A C T A   I C H T H Y O L O G I C A   E T   P I S C A T O R I A

Vol. XXIV, Fasc. 1 Szczecin 1994

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Fish biology

GROWTH RATE AND AGE COMPOSITION OF ASP *ASPIUS ASPIUS* (L., 1758) FROM PIERZCHAŁY RESERVOIR

SZYBKOŚĆ WZROSTU I SKŁAD WIEKOWY BOLENIA *ASPIUS ASPIUS* (L., 1758) W ZBIORNIKU PIERZCHAŁY

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Age and growth rate of asp (Aspius aspius) from the Pierzchały Reservoir were estimated by backcalculations based on scale readings (annual rings identification). The scale reading procedure was complicated by presence of additional rings, called "juvenile" (these appearing within the first year's increment) and "spawning" (present on scales taken from individuals older than 3 years). These additional structures were not characteristic for all the examined individuals. Localisation of the first annual ring was complicated by fairly fast growth rate during winter, so the typical zones of narrow sclerites, indicating slow–growth season did not occur, affecting the scale readability. The quantitative share of asp in control catches amounted to 9%. Most of these individuals (70%) were to 4 to 7 years old. The oldest asps were aged 12, at body length of 66 cm and body weight of 4500 g. The Pierzchały reservoir is merely exploited by fishermen.

INTRODUCTION

Ichthyological research works on water bodies, included in national nature preservation areas, are carried out sporadically, as they are restricted by nature preserving legal regulations. Although these limitations, such reservoirs play an important role in experiments dealing with fish growth and age composition, due to limited human impact, imposed on such water bodies. The Pierzchały Reservoir as well as adjacent area were established as a sanctuary mainly because they are a habitat of beaver. This reservoir was a place of numerous ecological studies.

Commercial catches usually destroy natural trophic relationships of ecosystem, as professional fishermen's attention is usually focused on high–market–value fish species, mainly predatory ones. However, fishermen are marely interested in catching asp, while anglers find this species valuable.

The number of researches dealing with asp in Poland is very limited, and these works concern populations inhabiting Vistula River (Backiel, 1964; Kopiejewska, 1986). Other data related to this topic are presented in papers by Cihara (1960), Fortunatova and Popova (1973), and Kazančeev (1981). Hence, researches concerning growth of asp are strongly required, especially those focused on the role of asp as a predatry species. It's main food in Vistula River are bleak, gudgeon, roach, dace and periodically undermouth (Horoszewicz, 1964) and in the Pierzchały reservoir – roach (Martyniak and Terlecki, 1994). Hence, asp can be used as a tool in reconstruction of natural predator–prey relationships in degradated dam reservoirs and rivers.

The aim of this study was threefold: evaluation of possibility to use scales in ageing, specification of age composition and estimation of growth rate of asps from the Pierzchały Reservoir.

STUDY AREA

The Pierzchały Reservoir is situated in northern Poland, south from Braniewo town. Its total area is 240 ha, and volume amounts to 11 450 000 m^3. Construction of the reservoir has been completed in 1917 on the river Pasłęka. Spring of the Pasłęka River is situated near Gryźliny village, north of Olsztyn town. In its upper part the rivers flows through several lakes and, in its lower part, through the Pierzchały Reservoir, where its bed's width is around 20 m, and the maximum depth is 5 m. The Pasłęka River is 211 km long and the area of its drainage–basin amounts to 2 330 km^2.

Bathymetric as well as phytosociological studies revealed that the Pierzchały Reservoir resembles "gutter–type" lakes. The reservoir does not have continuous and dense bulrush zone. The bulrush communities are formed by: *Phragmites communis, Gliceria aquatica, Schaenoplectus lacustris, Carex flava, Typha latifolia, Carex rostrata* and *Irys pseudoacorus*. The nympheid zone is formed by: *Nuphar luteum, Myriophyllum spicatum, Potamogeton lucens, Potamogeton crispus, Potamogeton demersum* and *Elodea canadensis* (Scientific Club of Hydrobiologists and Fishermen, 1977).

On the ground of control catches the presence of 20 fish species was stated in the Pierzchały Reservoir: carp (*Cyprinus carpio*), tench (*Tinca tinca*), bream (*Abramis *brama*), white bream (*Blicca bjoerkna*), crucian carp (*Carassius carassius*), golden carp (*Carassius auratus gibelio*), chub (*Leuciscus cephalus*), orfe (*Leuciscus idus*), roach (*Rutilus rutilus*), rudd (*Scardinus erytrophtalmus*), bleak (*Alburnus alburnus*), gudgeon (*Gobio gobio*), asp (*Aspius aspius*), undermouth (*Chondrostoma nasus*), spiny loach (*Cobitis taenia*), perch (*Perca fluviatilis*), pike–perch (*Stizostedion lucioperca*), ruffe (*Gymnocephalus cernuus*), eel (*Anguilla anguilla*), pike (*Esox lucius*) and burbot (*Lota lota*). The experimental catches were dominated by roach, bream, asp, tench and perch.

MATERIALS AND METHODS

Samples of asps were catched with gillnets (35–100 mm mesh size). In total 224 individuals were collected from 1975 till 1979. Catched fishes were weighed with accuracy up to 10 g. Body length (l.c.) as well as total length (l.t.) were measured with accuracy up to 0,5 cm. Total length corresponds with that defined by Ricker (1979) as natural length. From 5 to 10 scales from the first row over lateral line at altitude of first rays of dorsal fin were collected from each individual. Scale caudal radius measurements for backcalculations purposes were performed under a low–power stereo–microscope, equipped with special messuring table. Detailed observations of scales were performed under a microfilm reader (magnification 17,5 x). Validation of age estimation based on scale readings was made according to the procedure given by Sych (1971, 1974).

Growth rate was calculated on the ground of scale readings, performed for each individual and every consecutive annual increment. The dependence of scale caudal radius's growth (S) upon body length (L) was described by polinomial of the third degree (Fig. 1). In the case of asp, the first scales form at the fish length of around 2 cm (Koblickaja, 1981). By implementation of the above mentioned value, of coordinates S=0 and L=2 cm, into the L – S relationships analysis, better adjustment of estimated model to empiric data has been achieved (Heese, 1992).

The growth rate calculations are based on two function of L – S dependence and its reverse form S – L (Heese, 1992). The reverse function was calculated by change of data in the set of coordinates.

$$L_n = a + bS_n + cS_n^2 + dS_n^3 \quad (1)$$

$$S_t = a_1 + b_1L_c + c_1L_c^2 + d_1L_c^3 \quad (2)$$

where: L_n – fish length in age n,

L_c – fish length at the time of sampling,

S_n – length of scale's caudal radius, corresponding to certain annual rings,

S_t – theoretical length of scale's caudal radius at given fish length L_c,

a, b, c, d, a_1, b_1, c_1, d_1 – polynomial parameters.

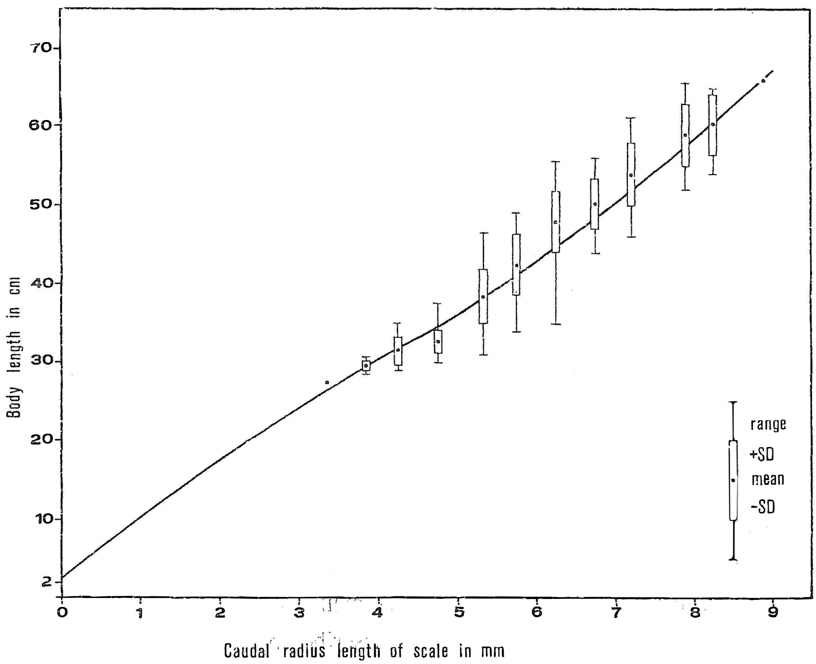

Fig. 1. Relationship between length of scale's caudal radius and asp's body length

Procedure:

a. function S_t (2) was used to calculate theoretical length of scale's caudal radius, with L_c = fish length at the time of sampling,

b. corrective alteration was calculated: $f = S_t/S_c$ (S_c = total length of scale's caudal radius),

c. for values red from scale $S_1, S_2, \ldots, S_n$ following products were calculated $fS_1, fS_2, \ldots, fS_n$,

d. values of these products $fS_1, fS_2, \ldots, fS_n$, were then used in function (1), to calculate $L_1, L_2, \ldots, L_n$, for instance:

$$L_1 = a + b\,fS_1 + c\,fS_1^2 + d\,fS_1^3$$

Below the formulas used for asp growth rate calculations are presented:

$$L = 2.15 + 7.58\ S - 0.198\ S^2 + 0.0167\ S^3 \qquad (3)$$

$$S = -0.29 + 0.1366\ L + 0.000288\ L^2 - 0.000004\ L^3 \qquad (4)$$

The calculations were performed using computer technique. Application of the above presented procedure should reduce influence of non–proportional growth of scale, during body length growth, on growth rate calculations.

The growth rate was estimated with application of von Bertalanffy's equation (Beverton and Holt, 1957):

$$L_t = L_\infty\ [1 - e^{-K(t - t_0)}] \qquad (5)$$

where: L_t – length of fish in age t,
L_∞, K, t_0 – parameters calculated on the ground of empirical data.

The dependence of body weight upon body length was estimated by the method of smallest squares, using the below presented function:

$$W = a\ L^n \qquad (6)$$

or

$$\log W = \log a + n \log L \qquad (7)$$

where: L – fish body length,
W – fish body weight,
a, n – proportionally coefficients.

On the ground of calculations based on formulas (5) and (7) modified von Bertalanffy's equation, concerning growth of fish body weight, was estimated:

$$W_t = W_\infty\ [1 - e^{-K(t - t_0)}]^n \qquad (8)$$

where: W_t – fish body weight in age t,
W_∞ – asymptotic body weight, calculated according to equation (7), where L is substituted with L_∞,
K, t_0 – parameters from equation (5),
n – proportionally coefficient taken from equation (6).

RESULTS AND DISCUSSION

Evaluation of possibility to use asp scales for age validation purposes

Scales of asp, at the place from which they are taken for age validation purposes, are relatively big and of proportional shape. Detailed examination of the scales, using high magnifications, assure the previous reports (Backiel, 1964), that scales can be used for age validation of asps (Fig. 2). Scales collected from around 30% of the investigated individuals were very readable. Annual rings were very distinct and the scale's increments enclosed between them consisted of two groups of sclerites: widely and tightly packed. The latter part was usually much narrowes. This occured only on oral and lateral parts of scale, as within caudal part of scale sclerites are dispersed rather evenly. In the case of asp, the number of sclerites on caudal part of scale is also smaller than on other parts of the same scale (Fig. 3). Group of 2 – 3 sclerites from lateral part of the scale is represented by only one sclerite on caudal part of the same scale.

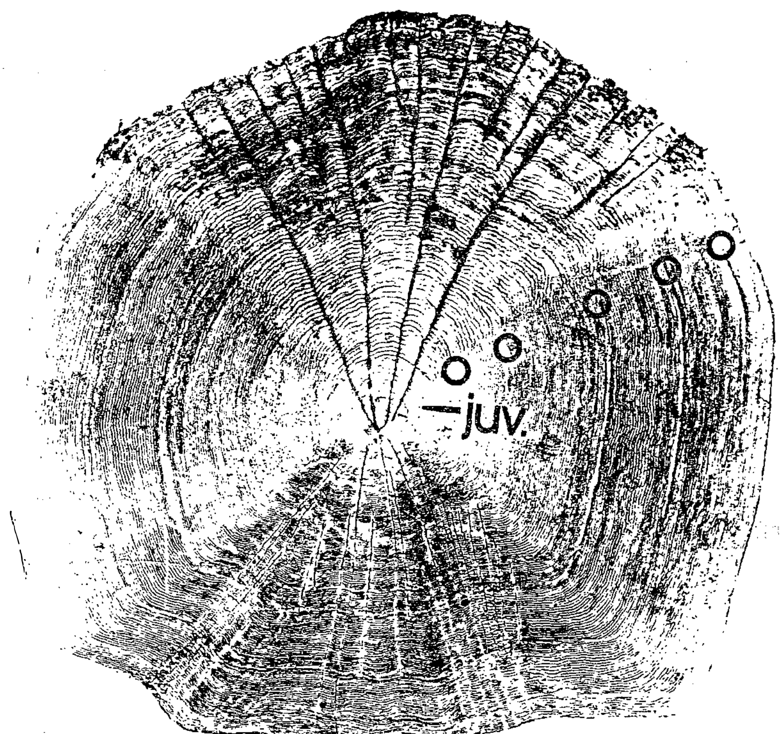

Fig. 2. Scale collected from asp of 44 cm body length (l.c.). The fish age was estimated as 5+. Annual rings (○) as well as juvenile ring (juv.) are indicated

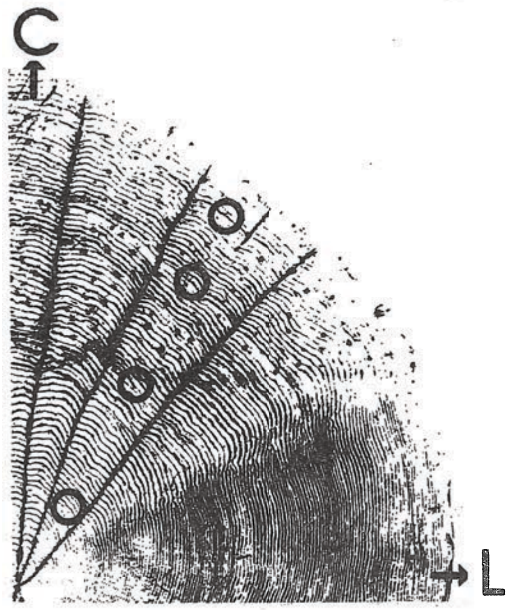

Fig. 3. Diference in image of sclerites between caudal (c) and lateral (l) parts of scale. The scale was collected from fish of body length (l.c.) equal to 34 cm. The fish age was estimated as 4+. The first two annual rings poorly visible

However, despite high scales readability (big, proportional and easy to observe), some additional structures occur, affecting correctness of age validation. Among these structures the most important ones are two kinds of additional rings: so called "juvenile" and "spawning".

The first one (juvenile) is always the closets to the scale center and if it occurs, it is usually easiest to find in on the lateral part of the scale. The juvenile ring was distinguished on the ground of the fact that the width of scale's increment between that ring and the ring marked as the first year's annual ring was very narrow. the backcalculated fish length at the time of the juvenile ring formation was about 9 cm, while the length at the time of first–year ring formation averaged 13.5 cm. Asps from delta of Volga River reached 9 cm of body length in August, after the first 3 – 4 months of their life (Kazančeev, 1981).

Additional rings, recognized as spawning, also called "double rings", occur after third year of asp,s life and are especially distinct on caudal part of scale (Fig. 4). They are situated close before the true annual ring. Asp spawns in April/May (Kopiejewska, 1986) –

at the same time when the annual ring is being formed (Backiel, 1962). The aforementioned author claims that annual rings form during the period lasting from May to beginning of July. On the ground of analysis of scales collected from the investigated asp population, inhabiting the Pierzchały Reservoir, this period should be even prolonged to beginning of August.

Fig. 4. Additional ring (add.) called "spawning" or "double ring" visible before the fifth annual ring. The scale was collected from fish of body length (l.c.) equal to 49 cm. The fish age was estimated as 5+

Another difficulty, disturbing correct interpretation of asp age, is poor clarity of scales within the first two years of its life. Both first and second annual rings can be identified only by careful examination of patterns, created by zones of narrow and wide sclerites, under high magnifications. Kohija (1978) stated that juvenile asps fed intensively also during winter. The fact of intensive feeding of asps in winter may be the main reason of the indistinct picture of annual ring on scales.

Age composition

The catched individuals age from 2 to 12. During the first two years of the study (1975, 1976) about 1/3 of asps were 6 years old (Table 1). During the next consecutive years (1977, 1978) the tendency was similar, although 7 and 8 years old individuals dominated. In the last year •f the study (1979) catches were dominated by asps aged 3 (42%). That was most probably caused by change of sampling sites as well as by application of different fishing techniques. Taking into account the whole study period 70% of collected asps were aged as 4 to 7 years old.

In the case of Vistula River, where between 1955 and 1957 asp was one of intensively exploited fish species (Backiel, 1964), most of catched individuals were 3 to 6 year old.

Table 1

Age composition of asps from the Pierzchały reservoir collected during conswecutive years of experiment

Year	Share	Age classes											Total
		2	3	4	5	6	7	8	9	10	11	12	
1975	n	1	7	11	10	17	6	4					56
	%	1.8	12.5	19.6	17.9	30.4	10.7	7.1					100
1976	n		1	7	3	11	9	2	3	1			37
	%		2.7	18.9	8.1	29.8	24.3	5.4	8.1	2.7			100
1977	n		2	9	9	9	12	9	2		1	1	54
	%		3.7	16.7	16.7	16.7	22.2	16.7	3.7		1.8	1.8	100
1978	n	1	2	7	4	7	5	8	4	2			40
	%	2.5	5.0	17.5	10.0	17.5	12.5	20.0	10.0	5.0			100
1979	n	1	13	4	5	3	1	2	2				31
	%	3.2	41.9	12.9	16.1	9.7	3.2	6.5	6.5				100
Total	n	3	25	38	31	47	33	25	11	3	1	1	218
	%	1.4	11.5	17.4	14.2	21.5	15.1	11.5	5.0	1.4	0.5	0.5	100

The growth rate

Natural length of investigated fishes remained within the range of 33 ÷ 78 cm; the respective values for body length were 27.5 ÷ 66.0 cm. Weight of these individuals ranged from 240 to 4530 g.

Intensive growth of asp takes place, beside the first year, during the first 5 years, when the average annual length increments are higher than 6 cm (Table 2). In comparison to asp's population from Vistula River (Table 3), asps from the Pierzchały Reservoir grow faster during the first few years of their life. Later – e.g. in 6 to 9 years their growth rate is similar. Among the comparable data, characteristic of asp's population from the delta of Volga River (Fortunatova and Popova, 1973) was given – they grew much faster than asp's populations, inhabiting Polish inland waters.

Table 2

Growth rate of investigated asp population from the Pierzchały reservoir

Method	Body length (l.c.) in consecutive years, expressed in cdntimeters											
	1	2	3	4	5	6	7	8	9	10	11	12
Back calcu-lations	13.5	20.8	27.5	34.1	40.2	44.8	48.7	52.2	55.2	58.3	61.2	64.1
SD	1.6	2.2	2.6	3.3	2.9	2.4	2.2	1.8	2.7	2.5		
N	218	218	213	186	148	111	68	32	15	5	3	1
Mean annual growth	13.5	7.3	6.7	6.6	6.1	4.6	3.9	3.5	3.0	3.1	2.9	2.9
Theore-tical*	9.3	20.0	27.2	34.2	40.1	45.2	49.4	53.1	56.1	58.7	61.0	62.8
Body weight in consecutive years, expressed in grams												
Theore-tical**	14	107	310	608	975	1381	1803	2220	2621	2996	3341	3653

* – based on equation (5)

** – based on equation (8)

The model of growth rate of body length (parameters – $L_\infty = 73.3$, $K = 0.1646$ and $t_0 = 0.18$) is presented by the formula:

$$L_t = 73.3\,[1 - e^{-0.1646(t - 0.18)}]$$

Table 3

Comparison of growth rate of asp's populations inhabiting different sites

Water body (Author)	Body length (l.c.) in consecutive years, expressed in centimeters											
	1	2	3	4	5	6	7	8	9	10	11	12
Slapskie Reservoir (Cihar, 1960)	10.7	16.5	21.2	28.1	36.2	43.3	50.6					
Delta of Volga River (Fortunatova and Popova, 1973)	15.8	27.7	35.5	39.8	46.0	50.0	53.2	56.0				
Vistula River (Backiel, 1964)	8.3	14.8	23.3	29.0	36.3	42.4	46.6	51.0	56.3			
Pierzchały Reservoir (original)	13.5	20.8	27.5	34.1	40.2	44.8	48.7	52.2	55.2	58.3	61.2	64.1

Growth rate of body weight is presented by means of multiplicative as well as logarythmic functions:

$$W = 0.0185\ L^{2.9452}$$

or:

$$\log W = 2.9452 \log L - 1.7328$$

where: W – body weight in grams,
L – body length in centimeters.

The model of body weight growth, expressed by modified von Bertalanffy's equation (parameters – $W_\infty = 5758$, $K = 0.1646$ and $t_0 = 0.18$) is presented below:

$$W = 5758\ [1 - e^{-0.1646\ (t - 0.18)}]^{2.95}$$

In this study asp's growth rate calculations were performed according to the procedure based on polynomial of the third degree. The aim of such solution was to achieve high precision in estimation of growth rate. It was assumed, that non–proportional growth of scales (see: Fig. 1) would have influence the results of backcalculations.

Results, obtained in this study, were compared to calculations of growth rate, performed according to Fraser–Lee equation (9) with "C" constant value. These calculations brought very similar results, and the differences were statistically insignificant. (Heese, 1992). The "C" constant value used in these calculations was equal to the body length of asp at the time when the first scales were being formed – i.e. 2 cm. This equation is presented below:

$$L_n = C + (S_n / S_c)(L_c - C) \quad (9)$$

where: L_n – fish length at the age of n years,

C – 2 cm,

L_c – fish length at the time of sampling,

S_c – total length of scale's caudal radius,

S_n – length of scale's caudal radius from the scale center to the annual ring.

So, the practical conclusions arises, that asp growth rate backcalculations can be made, applying easy–to–use Fraser–Lee equation, with constant value "C" = 2.0 cm.

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SZYBKOŚĆ WZROSTU I SKŁAD WIEKOWY BOLENIA, *ASPIUS ASPIUS* (L., 1758) W ZBIORNIKU PIERZCHAŁY

STRESZCZENIE

Ryby do badań pozyskano w zbiorniku zaporowym Pierzchały utworzonym na rzece Pasłęce. Zbiornik oddano do użytku w 1917 r. Dominującymi gatunkami w połowach kontrolnych były, kolejno: płoć, leszcz, boleń, lin i okoń. Ogółem w zbiorniku stwierdzono obecność 20 gatunków ryb. Badania szybkości wzrostu wykonano metodą odczytów wstecznych prowadzonych z łusek dla 224 sztuk boleni. Ryby łowiono przy użyciu wontonów o rozmiarach oczek od 35 do 100 mm. Materiał badawczy pochodzi z kolekcji z lat 1975–1979.

Łuski boleni okazały się stosunkowo dobrze czytelne, a ze względu na duże rozmiary i proporcjonalne kształty są dogodnym obiektem do pomiarów i określania liczby pierścieni rocznych. Określanie wieku z łusek boleni jest utrudnione przez pierścienie dodatkowe typu młodocianego i tarłowego. Wzrost bolenia w zbiorniku Pierzchały jest zbliżony do boleni z Wisły, choć w pierwszych czterech latach rośnie zdecydowanie szybciej.

Podstawą do zastosowanej w tej pracy procedury obliczeń tempa wzrostu był charakter zależności L – S, którą opisano wielomianem trzeciego stopnia. Szczegółowe badania porównawcze sugerują możliwość obliczania tempa wzrostu bolenia metodą odczytów wstecznych wykorzystując prosty w zastosowaniu wzór Frasera–Lee ze stałą "C" równą 2 cm.

Received: 1992.07.23

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