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. XXVII, Fasc. 1 Szczecin 1997

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Fish biology

DIAGNOSTIC FEATURES OF SCALES OF BREAM *ABRAMIS BRAMA* (L.) AND WHITE BREAM *BLICCA BJOERKNA* (L.)

CECHY DIAGNOSTYCZNE ŁUSEK LESZCZA *ABRAMIS BRAMA* (L.) I KRĄPIA *BLICCA BJOERKNA* (L.)

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Diagnostic features of bream and white bream scales were investigated. Bream scales were collected from seven sites and white bream ones came from four sites. Both environmental conditions and fish growth rate varied in the chosen sites. The scales taken from the analysed populations varied in shape, localisation of the scale nucleus, number of radii on caudal and oral fields, and by different ratio between their height and width.

INTRODUCTION

The first communications concerning scales come from the middle of the 12^{ve} century. The number of papers related to this topic increased significantly in the 19th century, developing our present knowledge of the scale structure. This progress enabled not only the description of various fish species but also their classification.

In some of the fish species the characteristic shape and structure of their scales may be a background criterion for determination of species. Susłowska and Urbanowicz (1984) developed a key to determine the scales of cyprinids inhabiting Polish waters. The material used in their study originated mainly from Łódzka Height (the Biebrza River basin).

The aim of the present study was to compare selected diagnostic features of scales of the bream and the white bream, representing different bodies of water, with the corresponding data from the literature. The selected sites varied in the fish growth rate and environmental conditions.

Morphology of scales

Body of bream and white bream is covered with cycloid (a type of elasmoid) scales. They consist of two layers: thinner ornamented superficial layer—hyalodentine (or osseous) and internal thicker lamellar layer—isopedine (the basal plate). The external layer is acellular and well mineralized (Meunier 1984). The most common kind of ornamentation

of this layer are circuli. Further analysis of the circuli under a SEM microscope reveal presence of small convexities, sitting on their surface, which are needle-like or more rounded in shape. Meunier and Sire (1981) suggested that these small circuli "teeth" may serve as a taxonomic feature. The basal plate is a stacking of collagenous fibred layers. In one layer, fibrils are parallel to each other (Nagięć and Murawska 1992). Scales of cyprinids are usually shield-shaped (Fig. 1). The scale may be divided into two parts: oral (anterior) and caudal (posterior). The oral part sits in a pocket and is oriented towards the fish head, and the caudal part is oriented towards the fish tail. Usually the caudal part is darker, because it is covered with pigments (Brylińska et al. 1991).

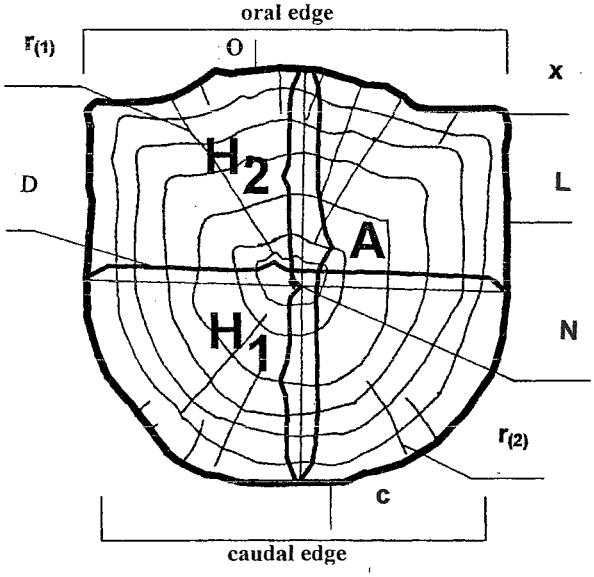

Fig. 1. Morphological and diagnostic features of a scale
$r_{(1)}$—primary ray; $r_{(2)}$—secondary ray; N—nucleus;
$A = H_1 + H_2$—height of a scale; D—width of a scale;
a—anterior edge; c—corner; L—lateral edge;
p—posterior edge.

Susłowska and Urbanowicz (1984) distinguish four edges of scale: frontal (a), two lateral (L) and posterior (p) (Fig. 1). They claim that the frontal edge is the most differentiated. Many modifications of the edge shape may be found here, as convexities, incisions or notches. The ends of the frontal edge may form corners, which are limits between the frontal and lateral edges. The lateral edges may be slightly rounded or parallel to each other. The posterior edge is usually archous. Limits between the posterior and lateral parts are not always clear. The shape of scale edge and the ratio between height (A) and width (D) of scale are fish-species-dependent features. The following parts of scale are distinguished in its morphological description: nucleus, field, radii and circuli. The earliest part of scale is the nucleus—small area surrounded by circuli which form annuli (seasonal increments). It is not always located at the geometric centre of the scale. The location of the nucleus is an important diagnostic feature. Scale is conventionally divided into several fields placed around the nucleus: front field (oral), posterior field (caudal) or dorsal f. and ventral f. and two lateral fields. Primary radii begin at the nucleus, and the secondary ones begin at a certain distance from the scale nucleus. Both types of radii end at the edge of scale. Their function

consist in nourishment of scale and increasing its flexibility (Sire and Meunier 1981). The diagnostic features related to radii are the presence of radii on specific fields of scale and the ratio between the number of primary radii and secondary ones.

MATERIAL, METHOD AND STUDY SITE

Table 1

Characteristics of the collected material

Water body	Date	Body length (cm)	Number of scales
Bream *Abramis brama* (L.)			
Lake Sośno	15 May 1965	14.1–33.0	50
Włocławek Reservoir	22 Mar 1973	24.7–33.4	50
Lake Śniardwy	1978	22.3–41.0	50
Lake Oleckie Małe	25 Jun 1990	7.3–30.0	50
Lake Sunowo	27 Aug 1990	20.2–36.8	50
Lake Jemieliste	29 Aug 1990	20.2–36.8	50
Lake Łaźno	17 Mar 1991	25.8–39.0	250
White bream *Blicca bjoerkna* (L.)			
Lake Gosławskie	5 Mar 1971	18.0–25.5	30
Vistula Estuary	6 Aug 1974	15.0–21.9	45
Włocławek Reservoir	4 Aug 1982	17.1–26.9	45
Lake Bełdany	26 Sep 1990	15.5–28.4	288

The material used in this study consisted of scales of the bream and the white bream. Specification of the collected material and characteristics of the water bodies is given in Tabs. 1 and 2. Scales for systematic purposes were taken from the first or second row above the lateral-line at the middle part of fish body, under the dorsal fin. All scales were collected from the left side of fish body. Fish were weighed and their body length (standard length) was measured to the nearest 1 mm. Samples (3–5 scales each) were taken from 10–20 individuals from each analysed population. Additional samples were also collected from chosen populations to determine the diversity of diagnostic features of scales taken from different body locations. For the bream these samples were collected from Lake Łaźno population. The scales were taken from five locations: near the head, below the dorsal fin, near the caudal fin, stomach area, and middle part of body, below the dorsal fin, above the lateral-line (Fig. 2). In the white bream these scales were collected from Lake Bełdany population in 6 locations shown on Fig. 3. Shape of edge was described for each analysed scale. All the scale measurements were done to the nearest 0.01 mm. Both the scale height (A) and width (D) were measured. Two measurements of height were considered: H_1—from the nucleus to the caudal edge, and H_2—from the nucleus to the oral edge. Number of primary and secondary radii on oral field (r_a) and caudal field (r_p) was counted, and relative values A/D—describing scale shape, and H_1/H_2—describing location of the scale nucleus were calculated. If $H_1 = H_2$ then the nucleus shift factor equals 1, and the nucleus is located in the center of the scale; when the shift factor > 1 then the nucleus is located closer to the caudal edge of scale; when s.f. < 1 then the nucleus is closer to the oral edge.

Table 2

Characteristic of the water bodies, from which the collected material originated

Water body	River basin	Area (ha)	Average depth (m)	Fish condition	Fish growth	Source
Bream *Abramis brama* (L.)						
Lake Śniardwy	Pisa—Narew—Vistula	11340.4	5.8	good	average	IFI
Lake Sunowo	Ełk—Łęg—Biebrza	176.3	9.3	good	average	IFI
Lake Sośno	Drwęca—Vistula	187.8	4.8	v. good	v. good	IFI
Lake Oleckie Małe	Lega—Jegrznia—Ełk—Narew	220.8	10.3	average	feeble	IFI
Lake Jemieliste	Czarna Hańcza—Niemen	58.8	7.5	average	average	IFI
Lake Łaźno	Ełk—Biebrza—Narew—Vistula	604.4	5.7	bad	feeble	IFI
Włocławek Reservoir	Vistula	7040	5.5		good [1]	Bierwagen 1973
White bream *Blicca bjoerkna* (L.)						
Włocławek Reservoir	Vistula	7040	5.5		good [2]	Bierwagen 1973
Vistula Estuary		32000	2.3	good	v. good[3]	Żmudziński and Szarejko 1955
Lake Gosławskie *	Warta	378.9	1.3	good	v. good[4]	Zdanowski and Korycka 1976
Lake Bełdany	Pisa—Narew—Vistula	940.0	10.1	bad	feeble	IFI

[1] Brylińska 1996;
[2] Brylińska and Żbikowska 1996;
[3] Filuk 1963;
[4] Marciak 1977;
* Thermally polluted lake;
IFI—unpublished data from Inland Fisheries Institute, Olsztyn, Poland.

Mean value (m), standard deviation (SD), and coefficient of variability (V) were calculated for each analysed feature. Relationships between body length (x) and three selected features (y), i.e.: scale shape described by A/D ratio, location of the nucleus (H_1/H_2), and number of radii on oral and caudal fields, were determined with correlation factors (both linear and multiplicative), according to the formulae:

$$y = ax + b$$

$$y = ax^b$$

where a, b—correlation factors.

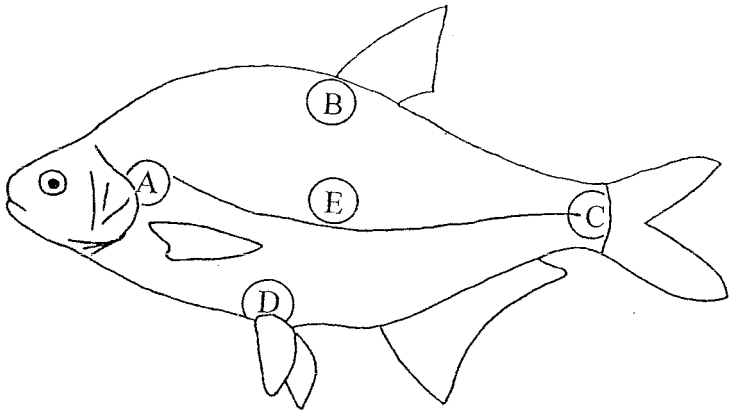

Fig. 2. Places where bream scales were taken for investigations
A–D—points for individual mutability,
E—point for populations mutability.

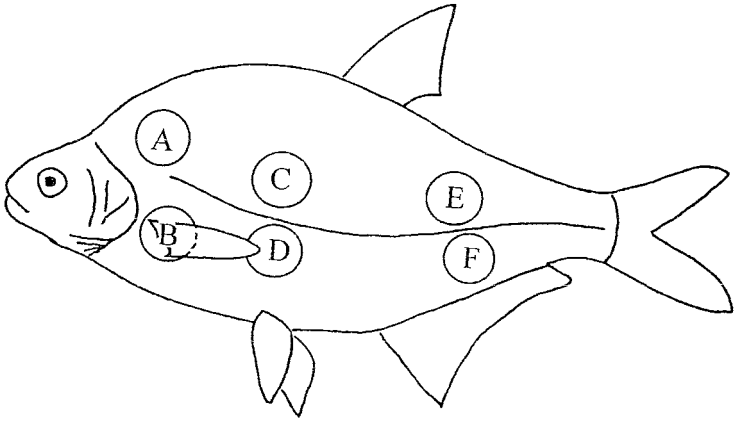

Fig. 3. Places where white bream scales were taken for investigations
A–F—points for individual mutability,
C—point for populations mutability.

RESULTS

Bream

Variability of diagnostic features of scales taken from different body locations

Scales taken from near the head (point A) and back area (point B) were smaller than these collected from other locations. Shape of scales from the head area was usually circular. The nucleus shift factor ranged from 0.9 to 1.7 (Tab. 3). The smallest number of primary and secondary radii was observed on oral and caudal fields of scales taken from the head area. These scales had poorly developed corners and their oral edge was usually undulated. Lateral edges were archeous and did not disperse in caudal part.

Table 3

Variability of diagnostic features of bream scales taken from different body sites

Point		Sandard length (cm)	A (mm)	D (mm)	A/D	r_{a1}	r_{a2}	r_{p1}	r_{p2}	H_1 (mm)	H_2 (mm)	H_1/H_2
A	Range	25.8–39.0	7.50–11.59	7.36–12.44	0.90–1.05	0–1	0–3	0–4	8–20	4.15–6.12	2.96–5.47	0.9–1.7
	$\bar{x}$	33.0	8.78	9.20	0.95	0.1	0.3	1.4	14.6	4.67	4.10	1.2
	SD	4.09	1.23	1.47	0.06	0.31	0.94	1.07	4.57	0.61	0.71	0.18
	V	12.41	14.07	16.00	6.41	316.23	316.23	76.78	31.34	13.09	17.35	16.21
B	Range	25.8–39.0	7.96–10.78	8.41–11.88	0.84–1.00	0–2	0–5	1–4	13–21	4.80–5.67	3.52–5.73	0.9–1.4
	$\bar{x}$	33.0	9.53	10.21	0.93	0.4	1.3	2.3	16.4	5.07	4.47	1.15
	SD	4.09	0.96	1.14	0.05	0.6	1.4	0.9	3.2	0.51	0.61	0.14
	V	12.41	10.14	11.24	5.74	174.80	109.09	41.25	19.75	10.09	13.70	13.36
C	Range	25.8–39.0	7.98–13.14	8.01–11.72	0.99–1.12	0–2	0–6	1–4	13–26	4.02–6.97	3.96–6.94	0.85–1.31
	$\bar{x}$	33.0	10.9	9.79	1.06	1.0	1.8	2.9	17.8	5.59	5.34	1.08
	SD	4.09	1.56	1.30	0.10	0.81	1.81	0.87	4.7	0.77	1.04	0.16
	V	12.41	14.36	13.30	10.30	81.65	100.75	30.19	26.46	13.77	19.49	14.84
D	Range	25.8–39.0	7.98–13.14	7.97–14.92	0.89–1.04	0–2	0–3	1–4	14–26	4.44–6.04	3.62–6.35	1.00–1.27
	$\bar{x}$	33.0	10.9	10.89	0.95	0.4	1.0	2.4	19.50	5.55	4.84	1.14
	SD	4.09	1.56	1.91	0.05	0.69	0.81	1.42	4.32	0.75	0.71	0.07
	V	12.41	14.36	17.57	5.70	174.80	81.65	59.58	22.19	13.60	14.66	6.76
E	Range	25.8–39.0	8.28–14.37	8.55–15.02	0.91–0.96	0–2	0–3	1–5	11–28	4.31–7.19	3.97–7.18	1.00–1.17
	$\bar{x}$	33.0	11.30	12.01	0.94	0.2	1.5	2.5	18.3	5.89	5.38	1.0
	SD	4.09	1.67	1.98	0.02	0.42	1.17	1.08	4.76	0.81	0.88	0.05
	V	12.41	14.83	16.50	2.71	210.82	78.57	43.2	26.02	13.77	16.51	4.94

Scales taken from the back area (point B) were wide, almost circular. A/D ratio ranged from 0.84 to 1.00 (Tab. 3). The mean value of the nucleus shift factor H_1/H_2 reached 1.15 and it was the highest value from among all the analysed scales from different body locations. The scales taken from the back area did not have corners or sometimes one corner was present. Oral and caudal edges varied from straight line to arch; oral edge was often undulated. Lateral edges were archeous, not always dispersing in caudal part.

Scales taken from the tail area (point C) had characteristic elongate shape. The A/D ratio reached 1.06, which was the highest value observed on bream scales taken from different body locations. The nucleus shift factor averaged 1.08. Corners were well developed. The oral edge was undulated and lateral ones were straight or slightly archeous. The average number of primary and secondary radii on the oral field reached the highest values, in comparison to scales from other locations.

Shape of scales from the stomach area (point D) was more differentiated. Both almost circular and wide, short scales were found in this location. The number of secondary radii was relatively high (19.5) on caudal field of these scales (Tab. 3).

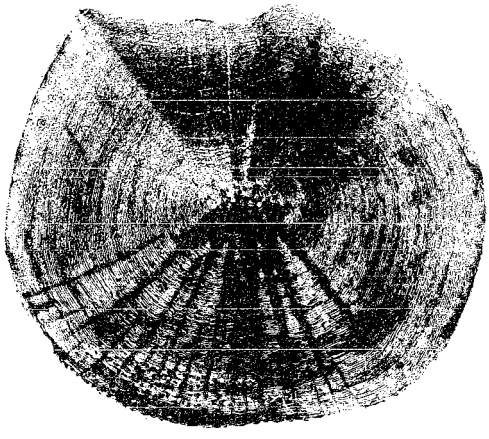

Fig. 4. Scale of bream taken from below dorsal fin and over lateral line (point E)

Scales taken from the middle part of body (point E) were shield-shaped. The nucleus was shifted to the oral edge or remained in the central part of scale (range 0.91–0.96, mean 0.94).

The H_1/H_2 ratio ranged from 1.00 to 1.17. Corners were poorly developed. The caudal edge had shape of flattened arch, oral edge was convex or almost flat, slightly undulated. Lateral edges were slightly archeous, dispersing in the caudal part (Fig. 4).

Variability of diagnostic features in individuals from the same population

Two populations from lakes Sośno and Oleckie Małe were investigated. Fish differed in body length. Scales were shield-shaped. Height to width ratio ranged from 0.77 to 0.96 in Lake Sośno population (Tab. 4), and from 0.77 to 0.95 in Lake Oleckie Małe population (Tab. 5). These scales had convex oral edge, almost flat, sometimes slightly undulated. Lateral edges were slightly archeous. The caudal edge was shaped as a flattened arch. One cor-

ner was usually better developed. The nucleus was shifted towards the oral edge. H_1/H_2 ratio in scales originating from Lake Sośno ranged from 1.09 to 1.85 (Tab. 4), and in these from Lake Oleckie Małe—from 0.90 to 1.57 (Tab. 5).

Table 4

Variability of diagnostic freatures of bream scales from Lake Sośno population (fish growth rate—very good)

	Standard length (cm)	A (mm)	D (mm)	A/D	r_{a1}	r_{a2}	r_{p1}	r_{p2}	H_1 (mm)	H_2 (mm)	H_1/H_2
	13.0	3.45	4.48	0.77	0	2	4	6	2.11	1.34	1.58
	14.1	4.35	4.85	0.89	0	3	2	8	2.82	1.53	1.85
	15.2	5.41	6.38	0.84	0	2	4	7	3.00	2.41	1.26
	18.2	6.50	7.16	0.90	0	3	3	9	3.45	3.05	1.11
	20.0	6.66	7.87	0.84	0	2	4	6	3.82	2.84	1.35
	28.2	9.94	10.74	0.92	2	1	1	19	5.60	4.34	1.29
	28.7	9.68	10.59	0.91	0	2	2	20	5.22	4.46	1.17
	33.0	12.10	13.36	0.90	0	3	2	21	6.39	5.71	1.12
	34.7	12.49	13.29	0.94	2	6	2	22	6.73	5.76	1.16
	38.5	12.25	12.72	0.96	0	2	2	22	6.41	5.84	1.09
$\bar{x}$	24.36	8.28	9.14	0.88	0.4	2.6	2.6	14.0	4.55	3.73	1.30
SD	9.37	3.42	3.42	0.05	0.84	1.3	1.0	7.27	1.70	1.73	0.24
V	38.47	41.35	37.49	6.31	210.82	51.92	41.34	51.95	37.49	46.42	18.61

Table 5

Variability of diagnostic freatures of bream scales from Lake Oleckie Małe population (fish growth rate—poor)

	Standard length (cm)	A (mm)	D (mm)	A/D	r_{a1}	r_{a2}	r_{p1}	r_{p2}	H_1 (mm)	H_2 (mm)	H_1/H_2
	7.3	2.00	2.57	0.77	0	0	4	2	1.16	0.84	1.38
	12.0	4.08	4.81	0.85	1	0	2	7	2.29	1.79	1.28
	15.0	4.93	5.29	0.93	3	2	3	4	2.70	2.23	1.21
	17.0	5.65	6.12	0.92	2	1	4	6	3.08	2.57	1.37
	18.1	5.85	7.08	0.82	3	3	5	8	3.57	2.28	1.57
	22.0	7.12	8.00	0.88	4	3	7	11	4.13	2.99	1.40
	25.0	8.00	8.67	0.92	0	2	4	10	4.15	3.85	1.08
	26.2	9.23	10.70	0.86	5	4	17	6	4.84	4.39	1.12
	30.0	11.67	12.30	0.95	2	2	4	9	5.50	6.17	0.90
	32.1	11.86	14.27	0.83	5	4	8	11	6.16	5.70	1.08
$\bar{x}$	20.47	7.03	7.98	0.87	2.5	2.1	5.7	7.4	3.75	3.28	1.23
SD	7.98	3.20	3.60	0.05	1.8	1.4	4.3	2.9	1.51	1.72	0.91
V	39.03	45.51	45.13	6.57	73.64	69.01	76.27	40.39	40.44	52.43	16.02

In scales from Lake Sośno there were 0 to 2 primary and 1–6 secondary radii on the oral field; and 1–4 primary and 6–22 secondary radii on the caudal field, respectively. Total

number of radii increased with the body length. The highest variability characterised number of primary radii on scales from Lake Sośno (V = 210.82) (Tab. 4).

Both correlation and regression coefficients, describing relationship between diagnostic features and body length were determined. The correlation coefficients were statistically important at the level of $\alpha = 0.05$ (Tab. 6). These data suggest that the scale nucleus shifts from the oral edge towards the caudal one, as the fish grows. Number of radii on oral and caudal fields also increases with increase in the fish length. These relationships are shown in Fig. 5.

Variability of diagnostic features of scales collected from the analysed bream populations

The diagnostic attributes of scales from the seven analysed bream populations are presented in Tab. 7. The shape of these scales was similar—usually shield-like. Scale diameter was higher than its height. A/D ratio amounted from 0.88 (Lake Sośno population) to 0.94 (Lake Sunowo population). The oral edge was convex or almost flat, often slightly undulated. Lateral edges were archeous, dispersing in the caudal part of scale. The caudal edge usually resembled flattened arch in shape. Corners were poorly developed, usually one of them was more pronounced. The nucleus was situated almost in the center of scale (1.02 in Lake Śniardwy population) or shifted towards the oral edge (1.32 in Lake Sunowo population).

Coefficient of variability ranged from 4.67 (Włocławek Reservoir) to 18.61 (Lake Sośno). Lake Sunowo population was characterised by the lowest number of primary (0.1) and secondary (0.5) radii on the oral field of scale. The highest number of primary radii (5.7) and the lowest number of secondary radii (7.4) on the caudal field was observed in Lake Oleckie Małe population. The highest number of secondary radii on the caudal field was observed in Lake Śniardwy population (22.4).

White bream

Variability of diagnostic attributes of white bream scales situated on different body locations

Scales taken from different body locations varied significantly. Variability of the diagnostic attributes of lake Bełdany white bream population is shown in Tab. 8.

Scales collected just behind the head, over the lateral-line (point A) were oval-shaped. There were no notches in oral edge or corners at the limits between oral and lateral edges (Fig. 6). The nucleus was shifted towards the oral edge ($H_1/H_2 = 0.552$). Similarly, in scales taken from point B—behind the head but below the lateral-line, the nucleus was shifted towards the oral edge ($H_1/H_2 = 0.531$). In these scales notches were more pronounced, also corners were well visible (Fig. 7).

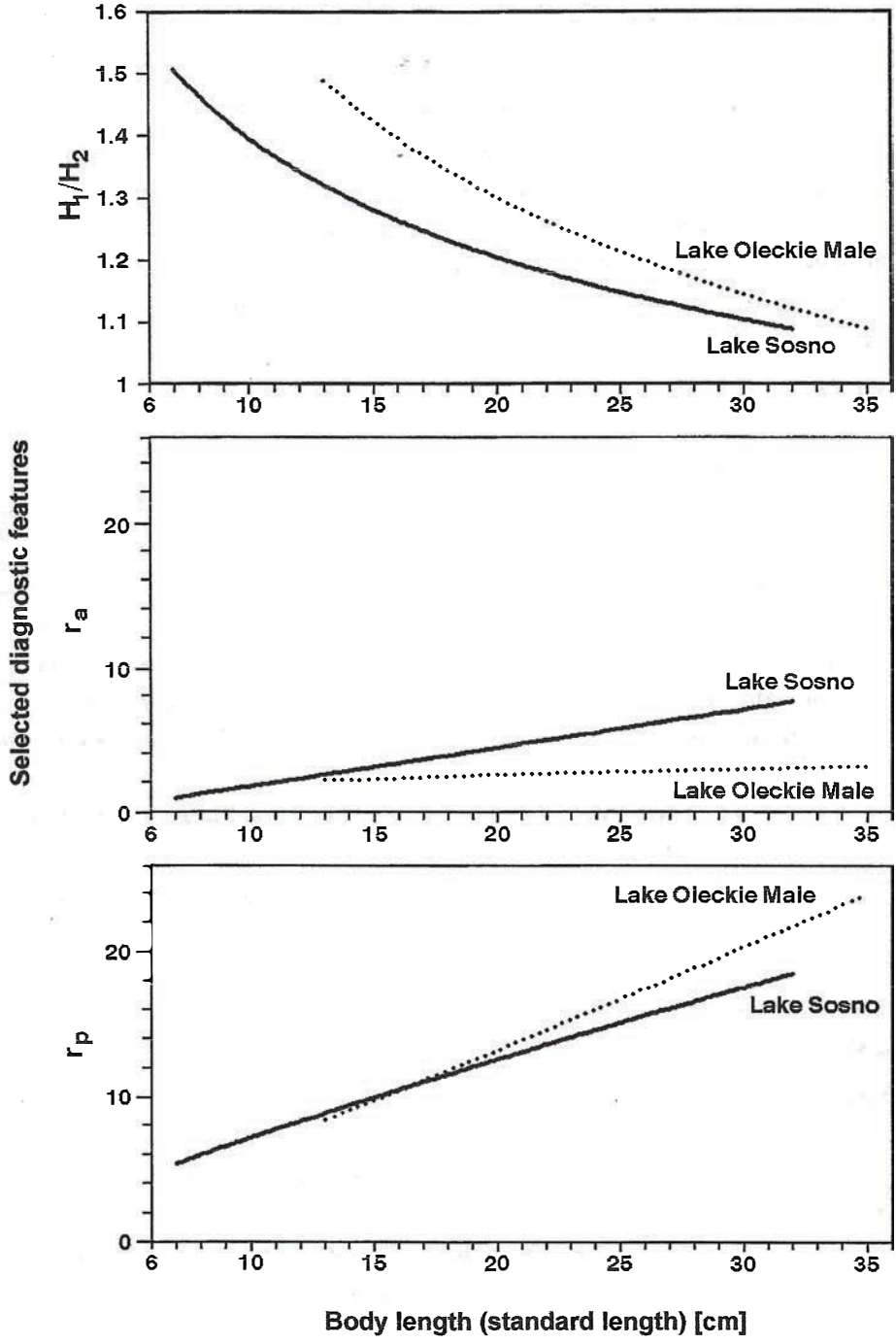

Fig. 5. Dependence between H_1/H_2—situated of focus, r_a—number of radii in anterior field, r_p—number of radii in posterior field with standard length in two investigated populations of bream

Table 6

Correlation (r) and regression (a, b) coefficients, describing the relationships between the selected diagnostic features of bream scales and fish standard length, in two of the investigated populations

		Diagnostic features											
Population	n	H_1/H_2				r_a				r_p			
			r	a	b		r	a	b		r	a	b
Lake Sośno	50	1	–0.7481[x)]	3.4307	–0.3152	1	0.3490[x)]	0.8427	0.3732	1	0.9360[x)]	0.5623	1.0559
Lake Oleckie Małe	50	1	–0.605[x)]	2.283	–0.2138	2	0.6743[x)]	0.2675	–0.8754	1	0.8529[x)]	1.1025	0.8149

n—number of scales;

r_a—number of radii on the anterior field;

r_p—number of radii on the posterior field;

H_1/H_2—location of the scale nucleus;

[x)]—r significant on level P = 0.05;

1—$y = ax^b$

2—$y = ax + b$

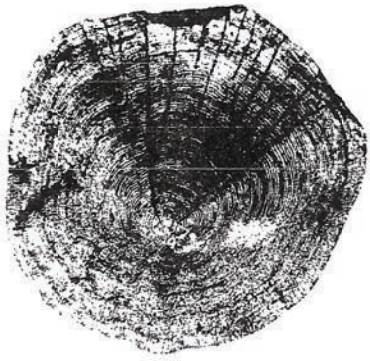

Fig. 6. Scale of white bream taken from above the lateral-line near head (point A)

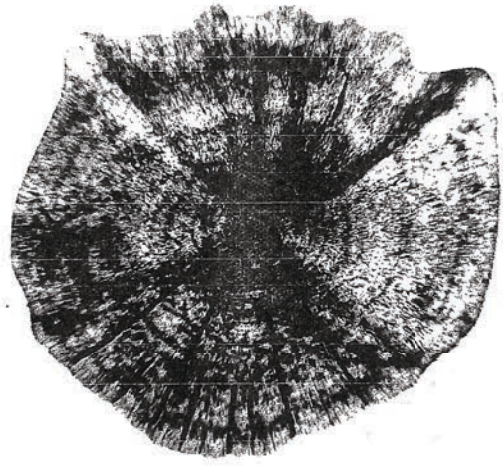

Fig. 7. Scale of white bream taken from above the lateral-line under dorsal fin (point C)

The nucleus in scales taken from points C and E was situated closest to the centre of scale. Mean values of H_1/H_2 ratio were C—0.794 and E—0.861.

By comparison of the A/D ratio among scales taken from points B–F (0.97–1.07) it may be observed that scales elongate from the head towards the tail. Scales taken from point C had clearly visible corners and notches in the oral edge. Analysis of the number of radii on oral and caudal fields shows increase in number of radii on the oral field in direction from head to tail. In scales collected at points A and B (just behind the head) there were no radii on the oral field, and the secondary radii occurred sporadically (0–1). On the caudal field the secondary radii were much more abundant (2–15). The highest number of radii on the oral field was recorded in scales collected at points closest to the tail—E and F (Tab. 8). The highest differences recorded in the value of coefficient of variability concerning the number of secondary radii on the oral field (from 27.52 to 346.4).

Table 7

Diagnostic features of scales collected from the analysed bream populations

Population		Standard length (cm)	A (mm)	D (mm)	A/D	r_{a1}	r_{a2}	r_{p1}	r_{p2}	H_1 (mm)	H_2 (mm)	H_1/H_2
Lake Śniardwy	$\bar{x}$	38.65	14.16	15.10	0.93	0.70	2.20	2.40	22.40	7.14	7.01	1.02
	SD	2.40	1.00	1.41	0.03	0.82	1.13	0.84	8.58	0.58	0.55	0.07
	V	6.22	7.07	9.36	3.39	117.6	51.6	35.14	38.30	8.09	7.81	6.87
Lake Sunowo	$\bar{x}$	34.62	11.01	11.64	0.94	0.10	0.50	2.20	16.80	6.23	4.78	1.32
	SD	2.56	0.78	0.85	0.02	0.31	0.70	1.39	7.49	0.54	0.53	0.13
	V	7.40	7.14	7.31	2.64	316.23	141.42	63.56	44.61	8.74	11.67	10.59
Lake Sośno	$\bar{x}$	24.3	8.28	9.14	0.88	0.4	2.6	2.6	14.0	4.55	3.27	1.30
	SD	9.4	3.42	3.42	0.05	0.84	1.34	1.07	7.27	1.70	1.73	0.24
	V	38.47	41.35	37.49	6.31	210.82	51.92	41.34	51.95	37.49	46.42	18.61
Lake Oleckie Małe	$\bar{x}$	20.47	7.03	7.98	0.87	2.5	2.1	5.7	7.4	3.75	3.28	1.23
	SD	7.98	3.20	3.60	0.05	1.84	1.44	4.34	2.98	1.51	1.72	0.19
	V	39.03	45.51	45.13	6.57	73.64	69.01	76.27	40.39	40.44	52.43	16.02
Lake Jermieliste	$\bar{x}$	32.31	10.39	11.36	0.90	0.30	0.90	2.20	15.10	5.64	4.72	1.28
	SD	4.24	1.17	1.32	0.04	0.48	0.73	1.37	2.64	0.59	0.64	0.12
	V	13.14	11.26	11.68	5.50	161.02	81.98	67.08	17.51	10.58	13.65	10.74
Lake Haśno	$\bar{x}$	33.0	11.30	12.02	0.90	0.20	1.50	2.50	18.30	5.89	5.38	1.09
	SD	4.09	1.67	1.98	0.01	0.42	0.17	1.08	4.76	0.81	0.89	0.05
	V	12.41	14.83	16.50	2.41	210.82	78.57	43.20	26.02	16.51	16.51	4.94
Włocławek Reservoir	$\bar{x}$	29.70	9.90	11.08	0.89	0.70	2.70	2.20	17.40	5.25	4.64	1.15
	SD	2.15	2.15	0.97	0.07	0.82	1.57	0.63	3.65	0.61	0.43	0.05
	V	7.23	10.37	8.76	8.14	117.61	58.04	28.75	21.02	11.64	9.20	4.67

Table 8

Variability of diagnostic features of white bream scales rom Lake Bełdany population, taken from different body locations

Point		Standard length (cm)	H_1 (mm)	H_2 (mm)	H_1/H_2	r_{a1}	r_{a2}	r_{p1}	r_{p2}	A (mm)	D (mm)	A/D
A	Range	15.5–28.4	1.95–3.59	0.87–2.29	0.4–0.64	0.00	0–1	0–4	2–15	2.86–5.88	2.51–5.61	0.87–1.0
	$\bar{x}$	20.183	2.722	1.434	0.522	0.00	0.083	2.167	5.750	4.157	4.159	0.99
	SD	4.862	0.623	0.449	0.081	0.00	0.289	0.937	3.334	1.040	0.903	0.07
	V	24.09	22.90	31.31	15.59	–	346.4	43.27	57.98	25.01	21.72	7.95
B	Range	15.5–28.4	2.51–5.19	1.16–3.07	0.35–0.67	0.00	0–1	1–3	1–9	3.84–8.13	4.07–8.29	0.89–1.0
	$\bar{x}$	20.183	3.546	1.906	0.531	0.00	0.333	2.333	4.000	5.452	5.598	0.968
	SD	4.862	0.995	0.718	0.091	0.00	0.492	0.779	2.796	1.678	1.586	0.04
	V	24.09	28.06	37.70	17.22	–	147.7	33.36	69.90	30.77	28.32	4.30
C	Range	15.5–28.4	2.59–5.27	1.88–4.23	0.65–0.87	0–2	0–4	2–4	1–12	4.53–9.5	4.85–9.49	0.9–1.0
	$\bar{x}$	20.183	3.441	2.750	0.794	0.750	2.083	2.750	4.667	6.323	6.519	0.96
	SD	4.862	0.945	0.868	0.071	0.754	1.564	1.055	3.367	1.758	1.723	0.07
	V	24.09	27.46	31.58	8.96	100.5	75.09	38.37	72.14	27.80	26.42	8.11
D	Range	15.5–28.4	2.57–5.8	1.52–4.31	0.55–0.84	0–2	0–3	2–4	3–15	4.3–9.53	4.51–9.26	0.9–1.0
	$\bar{x}$	20.183	3.673	2.602	0.702	0.667	1.583	3.333	7.083	6.275	6.401	0.97
	SD	4.862	1.170	0.978	0.081	0.651	1.165	0.651	3.605	2.121	1.897	0.04
	V	24.09	31.86	37.61	11.61	97.70	73.55	19.54	50.89	33.80	29.64	5.00
E	Range	15.5–28.4	2.61–5.51	1.81–4.64	0.62–1.13	1–6	4–8	2–5	2–14	4.74–10.07	4.53–9.3	0.97–1.0
	$\bar{x}$	20.183	3.651	3.128	0.861	2.250	6.000	4.250	4.667	6.773	6.448	1.04
	SD	4.862	1.081	0.961	0.129	1.357	1.651	0.965	3.525	1.989	1.653	0.05
	V	24.09	29.61	30.73	14.96	60.30	27.52	22.71	75.53	29.37	25.64	5.27
F	Range	15.5–28.4	2.49–6.22	1.28–4.17	0.46–0.83	0–3	3–9	3–6	2–15	4.07–9.72	4.00–8.39	0.93–1.0
	$\bar{x}$	19.740	3.592	2.349	0.667	1.60	4.70	4.70	6.50	5.939	5.471	1.07
	SD	5.226	1.254	0.760	0.116	0.966	1.889	0.823	4.673	1.925	1.365	0.08
	V	26.48	34.91	32.36	17.46	60.38	40.18	17.52	71.89	32.42	24.95	8.27

Table 9

Diagnostic features of scales collected from the analysed white bream populations

Population		Standard length (cm)	H_1 (mm)	H_2 (mm)	H_1/H_2	r_{a1}	r_{a2}	r_{p1}	r_{p2}	A (mm)	D (mm)	A/D
Włocławek Reservoir	Range	17.1–26.9	3.51–7.91	4.25–7.16	0.88–1.21	0–3	1–9	2–5	1–17	8.15–14.4	8.5–13.31	0.87–1.0
	$\bar{x}$	22.06	5.61	5.58	1.00	1.60	4.13	3.47	7.53	11.18	10.91	1.02
	SD	3.73	1.27	0.95	0.14	0.74	2.13	0.99	4.88	2.10	1.71	0.06
	V	16.91	22.67	17.11	13.96	46.05	51.62	28.57	64.81	18.80	15.69	6.34
Vistula Estuary	Range	15.0–21.9	3.21–6.05	2.86–5.35	0.88–1.26	0–3	1–7	2–5	3–29	6.1–11.2	6.27–12.56	0.86–1.0
	$\bar{x}$	19.27	4.82	4.55	1.06	1.07	4.60	3.13	15.47	9.34	10.01	0.92
	SD	2.05	0.82	0.73	0.12	0.80	2.32	0.99	9.26	1.47	1.80	0.05
	V	10.66	17.02	16.00	11.02	74.89	50.52	31.61	59.85	15.59	17.95	4.94
Lake Gosławskie	Range	18.0–25.5	4.49–6.24	4.53–6.69	0.87–1.1	0–3	1–4	2–5	5–14	9.02–12.9	7.64–12.87	0.95–1.0
	$\bar{x}$	23.50	5.77	6.05	0.95	1.40	2.60	3.70	11.50	11.83	11.47	1.04
	SD	2.08	0.62	0.66	0.07	0.84	0.97	0.82	2.88	1.21	1.49	0.06
	V	8.86	10.75	10.86	6.98	60.23	37.16	22.25	25.02	10.23	13.02	5.99
Lake Bełdany	Range	15.5–28.4	2.59–5.27	1.88–4.23	1.14–1.54	0–2	0–4	2–4	1–12	4.53–9.5	4.85–9.49	0.9–1.0
	$\bar{x}$	20.183	3.44	2.75	1.27	0.75	2.08	2.75	4.67	6.32	6.52	0.97
	SD	4.86	0.94	0.87	0.12	0.75	1.56	1.06	3.37	1.76	1.72	0.08
	V	24.09	27.46	31.58	9.42	100.5	75.09	38.37	72.14	27.80	26.42	8.11

Variability of the diagnostic features of scales from analysed white bream populations

Scales for analysis of the variability of the diagnostic features were taken from point C (above the lateral-line, under the dorsal fin). Scales had pronounced notches in the oral edge and corners at the limit between oral and lateral edges. The diagnostic features of the investigated white bream populations are shown in Tab. 9. The highest variability was recorded in the number of radii on oral (37.16–100.5) and caudal (22.25–72.14) fields. Coefficient of variability, defined by the H_1/H_2 ratio ranged from 6.98 to 13.96 and for the A/D ratio ranged from 4.94 to 8.11. The diagnostic attributes were described for individuals of different body length—to find possible relationship between the variability of these features and the fish length. The calculated correlation coefficients are presented in Tab. 10. There was no correlation between body length and A/D ratio. Clear relationship was found between body length and location of the scale nucleus. There is a clear tendency—as the fish grows the scale nucleus shifts towards the caudal edge. This phenomenon was observed in scales collected from populations inhabiting Lake Bełdany, Lake Gosławskie and Vistula Estuary. The number of radii on oral and caudal fields increased together with increase in the body length.

Table 10

Correlation coefficients (r), describing the relationship between the selected features of white bream scales and fish standard length in four of the investigated populations

Population	Diagnostic features						
	H_1/H_2			r_a		r_p	
	n		r	n	r	n	r
Włocławek Reservoir	24	1 2	0.2052 0.1803	24	0.1546 0.2133	12	0.2919 0.2735
Vistula Estuary	30	1 2	0.1039 0.0748	30	0.3154 0.2939	15	0.1794 0.1513
Lake Gosławskie	30	1 2	0.1367 0.1520	30		15	0.400 0.0762
Lake Bełdany	30	1 2	0.3223 0.3043	30	0.1300 0.2573	15	0.4573 0.3671

1—$y = a + bx$,
2—$y = a + b^x$,
r—not significant on level $P = 0.05$.

Variability of diagnostic features of white bream scales collected from different populations

Scales were taken at point C—below the dorsal fin, above the lateral-line. Their shape was shield-like. The oral edge had notches. Corners were well marked, and lateral edges slightly convex. The caudal edge was also a bit convex. The mean value of the height to length ratio (A/D) ranged from 0.92 (Vistula Estuary) to 1.04 (Lake Gosławskie) (Tab. 9). The shape of these scales was similar to a square with irregular edges. Location of the nucleus, expressed as H_1/H_2 ratio, was central (0.95–1.06) in three analysed populations originating from Włocławek Reservoir, Vistula Estuary and Lake Gosławskie. Only in the case of Lake Bełdany population the centrum was shifted towards the oral edge ($H_1/H_2 = 1.27$). In this population the lowest mean value of the number of radii on caudal and oral fields was recorded. Scales collected from individuals belonging to this population were also clearly smaller from these originating from other populations: D = 6.52; A = 6.32 (Tab. 9). The range and mean values of body length measurements do not explain these significant differences. Environmental conditions in Lake Bełdany indicate that these differences in the results of scales measurements may be caused by poor growth of white bream population in this lake. However, as the number of analysed individuals from Lake Bełdany was low, these results should be treated carefully—or as a notice.

DISCUSSION

Scales taken from different body locations varied in shape, size, and number of radii. These data confirm results given by Oliva (1952). Scales from different parts of fish body are worthless as a diagnostic tool. Oliva examined scales of bream and white bream, taken from different parts of body. The fore mentioned author claims that only typical scales should be taken for further analysis. They should be collected from the middle part of body, below or above the lateral-line. In this study scales for comparative studies were collected from the middle of fish body, above the lateral-line. The description of the shape of bream and white bream scales agrees with that given by Susłowska and Urbanowicz (1984). Those scales were shield-shaped. In the scales of bream from Biebrza River basin their diameter was higher than their height. The nucleus in analysed bream scales was clearly shifted towards the oral edge of scale, or located almost in the centre of the scale. The results achieved by Galkin (1955) from waters of the Soviet Union and Oliva (1952) from the Wełtawa River are very similar (Tab. 11) for populations of comparable range of fish body length.

In the analysed white bream populations the centrum was usually located in the centre of the scale (except Lake Bełdany population, which is characterised by poor growth). The same characteristics of white bream scales is given by Movčan and Smirnov (1983), and

Susłowska and Urbanowicz (1984). The height to width ratio (A/D) both in the analysed populations as well as in data collected from other waters, given in the cited literature, were also very similar (Tab. 12), as far as fish of comparable size are considered.

According to Susłowska and Urbanowicz (1984) the presence of radii on certain scale fields is a diagnostic feature. They claim that in some cases a fish species may be determined on this basis. Oliva (1952) claims that the number of radii cannot be used as a taxonomic feature. That author gives much wider range of the number of radii on the oral and caudal fields in bream and white bream than Hensel (1978) or Susłowska and Urbanowicz (1984). The results obtained in present study confirm high variability of this feature. In the analysed bream and white bream scales, small number of secondary radii on the caudal field is evident in populations characterised by poor growth (Lake Oleckie Małe—7.4, Tab. 7, and Lake Bełdany—4.67, Tab. 9). Number of radii varies both within a population as well as between different populations. Therefore, this feature (number of radii) may only serve as an additional information, because of high individual, intra- and inter-populational variability.

CONCLUSIONS

1. Scales located on various points of the bream and white bream body varied in shape. The shape of bream and white bream scales collected from the middle part of fish body was shield-like.
2. The nucleus of the bream scale was shifted towards the oral edge or remained in the central part of the scale. The scale diameter was higher than its height. Shape of these scales resembled rectangle with base longer than its height.
3. The scale nucleus in the bream and white bream migrates as the fish grow. This tendency makes difficult defining the differences between these two species.
4. As the diagnostic attributes may serve: scale shape, scale height to width ratio, and with certain restrictions location of the scale nucleus. The number of radii on oral and caudal fields can not be a taxonomic feature, because of its too high individual, intra- and inter-populational variability. This feature may be only an additional information.

Table 11

Comparison of investigated diagnostic features of bream scales with data obtained by the other authors

Diagnostic features	Investigated populations		Weltawa River	Reservoirs from Soviet Union	Dunaj River	Biebrza river basin	
	Present study		Oliva (1952)	Galkin (1955)	Hensel (1978)	Susłowska and Urbanowicz (1984)	
	$\bar{x}$ SD	$\bar{x}$ SD	$\bar{x}$	$\bar{x}$		r_{a1}	r_{a2}
A (mm)	7.03 (3.20)	14.16 (1.00)	11.20	14.0			
D (mm)	7.98 (3.60)	15.10 (1.41)	9.26	15.5			
A/D	0.87 (0.05)	0.94 (0.04)	1.20	0.90			
H_1 (mm)	3.75 (1.51)	7.14 (0.58)					
H_2 (mm)	3.27 (1.73)	7.01 (0.55)					
H_1/H_2	1.02 (0.07)	1.32 (0.13)	Range		Range		
r_a	0.1 (0.31)	2.70 (1.57)	4–17		0–26	1–3	*)
r_p	2.2 (1.39)	22.40 (8.58)	22–23		6–49	30	
Standard length (cm)	20.47–38.65		24.6	48.5			

SD—standard deviation,

r_{a1}—primary radii on apical field,

r_{a2}—secondary radii on apical field,

*)—radii not numerous.

Table 12

Comparison of investigated diagnostic features of white bream scales with data obtained by other authors

Diagnostic features	Investigated populations		Wełtawa River	Reservoirs from Soviet Union	Dunaj River	Biebrza river basin	
	Present study		Oliva (1960)	Galkin (1955)	Hensel (1978)	Susłowska and Urbanowicz (1984)	
	$\bar{x}$ SD	$\bar{x}$ SD	$\bar{x}$	$\bar{x}$		r_{a1}	r_{a2}
A (mm)	6.32 (1.76)–11.16 (2.10)		13.00	10.5			
D (mm)	6.52 (1.72)–11.47 (1.49)		12.40	10.0			
A/D	0.92 (0.05)–1.04 (0.06)		1.04	1.05			
H_1 (mm)	3.44 (0.94)–5.77 (0.62)						
H_2 (mm)	2.75 (0.87)–6.05 (0.66)						
H_1/H_2	0.95 (0.07)–1.06 (0.12)		Range		Range	1.0	
r_a	0.75 (0.75)–4.60 (2.32)		0–12		1–5	0–3	*)
r_p	2.75 (1.06)–15.47 (9.26)		17–21		7–16	2–6	**)
Standard length (cm)	19.27–23.5		22.2	24.5			

SD—standard deviation,

r_{a1}—primary radii on apical field,

r_{a2}—secondary radii on apical field,

*)—radii not numerous

**)—radii very variable.

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CECHY DIAGNOSTYCZNE ŁUSEK LESZCZA *ABRAMIS BRAMA* (L.) I KRĄPIA *BLICCA BJOERKNA* (L.)

STRESZCZENIE

Analizowanym materiałem były łuski leszcza i krąpia. Celem badań było porównanie cech diagnostycznych łusek ryb pochodzących ze zbiorników o różnym tempie wzrostu i różnych warunkach środowiska z danymi literaturowymi. Łuski leszcza zebrano z 7 zbiorników, a krąpia z 4 zbiorników. Określano kształt łuski, mierzono jej wysokość (A) i szerokość (D), obliczano promienie pierwotne i wtórne w polu oralnym (r_a) i kaudalnym (r_p) oraz określano położenie centrum łuski (H_1/H_2). Szukano zmienności cech diagnostycznych łusek obu gatunków, pobranych z kilku miejsc ciała jednego osobnika, poszczególnych osobników jednej populacji różniących się długością ciała oraz kilku populacji zamieszkujących różne zbiorniki wodne. Łuski pobrane z różnych miejsc ciała leszcza (Tab. 3) i krąpia (Tab. 8) charakteryzowały się dużą zmiennością kształtu. Kształt tarczowaty miały łuski pochodzące ze środkowej części ciała. Te wyniki porównano z danymi literaturowymi (Tab. 11 i 12).Cechami taksonomicznymi mogą być: kształt łuski, położenie centrum i wskaźnik wysokości łuski do jej szerokości. Liczba promieni w polu oralnym i kaudalnym może być tylko informacją dodatkową, gdyż charakteryzuje się zbyt dużą zmiennością osobniczą, populacyjną i międzypopulacyjną.

Received: 2 December 1996

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