ANNAL. BIOL. TIHANY	38	131—142	HUNGARIA 1971

GROWTH INVESTIGATION OF RUFFE (ACERINA CERNUA L.) IN LAKE BALATON

PÉTER BIRÓ

Biological Research Institute of the Hungarian Academy of Sciences, Tihany, Hungary

Received: 10th January, 1971

The ruffe is an important food-stuff of the pike-perch in Lake Balaton (Woynárovich, 1959). Still its biology and ecology are improperly known, only scattered references concerning its growth are found in hungarian literature (Ribiánszky and Woynárovich, 1962), although its food has been investigated by several authors (Entz and Lukacsovics, 1957; Tölg, 1960).

Regressive changes occurred in the ruffe population of Lake Balaton following the mass destruction of fish in 1965, which was indicated by a drop in per cent of the ruffe to other species in the food of pike-perch (Biró and Elek, 1969). Since the nutrition and the population density belong to the determinants of growth, it seemed to be desirable to investigate the growth of ruffes collected at several places of Lake Balaton as well as to describe and to compare it with several mathematical models in connection with my previous work (Biró, 1970).

Material and methods

Samples were collected by using a beam trawl of 2mm mesh and an otter trawl of 5 mm mesh, respectively, during 1969—70 at different parts of Lake Balaton. The samples (639 individuals) have been fixed instantly on the site in 4—5% formaldehyde. The body length and weight of each specimen have been measured in mm and in grams to an accuracy of 0.05.

Scales were collected (10—20 pieces per fish) from the rows below the lateral line on the left side behind the posterior margin of the pectoral fin *(Fig. 1)*. Intact, well developed scales had been selected and after cleaning they were compressed between glass slides. The preparations were projected by a profile projector at a 50 times magnification. Using a millimetre divided scale we measured from the focus of the scale the winter ring distances and the total oral radius. The age was determined by counting the number of completely developed annual rings.

The relation of standard length and oral radius as well as that of body dimensions at the time of scale-formation and the length of "key-scales" were expressed by the equation of a straight line. On the basis of these relationships and the radii of the annual rings we back calculated the standard lengths of different age groups by the Fraser's (1916) method, and the relation of the

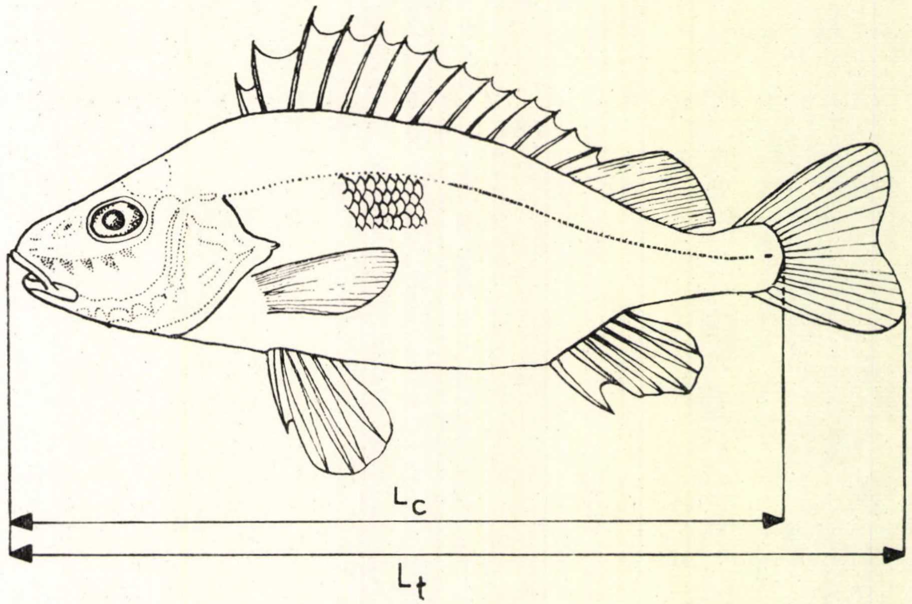

Fig. 1. Place of scale sampling on the left side of ruffe ("key-scales"). L_c = standard length, L_t = total length

body length and weight by HUXLEY's (1924; cit. BEVERTON and HOLT, 1957) allometric formula.

For the mathematical description of the growth of ruffe-population in Lake Balaton the growth-model of BERTALANFFY (1957) and KRÜGER (1965) was applied and compared, using the back calculated standard lengths.

Results

The extreme values for the standard length in the examined specimens of ruffes were 22—115 mm, while for the total length were 26.5—126 mm. Body weights yielded values between 0.21—30.65 g *(Table I, Fig. 2)*. Specimens of 3—6 cm standard length, aged 0+ and 1+ years were preponderant in the material; the age composition indicates a high natural mortality.

The growth zones of the scales form a stripe of varying width, however, in the majority of cases the winter rings are clearly separated. Among the scales numerous samples occur being regenerated after juvenile lesions. There are two characteristic types: 1. smaller or greater spot of regeneration is observable around the focus, 2. a marginal lesion of the scale is seen completely deformed, or perhaps several scales (as a rule 2) are adherent. The damaged scales often display no growth ring or in the case of their presence, they are rather indistinct.

Considering the examined samples a linear connection has been calculated for the relation of the standard length and the total oral radius. The several representives were plotted to give a straight line which shows an inter-

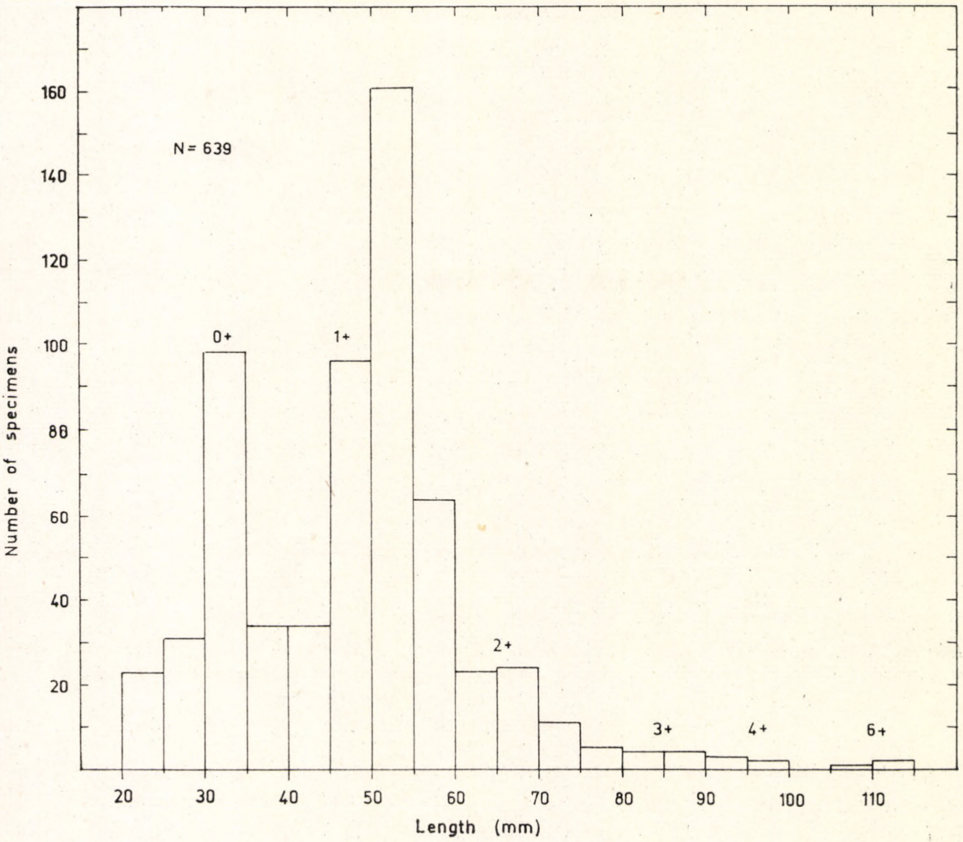

Fig. 2. Standard length-frequency of ruffes in different age groups

TABLE I

The measured averages of length and weight of examined ruffes

Age groups	L_c	L_t	W
0+	46.7	56.3	1.8
1+	54.0	65.0	2.8
2+	66.5	78.6	5.7
3+	90.0	107,0	13.8
4+	110.5	125.5	24.1

L_c = standard length in mm, L_t = total length in mm, W = weight in grams

section on the abscissa at 12.5 mm *(Fig. 3)*. This seemingly low value gives the standard length measurable at the time of "key-scales" formation. For both sexes the allometric curve expressing the relation of standard length and weight abruptly rises from a length of 7—8 cm agreeing well with the measured values *(Fig. 4)*.

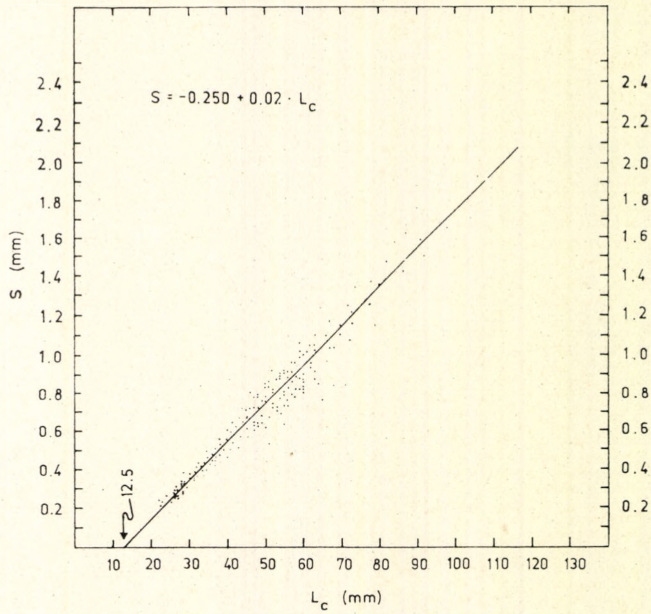

Fig. 3. Relation between the standard length and the total oral radius of the scales. The straight line has been plotted on the basis of representative data. S = total oral radius (mm), L_c = standard length (mm)

According to the directly measured average data, the total length was 56 mm in the first (0+), 65 mm in the second (1+), 79 mm in the third (2+), 107 mm in the fourth (3+) and 125 mm in the fifth (4+) year (rounded values of the standard length and body weight are summarized in *Table I)*. The body lengths calculated from the scales *(Table II)* are somewhat lower than tbe

TABLE II

Standard lengths back calculated from the scales, in mm

Size group	Age groups					Average	Difference
	1+	2+	3+	4+	6+		
l_1	46.0	44.2	47.3	45.8	46.0	45.9	
l_2	—	60.7	66.6	68.4	64.3	65.0	19.1
l_3	—	—	84.2	86.1	82.5	84.3	19.3
l_4	—	—	—	96.6	95.1	95.8	11.5
l_5	—	—	—	—	104.4	104.4	8.6
l_6	—	—	—	—	109.9	109.9	5.5

above values. When plotting them by the WALFORD (1964) transformation a value L_∞ = 13.0 cm is obtained for the asymptotic body length. According to the growth curve transformed into a straight line, the standard length of

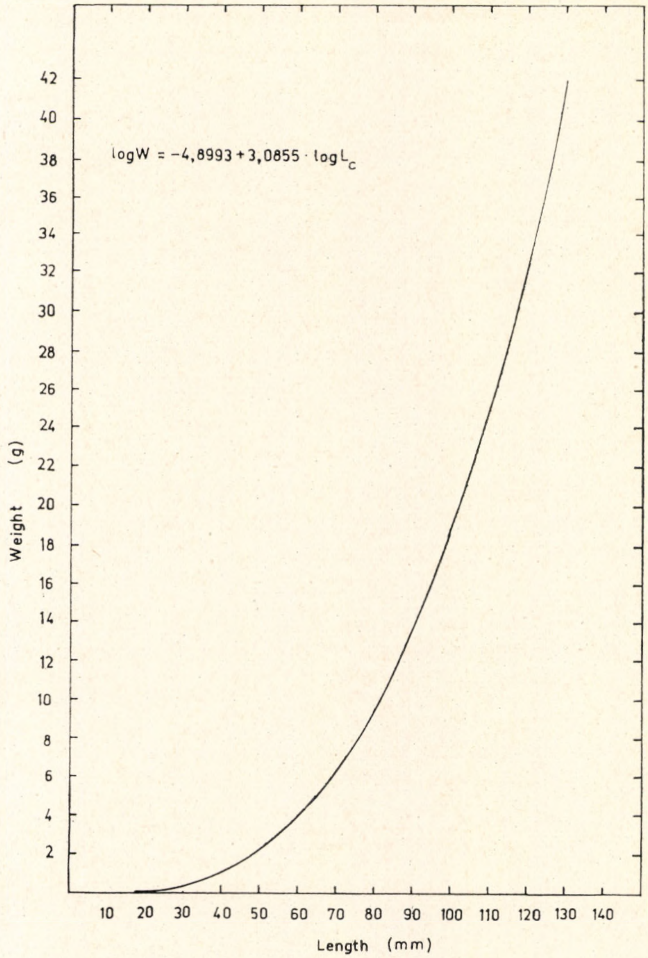

Fig. 4. Relation of standard length and weight calculated for both sexes. W = body weight (grams), L_c = standard length (mm)

age group 0+ is 3.2 cm. Other values except that of age group 1+ approximate the above straight line *(Fig. 5)*.

There is a linear connection between the log (L_∞ — 1_t) values and age. The straight line indicating the level of log L_∞ and another one determined by the logarithms of the body size differences give a point of intersection. When projecting this point to the abscissa, $t_0 = -0.522$ year is obtained, indicating that hypotetic period of time at which the size of the ruffe would have been zero. The slope of the straight line is $K = 0.287$ *(Fig. 6)*. Substituting the parameters thus obtained into the growth-model of BERTALANFFY, a slightly arched curve is obtained for the growth of ruffe population in Lake Balaton when plotting the desired values *(Fig. 7)*. The growth curve obtained from the equation of BERTALANFFY apart from the low value of age group 0+, shows no significant differences from the values calculated from the

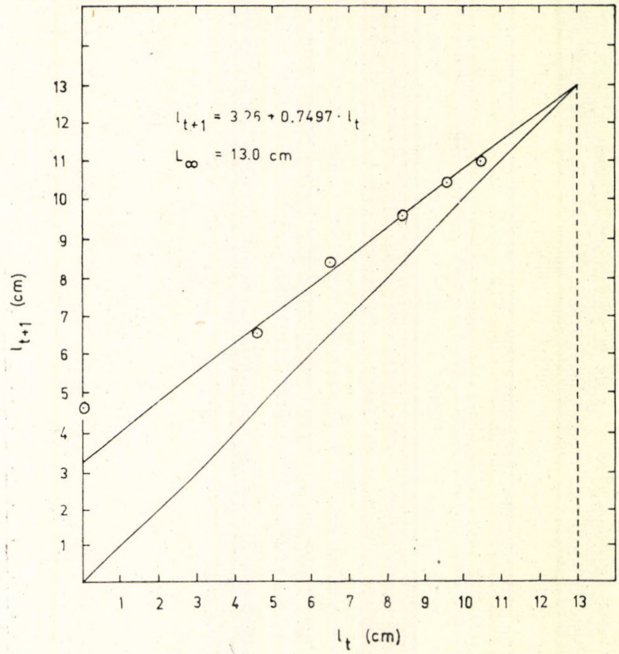

Fig. 5. Increase in the standard length of ruffe using WALFORD's method. l_t = body length in t time; l_{t+1} = the same one year later. The asymptotic length

$$L_\infty = \frac{3.26}{1-0.7497} = 13.0 \text{ cm}$$

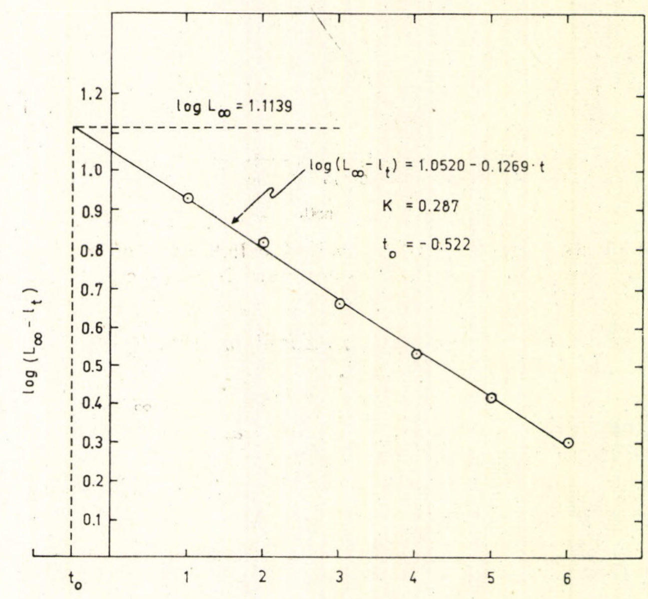

Fig. 6. Logarithms of the differences between the asimptotic length (L_∞) and the actual standard lengths at t period of time as plotted against the successive years. The slope of the straight line: $K = 0.287$; $t_0 = -0.522$ year

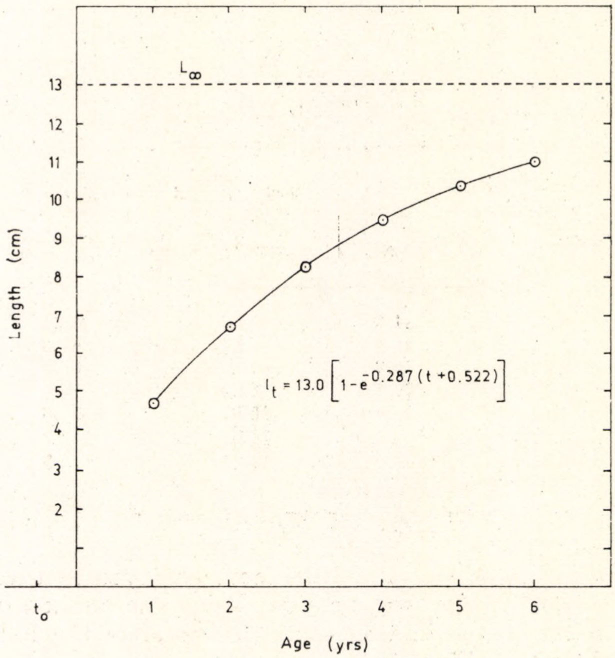

Fig. 7. Annual average growth rate of standard length plotted using BERTALANFFY's model, from the age group 1+ upwards

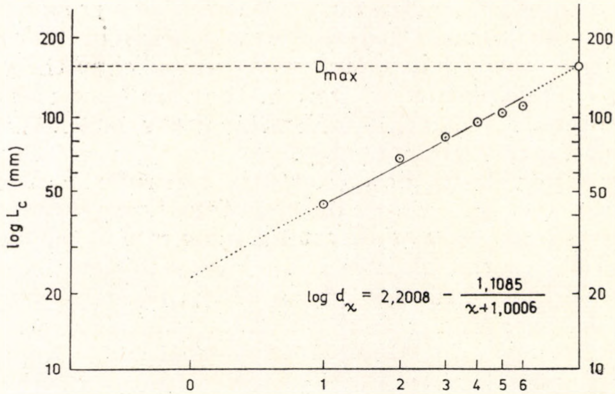

Fig. 8. Growth of ruffe population in Lake Balaton as plotted on the basis of KRÜGER's model on double logarithmic axes. The original equation in the logarithmic form:

$$\log d_\chi = \log D_{\max} - \frac{1}{\chi + \xi} \log N$$

where d is the standard length at an age of χ (χ is identical with t and d with l); $D_{\max}$ is the maximal size (identical formally with L_∞); N is the growth constant (identical formally with K); ξ is an additive value of time, matemathically it represents prenatal age (formally it is identical with t_0). See for comparisons the model of BERTALANFFY. L_c is the standard length in mm scales. In order to make comparisons the values derived by various methods are summarized in *Table III*. The highest values were gained by the WALFORD's plot.

TABLE III

Growth data of ruffe population in Lake Balaton on the basis of different methods

Age groups	Actual age (years) $(t + t_0)$	Back calculated standard length in mm			
		from scales	WALFORD's plot	BERTALANFFY's equation	KRÜGERS's equation**
0+	0.52	31.2	32.6	18.1	20.3
1+	1.52	45.9	55.1	46.3	44.3
2+	2.52	65.0	70.1	66.7	67.8
3+	3.52	84.3	85.1	82.6	83.9
4+	4.52	95.8	100.1	94.6	95.4
5+	5.52	104.4	107.6	103.2	103.8
6+	6.52	109.9	115.1	110.0	110.5

** In this case the actual ages expressed in years mean $\chi + \xi$ ($\xi = 1.00$; $\chi = t$).

In order to investigate the differences observed in the growth curves, the KRÜGER's (1965) model was applied. Using the method of calculation of GILLBRICHT in the determination of the parameters the following constant values were obtained *(Fig. 8):*

$$\log D_{max} = 2.2008; \quad \xi = 1.0006; \quad \log N = 1.1085.$$

Back calculated standard lengths for the different age groups by substituting the parameters in the original equation, are summarized in *Table III*. The values of standard length closely follow somewhat parabolically the straight line on the double-logarithmic plotting of growth. They are between the values back calculated from the scales and those of BERTALANFFY model. This method gives the lowest value for the age group 1+.

Thus the data reveal a slow growth rate in ruffe in Lake Balaton. Its body length is between 3—4 cm by the end of the first year of growth and the increase in standard length is of almost the same rate in the first 4 years (age groups 0+ and 3+), although later it diminishes to some extent. The divergence is not significant in the age groups indicating a rather uniform growth of fish of the same age. Among the methods used for matemathical description of the growth the model of KRÜGER (1965) yielded values from the age group 1+ upwards being nearer those back calculated from scales, however, neither values given by the model of BERTALANFFY (1957) differ significantly from the latter.

The evaluations carried out by employing different methods equally indicate that the growth of ruffe is slow in Lake Balaton, apart from sporadic extreme values.

Discussion

The formation of annual rings is almost uniform on the well developed scales of the ruffe though the random appearance of accessory and disturbing rings is also observed. The occurrence of indistinct or adherent rings is rarer than on the scales of pike-perch (Biró, 1970). In spite of the small size of the scales the annual rings can be studied well in all age groups. The change of the total oral radius is directly proportional with the increase in standard length.

The relatively slow rate of growth indicated by the data may be connected with the peculiar ecological factors of Lake Balaton as well as with feeding relations. According to previous investigations (Tölg, 1960) the food of ruffe in Lake Balaton is composed by benthic organisms, from a quantitative point of view the first place is occupied by Chironomids. The zooplankton is also significant in their feeding (*Cyclopids*, *Alona* sp. and intermittently *Corophium curvispinum* mainly for those hunting among the vegetation), however, it plays a more important role in the food of the fries. A decrease of benthic fauna has been observed (Ponyi et al. 1968) owing to pesticides pollution of the water. A similar cause may decrease the population of ruffe, too. The effect of pesticide accumulation probably directly manifests itself; unfortunately comparable data are not at our disposal from earlier investi-

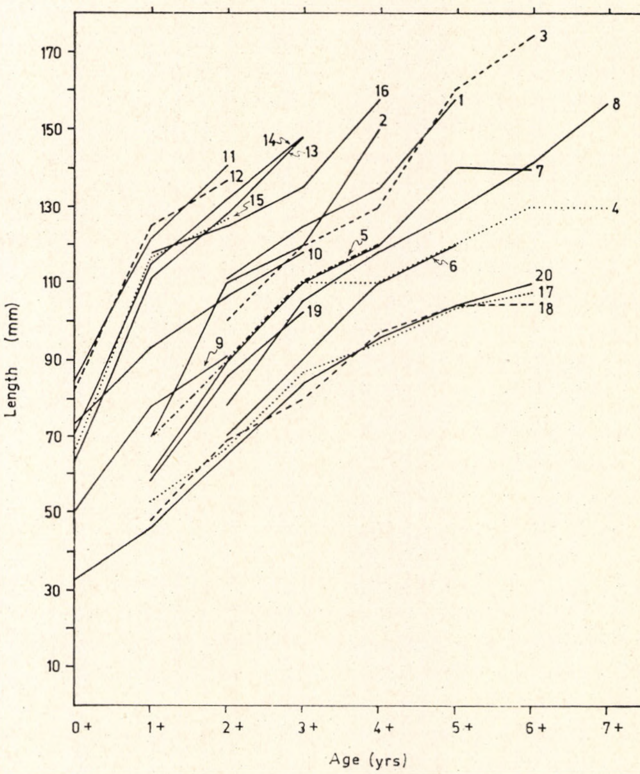

Fig. 9. Growth curves plotted from growth data observed in European waters (1—16 for total length, 17—20 for standard length): 1 — Ostsee (Neuhaus, 1934), 2 — Sakrower See, 3 — Darsser Bodden, 4 — Br. Lucin (Bauch, 1955), 5 — Oderhaff (Neuhaus, 1934), 6 — Müggelsee, 7 — average of 23 lakes (Bauch, 1955), 8 — waters of Roumania (Cărăusu, 1952), 9—10 — Stettiner Haff, 11—12 — Frischen Haffs (Neuhaus, 1934), 13 — Finkenwärden, 14 — Petroleumhafen, 15 — Holzhafen (Mohr, 1922, cit. by Neuhaus, 1934), 16 — Lebbiner Schaar (Neuhaus, 1934), 17 — Slapy Water, 18 — Pastviny, 19 — Slapy (Oliva and Vostradovský, 1960), 20 — Lake Balaton (present investigations)

gations. The age distribution of ruffes indicate a high natural mortality in which, beside the above reasons, the predatory fishes (pike-perch, eel) play also an important role.

Since ruffe represents one of the major components of the food of pike-perch (weight group of 300—500 g; BIRÓ and ELEK, 1969; BIRÓ unpubl.) it is desirable to know not only the rate of its growth but also its population dynamics and food in order to clear up the quantitative relations of the food-chain of pike-perch (these problems will be discussed elsewhere).

The data of scale investigations unanimously prove that ruffe in Lake Balaton grows slowly. The primary reason is most probably the qualitative and quantitative composition of the food and by no means the interspecific effects being realized in the otherwise not too dense population.

Among the mathematical models KRÜGER's (1965) proved to be reliable for the description of the growth of ruffe. Even according to KRÜGER his model is more suitable for describing the growth of small-sized fishes than the previous other formulas in both the embryonal and postlarval period of life. The plotted growth curve includes three points of inflexion (in our case only one, at an age of 2.7 years). The formally identical parameters of the models of BERTALANFFY and KRÜGER significantly differ from each other as far as their values are concerned, however, the curves are very similar.

Other data on the growth of ruffe reveal that the largest body size is rather different in examined waters. It is mainly between 10—15 cm, very seldom, e.g. in River Danube, it reaches 25—30 cm and 200 g. Extreme body lengths have been reported from Lake Ciarsamba-Turcia (40 cm) and from Siberian waters (50 cm, 400—600 g) (CĂRĂUSU, 1952). The latter data are inordinate, however, the growth of ruffe is generally more rapid in the waters of Europe than in Lake Balaton *(Fig. 9)*. The highest rate of growth has been observed in the waters of Germany (MOHR, 1922; NEUHAUS, 1934; BAUCH, 1955) while in Slapy Water and Pastviny of Czechoslovakia (OLIVA and VOSTRADOVSKÝ, 1960) almost identical rates have been observed as in Lake Balaton.

Summary

The growth rate of ruffe has been investigated by means of scalimetric measurements in Lake Balaton. It can be established that:

1. Annual rings of the scales are regularly formed in the majority of cases, accessory rings are rare, whereas injured, regenerated scales are frequent.

2. A rather linear connection exists between the standard length and the total oral radius of the scales.

3. The specific values of body weight calculated on the basis of the parabola describing the allometric relation of body length and weight for both sexes hardly differ from those obtained by direct measurements. The value of the allometric exponent is 3.0855.

4. The growth of ruffe is slow in Lake Balaton, it is of about the same rate in the first 4 years (up to age group 3+). The slow growth is probably bears a direct relation to the amount of food.

5. Among the mathematical models applied for the description of the growth rate of the standard length, KRÜGER's (1965) proved to be more reliable than BERTALANFFY's (1957), however, there are no great differences between the values calculated by the two methods.

6. The growth rate of standard length and weight of ruffe in Lake Balaton is slower as compared to those of waters abroad. It is near to the values observed in the waters of Czechoslovakia.

REFERENCES

BAUCH G. (1955): Die Einheimischen Süsswasserfische. — *Radebeul und Berlin*, pp. 64—65.

BERTALANFFY L. (1957): Quantitative laws in metabolism and growth. — *Q. Rev. Biol.* **32,** 217—231.

BEVERTON R. J. H., S. J. HOLT (1957): On the dynamics of exploited fish populations. — *Fishery Invest. Lond.* **19,** 533 p.

BIRÓ P., L. ELEK (1969): The spring and summer nutrition of the 300—500 g pike-perch (*Lucioperca lucioperca* L.) in Lake Balaton in 1968. I. Data bearing relation to the nutritional conditions succeeding the destruction of fish in 1965. — *Annal. Biol. Tihany* **36,** 135—149.

BIRÓ P. (1970): Investigation of growth of pike-perch (*Lucioperca lucioperca* L.) in Lake Balaton. — *Annal. Biol. Tihany* **37,** 145—164.

BIRÓ P. (unpublished): The food of pike-perch (*Lucioperca lucioperca* L.) in Lake Balaton.

CĂRĂUSU S. (1952): Tratat de ihtiologie. — *Bucureşti, Acad. R. P. R.* p. 802.

ENTZ B., F. LUKACSOVICS (1957): Vizsgálatok a téli félévben néhány balatoni hal táplálkozási, növekedési és szaporodási viszonyainak megismerésére. — *Annal. Biol. Tihany* **24,** 71—86.

FRASER C. MCL. (1916): Growth of the spring salmon. — *Trans. Pacif. Fish. Soc. Seattle, for* 1915, 29—39.

KRÜGER F. (1965): Zur Mathematik des tierischen Wachstums. — *Helgoländer wiss. Meeresunters.* **12,** 78—136.

MOHR E. (1922): Beiträge zur Naturgeschichte des Barsches und des Kaulbarsches. — *Mitt. a. d. Zool. Staatsinstitut u. Zool. Museum in Hamburg* 39.

NEUHAUS E. (1934): I. Studien über des Stettiner Haff und seine Nebengewässer. II. Untersuchungen über den Kaulbarsch. — *Zeitschr. f. Fischerei* **32,** 1—35.

OLIVA O., J. VOSTRADOVSKÝ (1960): Příspěvek k poznání rychlosti růstu Ježdíka obecného *Acerina cernua* (LINNAEUS). — *Čas. Národ. Mus.* **129,** 56—63.

PONYI J., F. CSONTI, F. BARON (1968): An investigation of the content of the chlorinated hydrocarbon residues of the crustacean plankton in the Balaton. — *Annal. Biol. Tihany* **35,** 183—189.

RIBIÁNSZKY M., E. WOYNÁROVICH (1962): Hal, halászat, halgazdaság. — *Mezőgazdasági Kiadó, Budapest.*

TÖLG I. (1960): Untersuchung der Nahrung von Kaulbarsch-Jungfischen (*Acerina cernua* L.) im Balaton. — *Annal. Biol. Tihany* **27,** 147—164.

WALFORD L. A. (1946): A new graphic method of describing the growth of animals. — *Biol. Bull.* **90,** 141—147.

WOYNÁROVICH E. (1959): A 300—500 g súlyú (IV. osztályú) süllő (*Lucioperca sandra* CUV. et VAL.) táplálkozása a Balatonban. — *Annal. Biol. Tihany* **26,** 101—120.

A VÁGÓDURBINCS (ACERINA CERNUA L.) NÖVEKEDÉSÉNEK VIZSGÁLATA A BALATONBAN

Bíró Péter

Összefoglalás

Scalimetrikus mérések alapján vizsgáltuk a Balatonból származó vágódurbincsok növekedés-ütemét. A kapott adatokból megállapítható, hogy

1. A pikkelyeken az évgyűrűk az esetek többségében, szabályosan alakulnak ki, a járulékos évgyűrűk képződése ritkább, ezzel szemben gyakoriak a sérült, regenerálódott pikkelyek.

2. A standard testhossz és a pikkelyek teljes orális rádiusza között az összefüggés eléggé lineáris.

3. A testhossz-testsúly allometrikus viszonyát mindkét ivarra kifejező parabola egyenletből kifejezhető specifikus súlyadatok a közvetlenül mért testsúly-értékektől alig térnek el. Az allometriai exponens értéke 3,0855.

4. A durbincs növekedése a Balatonban lassú ütemű, s a negyedik életévig (3+ korcsoport) közel azonos növekedési konstanssal jellemezhető. A lassú növekedés valószínűleg a rendelkezésre álló táplálékmennyiséggel függ össze.

5. A standardhossz növekedési ütemének leírására alkalmazott matematikai modellek közül Krüger (1965) módszere megbízhatóbbnak bizonyult Bertalanffy (1957) eljárásával szemben, bár a két úton számított értékek között nincs nagy eltérés.

6. Külföldi megfigyelésekhez képest, a balatoni durbincsok testhossz-, illetve testsúly-gyarapodásának menete lassúbb és a csehszlovákiai vizekben megállapított értékekhez áll közel.