Arch. Pol. Fish. (2012) 20: 109-122
DOI 10.2478/v10086-012-0013-3

RESEARCH ARTICLE

Effects of eutrophication on vendace, *Coregonus albula* (L.). III. Seasonal morphological variability of vendace from selected lakes in Wielkopolska

Małgorzata Fiszer, Antoni Przybył, Wojciech Andrzejewski, Jan Mazurkiewicz, Janusz Golski, Katarzyna Przybylska, Sławomir Runowski

Received – 05 December 2011/Accepted – 15 March 2012. Published online: 30 June 2012;
Citation: Fiszer M., Przybył A., Andrzejewski W., Mazurkiewicz J., Golski J., Przybylska K., Runowski S. 2012 – Effects of eutrophication on vendace, *Coregonus albula* (L.). III. Seasonal morphological variability of vendace from selected lakes in Wielkopolska – Arch. Pol. Fish. 20: 109-122.

Abstract. The aim of the study was to determine and compare the most important morphometric and meristic characters of vendace from four lakes located in the Wielkopolska region: lakes Dominickie, Gorzyńskie, Lubikowskie, and Strzeszyńskie. Biometric analyses were conducted based on the method developed by Prawdin. All morphometric characters are presented in relative values (%) of fork length (*longitudo caudalis*) according to the method developed by Smitt. Moreover, values of 14 meristic characters were also determined. The greatest differences in values of morphometric characters of vendace were recorded for measurements of head shape, including lateral head length, eye diameter, and postorbital distance, and adipose fin length. The smallest differences in the values of morphometric characters were observed in the largest linear body measurements, i.e., body length, predorsal distance, minimum body depth, and dorsal and anal fin lengths. Variation in morphometric characters in vendace from different lakes confirms the hypothesis that a specific form of vendace is found in each lake. Differences were found in the values of linear measurements of vendace caught in different seasons, which indicates that drawing conclusions on body conformation in vendace is justified only when they are caught in comparable periods of the year.

Keywords: meristic characters, plasticity features, vendace

M. Fiszer, A. Przybył, W. Andrzejewski [✉], J. Mazurkiewicz, J. Golski, K. Przybylska, S. Runowski
Department of Fisheries and Aquaculture, Institute of Zoology
Poznań University of Life Sciences
Wojska Polskiego 71c, 60-125 Poznań, Poland
Tel./fax: +48 618487706; e-mail: wojtek@up.poznan.pl

Introduction

Vendace, *Coregonus albula* (L.), is a species that exhibits considerable phenotypic variation, which is an intermediate reflection of particular environmental conditions which it inhabits. According to Gąsowska (1973), every lake has a different form of vendace that is specific to that lake. Pokrovskij (1967) and Brylińska (2000) also concluded that vendace occurs in various ecological forms, which provides justification for detailed analyses of populations inhabiting different lakes. The morphological plasticity of the species, which is most evident in body conformation, is influenced by certain morphometric and hydrochemical characteristics of lakes the most significant of which include maximum depth, mean depth, area, water transparency, and oxygen and nutrient contents in lake waters (Thienemann 1922, Bnińska 1994, 1998, Wołos 1994, Kaupinis and Bukelskis 2010).

The aim of this the third part of the present study is to identify and compare the most important morphometric and meristic characters of vendace from four lakes from the Wielkopolska region with differing degrees of eutrophication. The previous two parts of the current paper characterized vendace habitats and the most important biological characteristics of the populations inhabiting those lakes.

Study area

Analyses were conducted in four lakes in the Wielkopolska Region – lakes Dominickie, Gorzyńskie, Lubikowskie, and Strzeszyńskie. The parameters differentiating the lakes most strongly were area, depth, area-depth index, shoreline development, and fish yield index (Fiszer et al. 2012). In terms of morphometry, lakes Gorzyńskie and Lubikowskie are most suitable for optimal vendace fishery management. The least developed stratification was observed in Lake Dominickie, while the most marked stratification was noted Lake Gorzyńskie, which has the smallest epilimnion depth, the highest thermocline temperature gradient, and a deep, cool hypolimnion. Considerable deoxygenation was observed in the hypolimnion in the summer season in all the lakes; however, in Lake Strzeszyńskie oxygen deficits were also noted in the metalimnion. According to the analysis of physicochemical indexes and trophic state indexes, all of the analyzed lakes were of good water quality. The trophic states of lakes Gorzyńskie and Lubikowskie were designated as bordering on the mesotrophic and eutrophic states, while lakes Dominickie and Strzeszyńskie were designated as eutrophic.

Materials and methods

Four lakes in the Wielkopolska region were analyzed, namely lakes Dominickie, Gorzyńskie, Lubikowskie, and Strzeszyńskie, all of which were characterized in the first part of the study. The ichthyological material analyzed comprised vendace caught in 2005. A total of 1400 fish were analyzed with 350 specimens from each lake. Spring and summer samples comprised 100 specimens, while fall samples consisted of 150 specimens. The vendace age and sex structures were analyzed in detail and are presented in part II of the current paper.

After frozen specimens had been thawed, body weight was measured for each specimen using an AXIS electronic caliper to the nearest 0.1 g. Biometric measurements were based on the Pravdin method described by Brylińska (2000). Linear parameters were measured to the nearest 0.01 mm with a Helios electronic scale coupled with a computer, and all measurements were automatically recorded in an Excel spread sheet. A list of the morphometric characters and the symbols denoting them is presented in Fig. 1. All morphometric characters are presented in relative values (%) of fork length (X8, *longitudo*

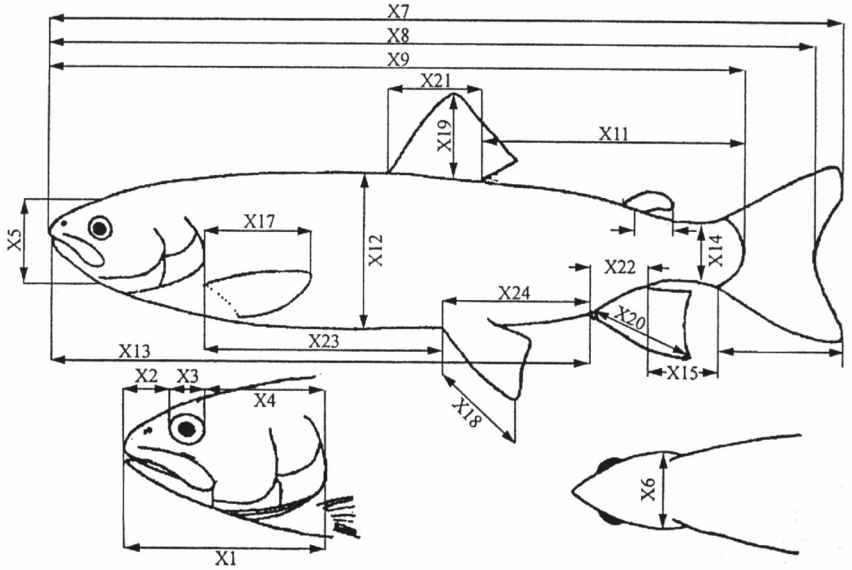

Figure 1. Measurements of morphometric features of vendace. X1 lateral head length; X2 preorbital distance; X3 eye diameter; X4 postorbital distance; X5 head depth; X6 head width; X7 total length; X8 fork length; X9 body length; X10 predorsal distance; X11 postdorsal distance; X12 body depth; X13 preanal distance; X14 minimum body depth; X15 caudal peduncle length; X16 caudal fin length; X17 pectoral fin length; X18 ventral fin length; X19 dorsal fin height; X20 anal fin height; X21 dorsal fin length; X22 anal fin length; X23 distance between pectoral and anal fins; X24 distance between ventral and anal fins; X25 adipose fin length.

caudalis), using the widely-known method by Smitt (1886). Meristic characters investigated in this study included hard fin ray counts for the dorsal (Du), anal (Au), pelvic (Vu), and pectoral fins (Pu); soft fin ray counts for the dorsal (Db), anal (Ab), caudal (Cb), pelvic (Vb), and pectoral fins (Pb); the number of lateral line scales (l.l.); longitudinal rows of scales above the lateral line ($l.l._1$) and below the lateral line ($l.l._2$); gill raker count (sp.br.); and branchiostegal ray count (r.br.). The analyses of these characters were conducted using a dissecting needle and a measuring magnifier (magnification 2.5 x).

The data were analyzed statistically with Statistica 5.0 PL. The verification of the hypothesis of mean differences was preceded by an examination of the normal distribution of the analyzed characters and a homogeneity of variation test (Levene's test). Then the post-hoc Tukey HSD test was used at a significance of $P \leq 0.05$.

Results

Biometric characteristic

For all samples the statistical analysis showed high variation (CV>10) for three morphometric characters – head width (X6), caudal peduncle length (X15), and adipose fin length (X25). Significant variation was also noted in fish caught in fall regarding preorbital distance (X2), eye diameter (X3), and minimum body depth (X14). Head width (X6) in specimens caught in this season was exceptionally characterized by a lower coefficient of variation (CV=7.04) (Table 1). Moreover, maximum body depth (X12) in vendace caught in fall was characterized by over two-fold greater variation than in those caught in spring and summer. The lowest coefficient of variation among other morphometric characters was noted in total length (X7, 1.85, 1.69 and 1.84, respectively) and body length (X9, 1.03, 1.19 and 1.75, respectively) of the fish caught in spring, summer, and fall. It must be emphasized that the least variation was noted in the largest linear body dimensions of vendace, while the smallest parameter, adipose fin height, was characterized by the greatest variation.

Statistical analysis indicated there were statistically significant differences ($P \leq 0.05$) in 19 of the 24 linear characters (Table 1). No significant differences were noted between vendace specimens from Lake Dominickie caught in different seasons with regard to the other five characters of preorbital distance (X2), total length (X7), caudal fin length (X16), pectoral fin length (X17), or dorsal fin length (X21). It was noteworthy that six characters were found to differ significantly among all fish specimens. These were head depth (X5), postdorsal distance (X11), caudal peduncle length (X15), anal fin height (X20), anal fin length (X22), and adipose fin length (X25).

Statistical analysis indicated there was high variation with regard to head width (X6), caudal peduncle length (X15), anal fin height (X20), and adipose fin length (X25) in fish from spring and summer catches (Table 2). The linear measurements of adipose fin length and caudal peduncle length also varied highly among fish caught in fall. In the case of head width (X6), a statistically non-significant value of the coefficient of variation (5.77) was noted in vendace caught in the fall. High variation (CV=10.32) was noted for maximum body depth (X12), and it was two-fold higher than that in fish caught in spring and summer. The lowest coefficients of variation were recorded for the linear parameters regarding the longest body dimensions in fish, i.e., total length (X7) and body length (X9) for all vendace groups.

Statistically significant differences ($P \leq 0.05$) in the values of linear measurements among all samples (spring, summer, fall) of vendace from Lake Gorzyńskie (Table 2) were recorded for lateral head length (X1), eye diameter (X3), postorbital distance (X4), head depth (X5) caudal peduncle length (X15), abdominal fin length (X18), and anal fin length (X22). No significant differences were among the following five parameters in samples of fish caught in different seasons of the year: predorsal distance (X10), maximum body depth (X12), caudal fin length (X16), adipose fin length (X25), and dorsal fin length (X21).

Table 1
Selected statistical values of morphometric characters of vendace from Lake Dominickie (% *longitudo caudalis*)*

	Spring					Summer					Autumn				
Character	M	Range	W	SD	CV	M	Range	W	SD	CV	M	Range	W	SD	CV
X1	20.99[a]	19.47-22.60	0.48	0.69	3.29	20.80[a]	19.18-22.67	0.63	0.79	3.80	20.39[b]	17.22-22.82	0.87	0.93	4.56
X2	5.50[a]	4.34-6.73	0.22	0.47	8.55	5.67[a]	4.38-7.07	0.26	0.51	8.99	5.55[a]	3.67-7.55	0.39	0.62	11.17
X3	5.28[ab]	4.67-6.10	0.11	0.34	6.44	5.24[b]	4.16-6.61	0.18	0.42	8.02	5.43[a]	4.40-10.61	0.47	0.69	12.71
X4	10.71[b]	9.52-14.73	0.59	0.77	7.19	10.41[a]	9.03-11.85	0.37	0.61	5.86	10.44[a]	8.62-12.30	0.61	0.78	7.47
X5	13.94[c]	10.93-23.67	1.92	1.39	9.97	1326[b]	11.23-16.04	0.94	0.97	7.32	10.90[a]	9.25-13.78	0.60	0.77	7.06
X6	7.65[a]	5.73-9.09	0.79	0.89	11.63	8.02b	6.29-9.56	0.66	0.81	10.10	7.96b	6.80-9.57	0.32	0.56	7.04
X7	110.42[a]	101.50-114.21	4.14	2.04	1.85	110.85[a]	105.58-115.18	3.51	1.87	1.69	110.26[a]	102.74-114.81	4.11	2.03	1.84
X9	93.53[b]	91.30-96.15	0.92	0.96	1.03	93.98[c]	90.95-99.32	1.24	1.12	1.19	89.16[a]	84.02-91.96	2.44	1.56	1.75
X10	45.59[b]	41.01-50.31	2.56	1.60	3.51	44.72[a]	38.62-48.07	3.03	1.74	3.89	45.00[a]	39.55-48.09	2.72	1.65	3.67
X11	37.32[c]	31.65-41.15	2.39	1.55	4.15	36.39[b]	29.29-39.71	2.63	1.62	4.45	34.72[a]	29.19-39.57	3.85	1.96	5.65
X12	22.86[b]	20.01-25.75	1.25	1.12	4.90	21.43[a]	18.86-24.29	1.08	1.04	4.85	21.25[a]	16.01-25.64	4.44	2.11	9.93
X13	70.55[b]	49.93-76.45	18.02	4.25	6.02	70.32[b]	66.31-74.47	2.66	1.63	2.32	68.15[a]	61.43-72.73	4.22	2.05	3.04
X14	7.11[b]	5.59-8.17	0.27	0.52	7.31	7.15[b]	5.65-7.95	0.20	0.45	6.29	6.77[a]	4.20-9.02	0.51	0.72	10.64
X15	8.85[b]	6.46-11.96	1.10	1.05	11.86	7.54[a]	5.76-9.42	0.60	0.77	10.21	10.46[c]	6.98-15.32	2.02	1.42	13.58
X16	22.21[a]	19.59-25.34	1.36	1.17	5.27	22.36[a]	19.38-25.82	1.89	1.37	6.13	22.11[a]	13.89-25.80	2.35	1.53	6.92
X17	15.01[a]	12.56-16.85	0.73	0.86	5.75	14.91[a]	12.94-17.54	0.77	0.88	5.90	15.07[a]	12.55-18.16	1.25	1.12	7.43
X18	14.63[a]	12.86-16.91	0.68	0.83	5.07	14.53[a]	12.75-17.23	0.74	0.86	5.92	14.95[b]	11.81-17.96	1.25	1.12	7.49
X19	17.53[b]	12.64-21.31	1.41	1.19	6.79	17.22[ab]	14.63-21.29	1.50	1.23	7.14	17.03[a]	10.71-19.83	1.47	1.21	7.11
X20	11.31[b]	8.74-13.58	0.72	0.85	7.52	10.84[a]	8.91-13.90	0.78	0.88	8.12	11.71[c]	9.12-15.03	1.16	1.07	9.14
X21	9.82[a]	8.09-11.78	0.61	0.78	7.94	9.99[a]	8.04-12.13	0.74	0.86	8.61	10.06[a]	7.62-12.92	0.86	0.93	9.24
X22	12.42[b]	7.01-15.24	1.28	1.13	9.10	19.95[c]	10.19-15.41	0.97	0.97	7.49	12.03[a]	9.65-14.07	0.96	0.98	8.15
X23	29.69[b]	25.77-33.83	2.59	1.61	5.42	28.42[a]	25.67-31.88	1.67	1.29	4.54	28.89[a]	23.91-33.49	3.62	1.90	6.58
X24	25.64[b]	22.12-29.99	2.97	1.72	6.71	23.59[a]	20.60-26.61	1.45	1.21	5.13	23.40[a]	20.07-27.45	2.01	1.42	6.07
X25	3.47[a]	2.27-4.92	0.32	0.56	16.14	3.69[b]	2.11-4.76	0.24	0.49	13.28	4.00[c]	2.31-5.89	0.49	0.70	17.50

M – mean values, W – variance, SD- standard deviation, CV – coefficient of variation
*Mean values with different superscript in rows are significantly different ($P<0.05$)

Table 2
Selected statistical values of morphometric characters of vendace from Lake Gorzyńskie (% *longitudo caudalis*)*

	Spring					Summer					Autumn				
Character	M	Range	W	SD	CV	M	Range	W	SD	CV	M	Range	W	SD	CV
X1	19.96^{c}	18.33-22.17	0.66	0.81	4.06	19.37^{b}	17.80-21.00	0.51	0.71	3.67	19.00^{a}	16.45-21.39	0.62	0.79	4.16
X2	5.29^{b}	4.27-6.17	0.16	0.40	7.56	5.25^{b}	4.11-6.33	0.17	0.41	7.81	5.11^{a}	3.89-6.11	0.17	0.42	8.22
X3	4.83^{c}	4.11-5.49	0.09	0.31	6.42	4.58^{b}	3.76-5.29	0.11	0.33	7.21	4.35a	3.53-5.27	0.09	0.31	7.13
X4	10.15^{c}	4.20-11.62	0.70	0.84	8.20	9.81^{b}	7.68-11.17	0.40	0.63	6.42	9.44^{a}	8.02-11.12	0.30	0.55	5.83
X5	12.74^{b}	10.64-15.65	0.68	0.82	6.44	13.36^{c}	10.55-15.92	1.17	1.08	8.08	10.98^{a}	9.08-21.08	1.12	1.06	9.65
X6	6.95^{a}	5.28-8.93	1.07	1.03	14.82	6.71^{a}	5.04-8.45	0.65	0.80	11.92	8.15^{b}	6.94-9.44	0.22	0.47	5.77
X7	110.01^{a}	66.51-114.58	21.44	4.63	4.21	110.39^{a}	106.00-124.88	5.17	2.27	2.06	111.78^{b}	105.12-118.19	2.90	1.70	1.52
X9	93.48^{b}	88.94-97.92	1.55	1.24	1.33	93.69^{b}	90.50-96.26	1.41	1.19	1.27	90.07^{a}	86.76-96.76	3.15	1.77	1.97
X10	44.90^{a}	40.01-47.71	2.03	1.43	3.10	44.49^{a}	40.56-49.33	3.03	1.74	3.91	44.93^{a}	41.08-49.47	2.09	1.45	3.23
X11	37.70^{b}	33.72-44.58	2.80	1.67	4.43	36.58^{a}	32.05-40.23	3.02	1.74	4.76	36.41^{a}	31.75-40.54	2.97	1.72	4.72
X12	21.18^{a}	17.97-25.05	1.47	1.21	5.71	21.15^{a}	18.31-23.75	1.31	1.15	5.44	21.31^{a}	15.92-26.23	4.83	2.20	10.32
X13	70.59^{b}	65.77-85.03	5.34	2.31	3.27	69.08^{a}	64.98-74.06	3.38	1.81	2.62	69.39^{a}	62.91-78.01	3.99	2.00	2.88
X14	6.89^{a}	5.30-8.45	0.33	0.58	8.42	6.74^{ab}	5.64-8.13	0.26	0.51	7.57	6.90^{b}	5.85-7.97	0.15	0.39	5.65
X15	9.16^{c}	7.07-13.84	1.37	1.17	12.77	7.99^{a}	5.43-10.12	0.88	0.94	11.76	8.70^{b}	4.77-11.72	1.07	1.04	11.95
X16	22.48^{a}	19.74-26.05	1.41	1.19	5.29	22.25^{a}	16.93-25.99	2.19	1.48	6.65	22.32^{a}	18.66-25.48	1.49	1.22	5.47
X17	15.02^{b}	10.24-17.45	1.15	1.07	7.12	14.24^{a}	11.87-16.17	0.68	0.82	5.76	14.53^{a}	11.46-16.94	0.97	0.98	6.74
X18	14.96^{c}	12.64-17.42	0.80	0.90	6.02	14.08^{a}	12.06-16.10	0.76	0.87	6.18	14.55^{b}	11.96-16.62	0.92	0.96	6.60
X19	17.61^{b}	14.64-21.43	1.28	1.13	6.42	17.32^{b}	14.57-20.43	1.41	1.19	6.67	16.77^{a}	13.53-19.52	1.08	1.04	6.20
X20	11.19^{b}	8.45-19.20	1.67	1.29	11.53	10.72^{a}	7.58-13.65	1.15	1.07	9.98	10.64^{a}	8.64-13.26	0.91	0.95	8.98
X21	9.93^{a}	8.39-12.03	0.51	0.72	7.25	10.10^{a}	7.65-13.35	0.88	0.94	9.31	9.93^{a}	8.00-12.37	0.55	0.74	7.45
X22	12.34^{b}	9.60-15.02	0.96	0.98	7.94	13.11^{c}	9.32-15.62	1.47	1.21	9.23	11.92^{a}	8.71-14.04	0.80	0.90	7.55
X23	28.79^{a}	25.31-33.63	2.38	1.54	5.35	28.86^{a}	25.03-44.61	5.31	2.30	7.97	29.78^{b}	24.91-33.93	3.52	1.87	6.28
X24	24.88^{b}	21.41-29.03	2.39	1.55	6.23	23.98^{a}	20.63-29.56	2.07	1.44	6.01	24.35^{a}	19.68-30.01	2.48	1.58	6.49
X25	3.37^{a}	2.46-4.47	0.24	0.49	14.54	3.43^{a}	1.86-4.69	0.38	0.62	18.08	3.28^{a}	1.80-5.04	0.30	0.55	16.77

M – mean values, W – variance, SD- standard deviation, CV – coefficient of variation
*Mean values (M) with different superscript in rows are significantly different ($P<0.05$).

Statistical analysis indicated high variation (CV>10) in all fish groups with regard to head width (X6), caudal peduncle length (X15), and adipose fin length (X25). The highest coefficients of variation for these characters were noted in vendace caught in fall at 31.66, 16.07, and 26.50 (Table 3). Very high, statistically significant ($P \leq 0.05$) variation was also observed among fish from the fall sample with regard to ten other linear measurements: preorbital distance (X2), eye diameter (X3), postorbital distance (X4), head depth (X5), minimum body depth (X14), caudal fin length (X16), pectoral fin length (X17), anal fin height (X20), dorsal fin length (X21), and anal fin length (X22). Statistically significant variation was also noted among fish from the summer sample regarding minimum body depth (X14) (CV=11.30). Among the other morphometric characters, the lowest variation in the three successive study seasons was observed for body length (X9) and total length (X7) at CV 1.59, 1.10 and 1.80 and 4.42, 1.42 and 2.24, respectively.

The statistical analysis of plasticity characters for vendace from Lake Lubikowskie showed a lack of statistically significant differences ($P \leq 0.05$) for six morphometric characters (Table 3), including lateral head length (X1), postorbital distance (X4), total length (X7), predorsal distance (X10), caudal fin length (X4), and pectoral fin length (X17). Only two characters were not noted to differ significantly among all fish samples: maximum body depth (X12) and preanal distance (X13).

The least stable linear measurements in all the seasons of the year were caudal peduncle length (X15) and adipose fin length (X25) (Table 4). Moreover, in fish from the spring and summer seasons head width (X6) was highly varied, while among fish caught in the spring it was preorbital distance (X2), anal fin height (X20), and anal fin length (X22). The greatest stability in all the study seasons was noted for total length (X7) and body length (X9). In contrast, no marked differences were observed for the coefficients of variation of maximum body depth (X12), as was the case with fish from the other lakes.

Statistically significant differences ($P \leq 0.05$) were recorded for 20 morphometric characters among the vendace from Lake Strzeszyńskie that were caught in spring, summer, and fall (Table 4). The values of the other four characters did not differ throughout the seasons investigated, and these were predorsal distance (X10), preanal distance (X13), abdominal fin length (X17), and dorsal fin length (X21).

A comparison of morphometric characters in vendace

Statistical analysis performed to compare plasticity characters in vendace from different lakes indicated there was a lack of significant differences ($P \leq 0.05$) for total length (X7), body length (X9), predorsal length (X10), minimum body depth (X14), dorsal fin length (X21), and anal fin length (X22). The greatest differences were observed for lateral head length (X1), postorbital distance (X4), and adipose fin length (X25).

Caudal fin length (X16) in vendace from Lake Strzeszyńskie diverged markedly from the value for this character recorded in fish from the other lakes. Eye diameter (X3) was similar in fish from lakes Dominickie and Lubikowskie, but it differed statistically significantly ($P \leq 0.05$) in the fish from the other lakes. Head depth (X5) in vendace from Lake Strzeszyńskie differed significantly from the value of this parameter in fish from lakes Gorzyńskie and Lubikowskie. An analogous dependence was recorded for head width (X6) in vendace from Lake Dominickie, the values of which differed significantly ($P \leq 0.05$) from those recorded in fish from lakes Gorzyńskie and Lubikowskie. When analyzing differences between morphometric characters in vendace from different lakes, it is noteworthy that dorsal fin height (X19) in fish caught in Lake Lubikowskie differed significantly from the heights recorded in material from lakes Dominickie and Gorzyńskie.

Meristic features

The meristic characters were determined in all fish that had previously been subjected to linear measurements. The number of hard rays in individual fins (D, A, V, P) in vendace from lakes Dominickie, Gorzyńskie, and Lubikowskie fell within the range of

Table 3
Selected statistical values of morphometric characters of vendace from Lake Lubikowskie (% longitudo caudalis)*

	Spring					Summer					Autumn				
Character	M	Range	W	SD	CV	M	Range	W	SD	CV	M	Range	W	SD	CV
X1	20.45[a]	18.03-22.19	0.55	0.74	3.62	20.48[a]	18.49-22.47	0.75	0.87	4.25	20.29[a]	18.17-25.41	1.77	1.33	6.55
X2	5.39[a]	4.58-6.30	0.15	0.38	7.05	5.43[a]	4.02-6.49	0.20	0.44	8.10	5.99[b]	4.32-13.60	1.88	1.37	22.87
X3	5.18[a]	4.41-5.96	0.10	0.32	6.46	5.13[a]	4.19-6.23	0.18	0.43	8.38	5.65[b]	4.19-9.39	1.33	1.15	20.35
X4	10.20[a]	9.02-12.00	0.30	0.55	5.33	10.27[a]	8.90-11.97	0.39	0.62	6.04	10.34[a]	8.07-15.07	1.81	1.34	12.96
X5	13.01[b]	11.52-14.12	0.34	0.58	4.46	12.49[b]	10.50-14.86	0.82	0.91	7.29	11.27[a]	7.25-44.69	9.10	3.02	26.80
X6	7.20[a]	5.42-8.77	0.95	0.98	13.61	6.75[a]	4.73-8.98	1.39	1.18	17.48	8.37[b]	6.58-37.33	7.04	2.65	31.66
X7	110.38[a]	105.71-156.00	23.86	4.88	4.42	110.24[a]	106.44-114.81	2.45	1.56	1.42	110.38[a]	102.78-123.21	6.09	2.47	2.24
X9	93.28[b]	85.11-96.10	1.70	1.30	1.59	93.37[b]	90.85-95.24	1.07	1.03	1.10	89.42[a]	82.97-92.70	2.60	1.61	1,80
X10	44.87[a]	42.23-48.07	1.89	1.37	3.05	45.01[a]	41.74-49.87	1.91	1.38	3.07	44.92[a]	40.53-49.58	2.99	1.73	3.85
X11	37.44[b]	34.14-40.42	1.98	1.41	3.77	37.99[b]	34.47-41.53	1.88	1.37	3.61	36.52[a]	32.09-43.05	4.62	2.15	5.89
X12	19.48[a]	16.58-21.25	0.86	0.93	4.77	20.98[b]	17.41-23.72	1.51	1.23	5.86	22.29[c]	16.04-27.23	3.70	1.92	8.61
X13	71.11[c]	66.43-74.84	2.16	1.47	2.07	70.40[b]	65.77-73.73	2.54	1.59	2.26	69.50[a]	65.01-80.48	5.77	2.40	3.45
X14	6.45[a]	5.26-7.84	0.27	0.52	8.06	6.46[a]	5.15-8.26	0.53	0.73	11.30	7.25[b]	4.68-20.73	3.64	1.91	26.34
X15	8.35[a]	6.68-11.16	0.78	0.88	10.54	8.42[a]	6.30-11.16	1.27	1.13	13.42	9.77[b]	6.17-13.78	2.48	1.57	16.07
X16	22.34[a]	18.75-25.68	1.57	1.25	5.60	22.01[a]	18.66-24.62	1.32	1.15	5.22	21.91[a]	9.28-27.05	5.70	2.39	10.91
X17	15.39[a]	13.71-17.98	0.66	0.81	5.26	15.06[a]	12.95-18.14	1.03	1.01	6.71	15.24[a]	12.66-22.90	2.47	1.57	10.90
X18	15.13[ab]	12.96-17.65	0.78	0.89	5.88	14.91[a]	11.55-24.42	1.69	1.30	8.72	15.39[b]	12.08-20.27	2.21	1.49	9.63
X19	17.87[b]	12.80-21.04	1.36	1.17	6.55	17.52[ab]	14.11-20.53	1.18	1.09	6.22	17.34[a]	10.78-22.24	2.86	1.69	9.75
X20	11.34[a]	9.49-14.47	0.61	0.78	6.88	11.14[a]	9.14-14.29	0.96	0.98	8.80	12.04[b]	9.14-16.00	4.12	2.03	16.86
X21	9.52[a]	6.96-11.97	0.62	0.78	8.19	9.54[a]	7.45-11.09	0.45	0.67	7.02	10.33[b]	7.92-17.06	2.09	1.44	13.94
X22	12.24[a]	10.28-14.88	0.73	0.85	6.94	12.80[b]	9.85-15.79	1.31	1.14	8.91	12.43[ab]	9.37-17.79	2.46	1.57	12.63
X23	28.31[a]	24.73-32.97	2.25	1.50	5.30	28.66[a]	26.02-31.66	1.23	1.11	3.87	32.20[b]	22.88-34.57	4.48	2.12	6.58
X24	25.48[b]	22.52-29.43	2.44	1.56	6.12	25.32[b]	21.23-29.04	2.95	1.72	6.79	24.74[a]	21.10-32.19	3.23	1.80	7.28
X25	3.55[a]	2.37-4.91	0.31	0.56	15.77	3.64[a]	2.34-5.48	0.45	0.67	18.41	4.34[b]	2.49-8.09	1.32	1.15	26.50

M – mean values, W – variance, SD- standard deviation, CV – coefficient of variation
*Mean values (M) with different superscript in rows are significantly different ($P<0.05$)

Table 4
Selected statistical values of morphometric characters of vendace from Lake Strzeszyńskie (% *longitudo caudalis*)*

	Spring					Summer					Autumn				
Character	M	Range	W	SD	CV	M	Range	W	SD	CV	M	Range	W	SD	CV
X1	20.40^{b}	16.47-22.87	1.29	1.14	5.56	19.60^{a}	16.94-24.75	1.20	1.10	5.61	20.14^{b}	17.80-24.04	1.01	1.00	4.97
X2	5.35^{b}	4.00-6.88	0.29	0.54	10.09	5.10^{a}	3.89-6.02	0.20	0.45	8.82	5.47^{b}	4.34-6.78	0.24	0.49	8.96
X3	5.03^{b}	4.05-6.05	0.17	0.41	8.15	4.93^{ab}	3.98-5.71	0.13	0.36	7.30	4.89^{a}	3.53-5.94	0.19	0.44	9.00
X4	10.36^{c}	8.43-11.60	0.48	0.70	6.76	9.91^{b}	8.43-13.14	0.57	0.75	7.57	9.67^{a}	7.89-11.60	0.33	0.57	5.89
X5	14.00^{c}	9.40-20.23	1.63	1.28	9.14	12.50^{b}	10.20-14.88	0.59	0.77	6.16	11.71^{a}	8.65-13.85	0.78	0.88	7.51
X6	7.16^{b}	3.75-9.24	0.81	0.90	12.57	6.75^{a}	5.04-9.26	0.88	0.94	13.93	8.51^{c}	7.12-12.51	0.36	0.80	9.40
X7	109.59^{a}	104.44-113.88	3.88	1.97	1.80	109.96^{a}	96.43-117.41	6.45	2.54	2.31	111.68^{b}	101.52-117.07	4.07	2.02	1.81
X9	93.70^{b}	89.00-96.30	1.54	1.24	1.32	93.67^{b}	84.52-99.53	2.99	1.73	1.85	89.39^{a}	84.02-94.63	2.10	1.45	1.62
X10	44.93^{a}	39.06-49.35	4.02	2.00	4.45	45.49^{a}	39.46-52.58	5.10	2.26	4.97	45.08^{a}	36.65-54.00	4.34	2.08	4.61
X11	37.05^{b}	31.38-42.93	4.51	2.12	5.72	37.46^{b}	25.81-45.05	5.48	2.34	6.25	35.48^{a}	27.87-46.33	3.32	1.82	5.13
X12	22.69^{b}	18.12-26.60	2.86	1.69	7.45	22.48^{b}	18.42-30.45	3.89	1.97	8.76	20.00^{a}	16.25-26.30	3.64	1.91	9.55
X13	69.61^{a}	7.21-74.70	44.95	6.70	9.63	69.30^{a}	60.81-79.79	7.60	2.76	3.98	69.32^{a}	64.13-78.40	3.99	2.00	2.89
X14	7.13^{b}	5.26-8.28	0.46	0.68	9.54	6.92^{b}	5.56-8.55	0.36	0.60	8.67	6.80^{a}	5.47-8.61	0.18	0.42	6.18
X15	8.97^{a}	5.34-13.11	1.90	1.38	15.36	7.93^{a}	5.79-10.74	0.86	0.93	11.73	7.97^{b}	6.16-10.91	0.82	0.90	11.29
X16	21.80^{a}	17.35-26.23	2.17	1.47	6.74	22.61^{b}	19.36-27.21	2.18	1.48	6.55	23.35^{c}	17.78-27.38	1.95	1.40	6.00
X17	14.81^{a}	11.23-17.07	1.10	1.05	7.09	15.30^{b}	13.06-17.34	0.90	0.95	6.21	15.18^{b}	12.87-18.11	0.73	0.89	5.86
X18	14.76^{a}	11.95-20.24	1.65	1.28	8.67	14.74^{a}	11.88-17.65	1.30	1.14	7.73	14.94^{a}	12.56-17.38	0.83	0.91	6.09
X19	17.50^{b}	12.77-20.17	2.00	1.41	8.06	17.77^{b}	15.04-20.87	1.57	1.25	7.03	16.99^{a}	14.16-19.49	0.89	0.94	5.55
X20	11.68^{b}	8.44-18.12	1.88	1.37	11.73	11.78^{b}	8.90-13.82	0.79	0.89	7.56	11.15^{a}	8.48-13.63	1.01	1.00	8.97
X21	9.94^{a}	8.18-14.24	0.85	0.92	9.26	10.05^{a}	8.05-12.87	0.60	0.77	7.66	9.80^{a}	8.20-13.67	0.67	0.82	8.37
X22	12.80^{b}	7.29-15.67	2.01	1.42	10.09	13.21^{b}	10.47-15.91	1.65	1.29	9.77	11.70^{a}	9.11-14.32	1.04	1.02	8.72
X23	29.00^{b}	24.25-32.74	2.72	1.65	5.69	28.74^{ab}	25.39-34.39	2.54	1.59	5.53	28.25^{a}	23.86-33.93	3.12	1.77	6.27
X24	25.65^{b}	20.62-31.78	2.75	1.66	6.47	23.98^{a}	18.89-28.33	2.49	1.58	6.59	23.93^{a}	19.47-30.11	1.91	1.38	5.77
X25	3.84^{c}	2.03-5.87	0.42	0.64	16.67	3.49^{b}	2.20-5.16	0.27	0.52	14.90	3.27^{a}	1.95-4.93	0.23	0.48	14.68

M – mean values, W – variance, SD- standard deviation, CV – coefficient of variation
*Mean values (M) with different superscript in rows are significantly different ($P<0.05$)

1-2, except for the numbers of these rays in the pectoral fin (P) in fish from Lake Gorzyńskie, of which there was just one. Vendace from Lake Strzeszyńskie had from 1 to 2 hard rays in their pelvic and pectoral fins, while in the anal and dorsal fins a broader range of values was found for this character at 1-3 and 1-4, respectively.

The number of rays in the caudal fin (r.d.C.) was the most variable meristic character among all the fish in each of the four analyzed lakes (CV range 14.47-17.54). The range of values for this character was 15-38, while means for individual lakes were very similar ranging from 27.02 for Lake Gorzyńskie to 28.04 for Lake Dominickie. Nearly identical variation was noted in the number of rays in the brachiostegal ray count (r.br.) in vendace from lakes Dominickie and Lubikowskie (CV 10.60 and 10.59, respectively). Gill raker count at the first gill arch (sp.br.) was a highly variable meristic character in the vendace from lakes Gorzyńskie and Strzeszyńskie (CV 12.90 and 14.04, respectively). Vendace from Lake Strzeszyńskie were also characterized by the widest range of this character (from 28 to 50 at a mean of 36.32; Table 5).

The other meristic characters of vendace from the analyzed lakes were characterized by low (<10%) coefficient of variation values. The values for the number of lateral line scales (l.l.) ranged from 4.03 for fish from Lake Dominickie to 7.92 for fish from Lake Strzeszyńskie. The mean count of scales in the lateral line in vendace from lakes Dominickie, Lubikowskie, and Strzeszyńskie was similar at 80.05, 80.26, and 78.32, respectively. Fish from Lake Gorzyńskie were characterized by a lower mean number of scales in the lateral line (74.99).

Discussion

The head is one of the most variable fish body parts in terms of morphometry (Anwand et al. 1996, Gąsowska 1973, Radziej 1973). Most frequently its length in relation to the fork length falls within the range of 17.6-22.6% (Kozikowska 1961, Svärdson 1979). Among the linear characters that describe the dimensions of this part of the fish body, eye diameter is an important character, the value of which indicates vendace affiliation with various populations or forms. For example, Thienemann (after Bernatowicz et al. 1975) used this character as a diagnostic for differentiating Lake Breiter and Schmaler Lucin specimens of *Coregonus albula* (the nominal form) from *Coregonus albula lucinensis* (the deep-water form). Statistical analysis shows there are significant differences in eye diameter among the vendace from lakes Dominickie, Gorzyńskie, Lubikowskie, and Strzeszyńskie. The highest mean value for this linear character was noted in fish from Lake Lubikowskie (range of 5.13-5.65% of fork length) and Lake Dominickie (range of 5.24-5.43% of fork length). The value of this character in vendace from Lake Gorzyńskie was 4.35-4.83%, while in those from Lake Strzeszyńskie it was 4.89-5.03% of fork length. These values are similar to measurements reported by Svärdson (1979) for four populations of vendace in Scandinavian lakes (range of 4.69-5.45%) and those recorded by Radziej (1973) for fish from Lake Wierzbiczany (mean 4.9%) and Lake Narie (mean 5.7%). Differences in the mean values of this character for fish inhabiting different lakes in the Pomerania region were explained by Kozikowska (1961) to have resulted from differing water transparency. The results of studies reported by Kozikowska indicated that the greatest value for eye diameter is found in lakes with the lowest water transparency. However, reference to data obtained in this study did not confirm this, at least not with respect to Lake Lubikowskie, which was characterized by the greatest water transparency.

Statistical analysis also showed significant differences in the lateral head length and postorbital distance. The highest values of the former character were noted in fish from Lake Dominickie (range 20.39-20.99% of fork length), while the lowest were noted in fish from Lake Gorzyńskie (range 19.00-19.96% of fork length). A similar trend was noted in the values for postorbital distance which were the longest in vendace from Lake Dominickie (10.44-10.71% of fork length) and the shortest in fish

Table 5
Selected statistical values of meristic characters of vendace from the studied lakes

	Lake Dominickie					Lake Gorzyńskie					Lake Lubikowskie					Lake Strzeszyńskie				
Character	M	Range	W	SD	CV	M	Range	W	SD	CV	M	Range	W	SD	CV	M	Range	W	SD	CV
r.d.D	9.02	7-11	0.57	0.76	8.42	8.82	7-11	0.41	0.64	7.25	8.88	7-11	0.50	0.71	7.99	8.72	7-11	0.42	0.65	7.45
r.d.A	10.54	9-14	0.71	0.84	7.96	11.18	8-13	0.78	0.88	7.87	11.00	8-14	0.98	0.99	9.00	10.87	9-13	0.73	0.85	7.81
r.d.C	28.04	15-36	16.96	4.11	14.65	27.02	19-36	22.50	4.74	17.54	27.91	20-35	16.37	4.04	14.47	27.97	20-38	22.70	4.76	17.01
r.d.V	9.61	8-11	0.56	0.75	7.80	9.19	8-11	0.37	0.61	6.63	10.10	8-12	0.46	0.68	6.73	9.31	8-11	0.46	0.67	7.19
r.d.P	13.37	11-15	0.75	0.87	6.50	13.06	10-15	0.95	0.97	7.42	13.67	11-15	0.71	0.84	6.14	12.91	11-15	0.81	0.90	6.97
l.l.	80.05	70-90	10.43	3.23	4.03	74.99	70-88	27.54	5.24	6.98	80.26	70-90	13.66	3.69	4.59	78.32	70-92	38.62	6.21	7.92
l.l.1	7.60	7-8	0.23	0.48	6.31	7.53	6-8	0.25	0.50	6.64	7.35	6-9	0.27	0.52	7.07	7.76	7-9	0.27	0.52	6.70
l.l.2	7.44	7-8	0.24	0.49	6.58	7.35	6-9	0.36	0.60	8.16	7.44	6-9	0.38	0.62	8.33	7.62	6-9	0.26	0.51	6.69
sp.br.	41.14	32-49	8.13	2.85	6.92	35.72	27-46	21.25	4.61	12.90	41.38	30-50	12.18	3.49	8.43	36.32	28-50	26.02	5.10	14.04
r.br.	8.20	7-12	0.77	0.87	10.60	8.96	7-11	0.50	0.70	7.81	8.12	6-11	0.74	0.86	10.59	8.96	6-11	0.57	0.75	8.37

M – mean values, W – variance, SD- standard deviation, CV – coefficient of variation

Table 6
Comparison of selected meristic characters of different vendace populations

Research site	Author	Fin ray count				Number lateral line scales	Gill raker count
		Dorsal	Anal	Pelvic	Pectoral		
Germany	Bauch (1961)	8-9	11-12	10	14-15	80-90	36-51
Sweden	Svärdson (1979)	10.8-11.8*	13.1-14.5*	-	14.7-16.2*	77.1-81.6*	44.3-45.7*
Lake Onega	Pokrovskij (1967)	7-10	10-14	-	-	72-90	39-49
Lake Ładoga	Dyatlov (1978)	7-11	8-14	-	-	62-90	35-52
Lake Naroć	Galcowa (1954)	8-11	10-14	-	-	70-90	36-46
Poland	Gąsowska (1962)	8-9	10-13	-	-	62-90	35-52
Lake Charzykowo	Walczak (1953)	8-11	9-14	7-12	12-15	-	39-48
Lake Bucerz		7-10	9-12	9-10	11-15	-	35-44
Lake Krzemień		8-10	10-14	9-11	11-15	-	42-51
Lake Kaleńskie		8-11	10-14	8-11	11-14	-	36-51
Lake Łańskie	Gąsowska (1973)	8-10	10-13	-	-	75-91	41-49
Lake Wigry		7-9	10-12	-	-	75-90	40-49
Lake Mamry		8-9	10-12	-	-	77-90	41-45
Lake Miedwie		8-9	10-12	-	-	73-88	37-47
Lake Bucerz		7-9	10-12	-	-	78-91	37-43
Lake Leśne	Czerniejewski (2002)	8-10	9-14	9-11	13-15	72-81	40-46
Lake Siecino	Czerniejewski et al. (2002)	8-10	10-13	9-12	13-15	71-82	39-45
Lake Drawsko	Czerniejewski and Filipiak (2002)	7-10	10-15	9-11	10-14	72-87	35-41
Lake Pełcz		7-10	9-14	9-11	12-15	73-88	36-43
Lake Dominickie	Own data	7-11	9-14	8-11	11-15	70-90	32-49
Lake Gorzyńskie		7-11	8-13	8-11	10-15	70-88	27-46
Lake Lubikowskie		7-11	8-14	8-12	11-15	70-90	30-50
Lake Strzeszyńskie		7-11	9-13	8-11	11-15	70-92	28-50

*Range of mean values from four Swedish lakes

from the population in Lake Gorzyńskie (9.44-10.15% of fork length).

In addition to morphometric characters concerning the head, significant differences were also observed in adipose fin length. The shortest adipose fins were noted for vendace from Lake Gorzyńskie, while the longest were noted in fish from Lake Lubikowskie. Moreover, differences were also observed in caudal fin length; the values for this character in the fish from Lake Strzeszyńskie were longer than those of the fish from all three of the other analyzed lakes. According to Nikanorov (1964), fin elongation in vendace, and particularly that of the caudal fin, is linked to the necessity of overcoming strong wave motion in lakes with large feeding areas. It is likely that the size and location of water bodies is a major factor affecting fluctuations in the values of morphometric characters connected with the motor function in this species. However, the example of vendace from Lake Strzeszyńskie, which has the smallest area among the analyzed lakes, does not confirm this hypothesis.

The range of the number of lateral line scales in vendace from Poland is relatively broad at 72-84 (Gąsowska 1962, Rolik and Rembiszewski 1987); however, in some lakes (e.g. lakes Łańskie and Bucerz) specimens with over 90 lateral line scales were noted (Gąsowska 1973). The range of this character in lakes Dominickie (70-90 scales), Gorzyńskie (70-88 scales), Lubikowskie (70-90 scales), and Strzeszyńskie (70-92 scales) fell within the ranges reported most frequently in the literature (Table 6).

An important taxonomic character in fish from the family *Coregonidae* is the structure of the

filtration apparatus. Based on the data presented in Table 6, the number of gill rakers on the first gill arch varies among vendace from different lakes. For example, the range of this character in vendace from Germany is 36-51 (Bauch 1961), Poland 35-52 (Gąsowska 1962), Belarus 36-46 (Galcova 1954), and Russia 36-49 (Pokrovskij 1967). Despite the characteristic high variation in the number of gill rakers in vendace, the mean value of this is a major meristic character that is suitable for differentiating individual populations as well as forms of this species (Dyatlov 1978, Svärdson 1979). The analysis of mean values of this character for lakes in Poland indicated that the highest number of gill rakers is found in vendace from Lake Krzemień (mean 45.87, range of 42-51), while it is lowest in Lake Bucerz (mean 39.95, range of 35-44). Disproportions in the values of the this character are ascribed by Walczak (1953) to the specific character of the environment (contents of oxygen and planktonic organisms in the water). When environmental conditions are stable there is considerable stability in the number of gill rakers (Gąsowska 1973). According to these authors the highest values of this character are observed in vendace from oligotrophic lakes, while lower values are noted in fish from eutrophic lakes. Among the four lakes from the Wielkopolska region analyzed in the current study, this character ranged from 35.72 in the vendace from Lake Gorzyńskie to 41.38 in those from Lake Lubikowskie. The number of gill rakers in vendace from Lake Strzeszyńskie was similar to that in fish from Lake Gorzyńskie at an average of 36.32, while in those from Lake Dominickie it was similar to those from Lake Lubikowskie at 41.14. Based on the above, it can be presumed that zooplankton availability in lakes Strzeszyńskie and Gorzyńskie is better than in the two other lakes, as this could have resulted in the inferior development of the filtration apparatus in vendace. Additionally, the analyzed lakes were stocked with material from other lakes, and this introduced specimens with varied numbers of gill rakers that differed from that in autochthonous forms of vendace.

A key character used to identify species is the number of rays in individual fins. Numerous taxonomic studies published to date on vendace indicate the occurrence of both hard and soft rays in this species (Berg 1948, Gąsowska 1962, Bauch 1961, Koskova 1977). However, since these fish lack typically hard rays (uniform, stiff, undivided), in many studies the analysis of meristic characters covers only typical soft rays (Walczak 1953, Kozikowska 1961, Gąsowska 1973).

The occurrence in vendace of both ray types was also verified by Nelson (1994). According to Krzykawski et al. (2001), fish from the order *Salmoniformes*, which also includes vendace, have no hard rays in their fins, but two varieties of soft rays do occur. However, traditional nomenclature was applied in this study since many authors still use it, and this also facilitates a more comprehensible comparison with the data in the literature. Typical soft rays are branched in the form of a fan and divided, while hard rays are not branched although they are also divided and elastic. The number of the latter rays in individual fins in vendace is almost a permanent character and falls within the range of 3-4 in anal and dorsal fins, as well as one in the pectoral fin and two in the pelric fin (Berg 1948, Gąsowska 1962). Much greater variation is recorded in the number of typical soft rays in individual rays. The value of this meristic character in the vendace analyzed in the present study was within a range of 7-11 for the dorsal fin, 8-14 for the anal fin, 8-12 for the pelric fin, and 10-15 for the pectoral fin. The range of these characters is completely consistent with data reported in vendace from lakes in Poland (Walczak 1953, Gąsowska 1962, 1973), Belarus (Galcowa 1954), Russia (Pokrovskij 1967, Dyatlov 1978), and Sweden (Svärdson 1979) (Table 6).

Conclusions

The greatest differences in morphometric character values in vendace were noted in measurements describing head shape, including lateral head length, eye diameter, postorbital distance, and adipose fin length. The smallest differences in the values of morphometric characters were recorded for the greatest linear measurements of the body, which

includes body length, predorsal distance, minimum body depth, dorsal fin length, and anal fin length. Differences were noted in the values of linear measurements of vendace caught in different seasons, which indicates that drawing conclusions on body conformation in vendace is justified only when the fish being analyzed were caught in comparable seasons of the year. Variation in morphometric parameters in vendace from individual lakes confirms the hypothesis that each lake has its own specific form of vendace. Such differences could also be a consequence of lake trophic state which influences, among other aspects, the amount of food available.

Acknowledgments. This study was conducted within a project supported by the Poznań University of Life Sciences.

Author contributions. M.F., A.P., W.A., and J.M. designed and performed the study; M.F., W.A., J.M., and J.G. analyzed the data; M.F., J.M., J.G., K.P., and S.R. prepared the paper.

References

Anwand K., Staaks G., Valentin M. 1996 – Two populations of *Coregonus albula* (Linnaeus, 1758) in Lake Stechlin (Germany, Brandenburg) – Fish Fish. Res. 1: 1-10.

Bauch G. 1961 – Die einheimischen Süsswaserfische – Neuman-Verlag, Radebeul, Berlin, 198 p.

Berg L.S. 1948 – Fish of Freshwaters of USSR and Neighboring Countries – Izdatel'stvo Akademii Nauk SSSR, Moskowva-Leningrad, 466 p. (in Russian).

Bernatowicz S., Dembiński W., Radziej J. 1975 – Vendace – PWRiL, Warszawa, 284 p. (in Polish).

Bnińska M. 1994 – Practical methods for the analysis of the effectiveness of stocking lakes – In: Current problems of lake fisheries (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 51-70 (in Polish).

Bnińska M. 1998 – Coregonid fish management against the background of environmental quality – In: Coregonid fish management - conditions and efficiency (Eds) A. Wołos, M. Bnińska. Wyd. IRS, Olsztyn: 29-43 (in Polish).

Brylińska M. 2000 – Freshwater Fishes of Poland – PWN, Warszawa, 520 p. (in Polish).

Czerniejewski P. 2002 – Biometric characteristics of the vendace (*Coregonus albula* L.) from Lake Leśne – Acta Sci. Pol. Piscaria 1: 5-14.

Czerniejewski P., Filipiak J., 2002 – Biological and morphological characteristics of vendace, *Coregonus albula* L., from lakes Drawsko and Pełcz – Acta. Ichthyol. Piscat. 32: 53-69.

Czerniejewski P., Filipiak J., Przybył A. 2002 – Preliminary biometrical characteristics of cisco (*Coregonus albula*) from the Tuczno Wielkie and Siecino Lakes – Sci. Pap. Agric. Univ. Pozn. Anim. Sci. 4: 91-103.

Dyatlov M.A. 1978 – O populacionnoj nieiednorodnosti rjapuski *Coregonus albula* L. Ladozskowo ozera – Vopr. Ikhtiol. 18: 615-623 (in Russian).

Fiszer M., Przybył A., Andrzejewski W., Mazurkiewicz J., Golski J., Przybylska K., Runowski S. 2012 – Effects of eutrophication on vendace *Coregonus albula* (L.). I. Limnological characteristic of selected lakes in Wielkopolska – Arch. Pol. Fish. 20: 85-95.

Galcova M.U. 1954 – Rjapuska (*Coregonus albula* L.) ozera Naroć – Ućenye Zapiski, Minsk, 17: 96-108 (in Russian).

Gąsowska M. 1962 – A guide for identifying vertebrates in Poland. Cyclostomates and fishes – PWN Warszawa-Kraków, (in Polish).

Gąsowska M. 1973 – Comparative and biometric studies of the *Coregonus albula* (Linnaeus 1758), (*Pisces, Coregoninae*) from the lakes of Poland and a few neighboring countries – Rocz. Nauk Rol. 95-H-1: 41-54 (in Polish).

Koskova L.A. 1977 – Bielozerskaja rjapuska *Coregonus sardinella vessicus* Drjagin v saratovskom vodochranilišce – Vopr. Ikhtiol. 17: 545-548 (in Russian).

Kaupinis A., Bukelskis E. 2010 – Morphological and genetic variations in vendace (*Coregonus albula* (L.)) in the lakes of Lithuania – Acta Zool. Lituanica 20: 51-60.

Kozikowska Z. 1961 – Impact of the environment on fish morphology and biology. Vendace, perch: selected elements – Ekol. Pol. 9: 541-712 (in Polish).

Krzykawski S., Więcaszek B., Keszka S., Antoszek A. 2001 – Systematics of Cyclostoma and Fishes. Guide to Exercises – Wyd. AR Szczecin, 437 p. (in Polish).

Nelson J.S. 1994 – Fishes of the world. 3rd ed. – John Wiley & Sons. INC, New York, 600 p.

Nikanarov J.I. 1964 – Morfologiceskie osobennosti lokalnyh stad evropeiskoj rjapuski *Coregonus albula* (L.) v zavisimosti ot uslovii obitanija – Vopr. Ikhtiol. 4: 411-422 (in Russian).

Pokrovskij V.V. 1967 – O morfologiceskich osobennostijach proishoždenii i geografićeskom rasprostranenii belomorskoj rjapuski *Coregonus sardinella maris-albi* Berg – Izv. Inst. Ozern. Recn. Rybn. Hoz. Leningrad, 62: 100-114 (in Russian).

Radziej J. 1973 – Environmental impact on slow-growing vendace (*Coregonus albula* L.) resettled from Lake Narie to the Lake Wierzbiczany – Rocz. Nauk Rol. 95-H-1: 129-146 (in Polish).

Rolik H., Rembiszewski J.M. 1987 – Fishes and cylostomes (*Pisces* et *Cyclostomata*) – PWN, Warszawa, 252 p. (in Polish).

Smitt F.A. 1886 – Kritik förteckning över de i Riksmuseum befnitliga Salmonider – Handl. Svenska Vet. Acad. 21: 1-290.

Svärdson G. 1979 – Speciation of Scandinavian *Coregonus* – Rep. Inst. Freshw. Res. Drottningholm 57: 1-95.

Thienemann A. 1922 – Weitere Untersuchungen an Coregonen – Arch. Hydrobiol. B-XIII: 414-468.

Walczak J. 1953 – Vendace (*Coregonus albula*) from several lakes of Western Pomerania – Rocz. Nauk Rol. 67-B-1: 21-37 (in Polish).

Wołos A. 1994 – Effectiveness of coregonid fish stocking – In: Current issues in lake fisheries (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 79-93 (in Polish).