesis and with F_{tab} for $d_1 = 1$ and for $d_2 = n_1 + n_2 - 1$ for the second hypothesis. All the calculations were carried out on the Odra 1204 computer at the Centre of Mathematical Computation of the Academy of Agriculture and Technology in Olsztyn.

3. Results

Conversion coefficients computed in the form of regression equations between particular measurements of peled length are presented in Table II. High correlation coefficients (0.91—0.99) were typical of these relationships. Nomograms were constructed for successive age groups (figs 1,2), in order to permit rapid conversion of one kind of length measurement into another.

After conversion formulae had been computed for particular age classes, an attempt was made to see whether it might not be possible to use a single formula to convert various measures of length in successive years of the fish's life. For this purpose, the statistically computed equations of regression lines were tested as to being equal and parallel (Table III).

The test results demonstrate that particular conversion formulae differ both between years and in dependence on which measurement is being calculated from the general equation $y = a + bx$.

Lines with describe the relationship $Lt = a + b \cdot Lc$ have different angles of inclination in different years and cannot be described by a common equation. However, the lines given by the equation $Lc = a + b \cdot Lt$ are parallel (value of test $F_B < F_{tab} = 3.860$), while in the case of the third

Table II. Regression equations for conversion of different length measurements of Coregonus peled. Lt - total length; Lc - standard length; Ls - Smitt's length. No - number of equation (see figs 1 and 2)

Age group	No	Regression equations: y = a + bx	Regression equations: x = a + by	Correlation coefficient
0+	1	Lt = 0.0737 + 1.1842 · Ls	Lc = 0.0421 + 0.8425 · Lt	0.9988
	2	Lt = -0.8961 + 1.1052 · Lc	Ls = 0.8809 + 0.9035 · Lt	0.9993
	3	Lc = -0.7702 + 0.9324 · Ls	Ls = 0.8870 + 1.0712 · Lc	0.9994
1+	1	Lt = 1.1477 + 1.1647 · Lc	Lc = 0.3611 + 0.8481 · Lt	0.9939
	2	Lt = 0.8511 + 1.0855 · Ls	Ls = 0.3239 + 0.9126 · Lt	0.9953
	3	Lc = 0.2034 + 0.9280 · Ls	Ls = 0.4271 + 1.0716 · Lc	0.9972
2+	1	Lt = 1.6755 + 1.1420 · Lc	Lc = 2.1180 + 0.8570 · Lt	0.9892
	2	Lt = 1.0139 + 1.0732 · Ls	Ls = 4.2892 + 0.9045 · Lt	0.9852
	3	Lc = -0.1509 + 0.9374 · Ls	Ls = 2.5044 + 1.0527 · Lc	0.9934
3+	1	Lt = 36.3030 + 0.9565 · Lc	Lc = -0.1832 + 0.8769 · Lt	0.9158
	2	Lt = 2.1063 + 1.0591 · Ls	Ls = 0.9731 + 0.9310 · Lt	0.9930
	3	Lc = -1.3891 + 0.9433 · Ls	Ls = 32.0294 + 0.9045 · Lc	0.9237

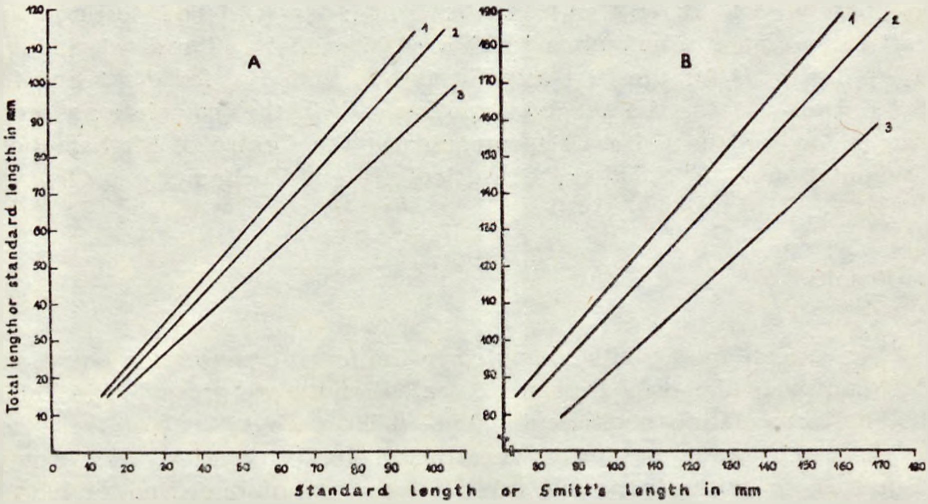

Fig. 1. Nomograms of the relationships between three measurements of length in the peled, *Coregonus peled* Gmel. in the first (A) and second (B) year of life. 1 — relationship of Lt-Lc; 2 — relationship of Lt-Ls; 3 — relationship of Lc-Ls

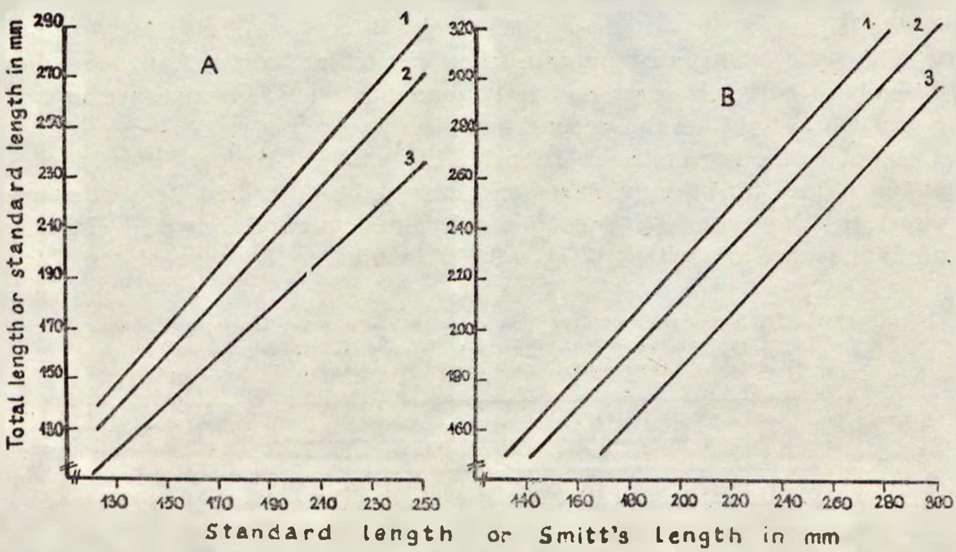

Fig. 2. Nomograms of the relationship between three measurements of length in the peled, *Coregonus peled* Gmel. in the third (A) and fourth year of life. Symbols 1, 2, and 3 as in fig. 1

Table III. Comparison of regression equations between successive age groups of Coregonus peled. When $F_B < F_{tab} = 3.860$ regression lines are parallel, when $F_A < F_{tab} = 3.860$ are equal and describing by a new combined equation (A: $Lc = -1.221 + 0.942 \cdot Ls$; B: $Lc = -1.502 + 0.943 \cdot Ls$; C: $Lc = -0.729 + 0.940 \cdot Ls$; D: $Lc = 1.787 + 0.881 \cdot Lt$)

Type of equation	Lt=a+b·Lc		Lt=a+b·Ls		Lc=a+b·Ls		Lc=a+b·Lt		Ls=a+b·Lt		Ls=a+b·Lc	
Age group comparison	test value											
	F_A	F_B	F_A	F_B	F_A	F_B	F_A	F_B	F_A	F_B	F_A	F_B
0+ - 1+		8.227		13.267	15.745	1.377	15.085	1.275		4.081	6.946	0.009
0+ - 2+		19.847		10.357	10.241	0.699		4.234	35.511	0.014		7.480
0+ - 3+		76.134		34.977	0.152^A	0.244	5.022	2.369		16.804		51.335
1+ - 2+		3.904	15.837	1.166	16.823	1.838	88.565	1.086	46.673	0.724		5.859
1+ - 3+		58.528		8.123	0.399^B	0.416	11.341	1.550		5.308		48.505
2+ - 3+		26.198	11.057	0.918	0.014^C	0.035	2.753^D	0.417		4.404		21.432

and fourth years they may be described by a common equation with the form $Lc = 1.787 + 0.881 \cdot Lt$ (value of test $F_A < F_{tab} = 3.860$).

In the case of the relationship between total length and Smitt's length, the lines of regression $Lt = a + b \cdot Ls$ were found to be parallel only between the second and third and fourth years. Thus, in none of these cases is it possible to use a common formula to describe the relationships

The greatest similarity of conversion formulae in successive years of peled growth was found in the relationship between standard length and Smitt's length. Lines describing the relationship $Lc = a + b \cdot Ls$ are parallel in all four years, and in three cases the pairs of lines compared may be described by using the common equations A, B, and C (Table III). In the case of the relationship $Ls = a + b \cdot Lc$, the regression lines are parallel only for the first and second years.

4. Discussion

In most ichthyological studies, measurement of the fish is one of the routine procedures. Despite its frequency, only rarely do authors provide information which would make it possible to interconvert various measurements. Pravdin (1966) and Lowe-McConnell and Lagler (1971) are among those who have expressed the need for conversion coefficients in order to unify measurements.

Most often, particular measurements of fish length are converted graphically, using plots or regression equations. Some authors also use other methods; Ristkok (1970) gave the ratio of total length to standard length for 34 Estonian fish species. He found that the values of the calculated coefficient were typical of carnivorous fish, while the highest values were obtained for the redfin, bream, and Amur goldfish. During studies of Canadian population of *Coregonus clupeaformis*, Healey (1975) used a conversion formula in the form $L_x = \frac{L_y \pm a}{b}$. In turn, Witkowski et al. (1984) give the conversion formula $L_x = L_y \cdot a$. As in the case of using various methods of measurement, so foo in their transformation authors enjoy a certain freedom. Some authors describe all the age classes of a given species by equations, while others construct them from data derived from only a small number of measurements. The statistical verification of conversion equations, computed for various age classes of the peled, indicate that their applicability in a unified form is limited. The difficulties arise mainly from the fact that as the fish grows, the nature of the relationship between total length and standard length changes, this resulting from changes in the length of the caudal fin. Ristkok (1970) drew attention to the phenomenon, claiming that the kind of change observed in the length of the caudal fin may vary according to species. In the peled the use of a unified conversion formula for several age classes is possible to a certain extent, i.e. in the transformation of standard length into Smitt's length in the age classes 1 and 4, 2 and 4, and 3 and 4. The ratio of the measurement in this case is more nearly constant than for other measurements of this feature.

5. Polish summary

Wzory konwersyjne i nomogramy dla różnych pomiarów długości u pelugi (*Coregonus peled* Gmel.)

Określono zależności pozwalające na wzajemne przekształcanie trzech pomiarów długości (długość ciała, długość całkowita, długość Smitta) dla roczników 0+ — 3+ (tabela II). Sporządzono nomogramy zależności dla kolejnych grup wiekowych (ryc. 1, 2). Na podstawie weryfikacji statystycznej równań regresji stwierdzono, że wzory konwersyjne dla poszczególnych roczników różnią się i zastosowanie wspólnych równań jest możliwe tylko dla części z nich (tabela III).

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