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PROOF RESEARCH PAPER

Sexual Dimorphism of European Perch, *Perca fluviatilis* Linnaeus, 1758 from Lake Skadar (Montenegro) Based on Morphometric Characters

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Abstract

The morphological variability of European perch from Lake Skadar was evaluated based on 19 morphometric measurements. Analysis of variance and covariance showed that seven morphometric characters were different among sexes: head length, preorbital distance, predorsal distance of first dorsal fin, predorsal distance of second dorsal fin, first dorsal fin height, second dorsal fin height and pectoral fin length. Characters: head length, preorbital distance, predorsal distance of first dorsal fin and predorsal distance of second dorsal fin showed no value overlap among males and females, which indicated significant differences between sexes in these characters. Growth analysis of individual morphometric parameters versus total length showed that: head length, preorbital distance, predorsal distance of first dorsal fin and predorsal distance of second dorsal fin have more or less isometric growth for both sexes and were mainly dependent on fish total length. This study determined that females have larger heads compared to males of the same age.

Keywords: Balkan, male, female, introduced species, sex determination.

Introduction

European perch, *Perca fluviatillis* Linnaeus, 1758 inhabits rivers, lakes and estuaries in Eurasia, except for the northernmost parts of Scandinavia, the Iberian Peninsula, central Italy, and the Adriatic Sea basin (Freyhof & Kottelat, 2008). In addition to its natural habitat, this species is wildly spread all over the world due to intentional or nonintentional translocation. As a result, European perch is present in numerous waterbodies in Europe (Elvira & Almodóvar, 2001; Vila-Gispert *et al*., 2005; Alessio *et al*., 1991), Asia (Berg, 1965; Yadrenkina, 2012), Australia (Weatherley, 1997; Morgan *et al*., 2003), New Zealand (Allen & Cuningham, 1957; McDowall 1990; Closs *et al*., 2003), and in South Africa (Hey, 1947; Jubb, 1967).

Perch was caught for the first time in Montenegro in 1979 when a sample of four specimens was collected in sublacustine spring “oko” Raduš (Knežević & Marić, 1979). However, there is a lack of accurate data about the time of introduction and origin of this species in Lake Skadar. Due to the fact that Lake Skadar is not a natural habitat of perch, natural adaptation had to occur with self-dislocation during areal spreading, alongside the adaptation to conditions in the new environment (Kuderskii, 1975). Such adaptations in introduced species produce changes in morphology, physiology and ecology. Being highly invasive (Simonović *et al*., 2013) and piscivorous species, high abundance of perch could lead to a reduction of autochthonous species in new environments (in Lake Skadar). Since Lake Skadar is the largest Balkan lake and a region well recognized as a European biodiversity hotspot (Gaston & David 1994; Griffiths *et al*., 2004) and one of Key biodiversity area in Mediterranean (Darwall *et al*., 2014), it is of high importance to research the morphology and the ecology of this invasive and relatively recently established species. So far, only two studies have been conducted regarding the morphology of perch, in Lake Skadar (Knezević & Marić, 1979; Marić & Ćirovic, 2002), however, little information is provided in these studies regarding sexual dimorphism of this fish species beyond the spawn period. The aim of this study was to test whether there are differences in morphometric characters among sexes which can allow sex determination before European perch develops full sexual maturity.

Materials and Methods

Study Area

The Lake Skadar drainage basin is located between 18º41' and 19º47' East and between 42º58' and 40º10' North in a karstic area in the outer part of the southeastern Dinaric Alps. It is the largest of the Balkan lakes and has a surface area which fluctuates seasonally from approximately 370 to 600 km^2.

The water level also varies seasonally from 4.7 to 9.8 m above sea level. The lake extends in the NW-SE direction, and it is approximately 44 km long. The Bojana River connects the lake with the Adriatic Sea, and the Drim River provides a link with Lake Ohrid. The exact origin of the lake is unknown but it probably originated by solution and tectonic processes during the Pleistocene (Stanković, 1960).

The Southern and southwestern sides of the lake are rocky, barren and steep, having bays in which the sublacustrine springs are usually found (so called “oka” – “eye”). On the northern side, there is a huge inundated area, the boundaries of which change as water levels fluctuate. The climate at the Lake Skadar drainage basin is typically Mediterranean, with a long, hot summer at lower and medium altitudes and a short winter with heavy and abundant rainfalls.

Sample Collection

Samples were collected in October and November 2013, in Lake Skadar localities of Vranjina, Virpazar, Grmožur with multi mesh size gill nets (EU standard EN 14757). Fish were removed from the catch and immediately deep-frozen for later analysis. A total of 19 morphometric characters were analyzed: TL - Total length, SL - Standard length, H - Maximum body height, h - Minimum body height, lc - Head length, Oh - Horizontal eye diameter, iO - Interorbital distance, prO - Preorbital distance, Lpc - Length of caudal peduncle, pDI - Predorsal distance of first dorsal fin, pDII - Predorsal distance of second dorsal fin, IDI first dorsal fin length, IDII - second dorsal fin length, hDI - first dorsal fin height, hDII - second dorsal fin height. IA - Anal fin length, hA - Anal fin height, IP - Pectoral fin length, IV - Ventral fin length. Data were only collected from the left side of the fish. Morphometric measurements were taken to the nearest 0.02 mm using calipers and in accordance with the scheme shown in Figure 1. For the sex determination, after measuring, the fish were dissected and the gonads removed.

Statistical Analyses

The resulting data were statistically analyzed using Statistica 7.0. and Minitab 16.0. All measurements were plotted against TL, in order to eliminate variability that could occur as a result of allometric growth. ANOVA was used to examine differences in both sexes, and statistical significance was determined by Tukey HSD Post-hoc test. ANCOVA was used to examine differences in body shape between sexes. The allometric growth relative to TL was calculated from the function $Y = a\mathrm{TL}^b$, where a and b are constants and Y is the morphometric variable (Minos *et al*., 1995). The 95% confidence intervals (Cls) of the parameters and the statistical significance of the regression relationship (r^2) were estimated. The morphometric variables were then divided into three categories: positive allometry (+ A), when the slope (*b*, allometry coefficient) was higher than 1 and the variable increased relatively to TL; negative allometry (- A), when the slope was

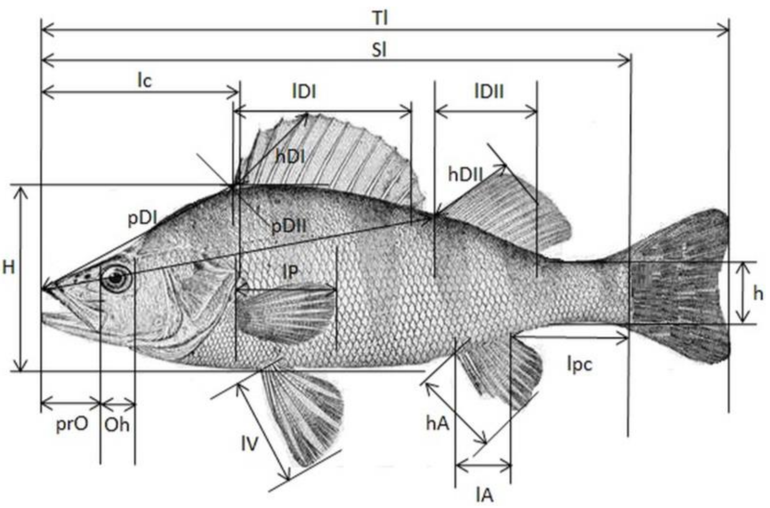

Figure 1. Morphometric measurements taken on European perch (*Perca fluviatilis*)
TL - Total length, SL - Standard length, H - Maximum body height, h - Minimum body height, lc - Head length, Oh - Horizontal eye diameter, iO - Interorbital distance, prO - Preorbital distance, Lpc - Length of caudal peduncle, pDI - Predorsal distance of first dorsal fin, pDII - Predorsal distance of second dorsal fin, IDI -first dorsal fin length, IDII second dorsal fin length, hDI - first dorsal fin height, hDII - second dorsal fin height. IA - Anal fin length, hA - Anal fin height, IP - Pectoral fin length, IV - Ventral fin length.

lower than 1, indicating direct proportionality beetwen the variable and TL. The significance of the slope was tested by means of a t-test (Zar, 1999).

Results

Data obtained from the measurements of morphometric characters of European perch from Lake Skadar (Montenegro) are provided in Table 1. Measurements were performed on 75 fish (40 of which were female and 35 male). Analysis of variance (ANOVA) revealed differences among females and males for seven morphometric characters (Table 2). Characters prO, and pDI showed extremely high significant differences (*P* < 0,001); lc, pDII, hDII showed high significant differences (*P* < 0,01) while characters hDI and lP showed moderate significant differences between sexes (*P* < 0,05) (Table 2). Characters lc, prO, pDI, pDII showed no value overlap, which indicated significant differences between sexes in these characters (Figure 2-5).

The parameters of the equation of each morphometric variable versus total length (TL) of females and males are presented in Table 3. In females, seven dimension (H, iO, Lpc, pDII, lDI, hDII and lA) revealed a positive allometric relationship,

Table 1. Summary of variation found in morphological characters in European perch, *Perca fluviatilis* from Lake Skadar.

Morphometric character	Male					Female				
	N	M	Min	Max	SD	N	M	Min	Max	SD
TL	35	162.25	113.00	235.00	24.28	40	172.92	140.00	276.00	27.66
SL	35	134.43	91.62	200.30	21.44	40	143.69	114.00	234.00	23.85
H	35	37.46	25.34	60.20	6.56	40	40.67	29.86	67.20	8.21
h	35	11.14	7.70	19.96	2.24	40	11.84	8.50	18.56	1.89
lc	35	42.29	28.14	66.08	7.25	40	46.33	34.74	73.04	7.66
Oh	35	9.01	7.18	10.74	0.86	40	9.52	7.94	12.28	0.91
iO	35	10.56	6.98	16.88	1.85	40	11.44	8.52	17.26	2.00
prO	35	10.77	7.30	16.88	1.90	40	12.05	9.46	19.76	1.99
Lpc	35	28.84	20.98	38.80	4.08	40	30.15	22.90	51.96	5.62
pDI	35	42.51	28.46	62.16	6.96	40	46.97	36.94	71.90	7.20
pDII	35	87.44	61.14	127.96	13.62	40	96.54	74.92	154.02	17.43
lDI	35	44.13	29.34	68.18	7.64	40	47.33	36.08	82.76	9.26
lDII	35	25.02	16.90	36.52	4.01	40	26.71	19.08	40.90	4.81
hDI	35	20.63	13.18	29.30	3.36	40	21.00	14.92	30.88	3.15
hDII	35	15.92	11.52	23.46	2.35	40	16.25	12.18	26.16	3.00
lA	35	15.90	12.36	24.06	2.47	40	16.95	12.16	28.58	3.21
hA	35	19.77	13.90	29.66	3.00	40	20.61	12.98	30.60	3.33
lP	35	22.69	16.30	30.96	3.16	40	23.54	18.20	33.96	3.52
lV	35	24.04	14.76	34.58	3.92	40	25.40	19.96	37.76	3.63

Shown are the: M - arithmetic means, SD – standard deviation Min - minimum and Max - maximum values.

Table 2. Analysis of variance and covariance (covariable is standard length SL) of morphometric characters of European perch between sexes

Morphometric character	ANOVA Male/Female		ANCOVA Male/Female	
	F	*P*	F	*P*
SL	1,16	0,285		
H	1,31	0,256	0,80	0,375
h	0,01	0,912	0,03	0,872
lc	8,38	0,005**	7,35	0,008**
Oh	0,17	0,677	0,08	0,782
iO	2,08	0,153	1,52	0,222
prO	12,44	0,0008***	11,08	0,001***
Lpc	2,53	0,116	2,94	0,091
pDI	12,60	0,0008**	11,11	0,001***
pDII	9,84	0,002**	8,46	0,005**
lDI	0,08	0,774	0,02	0,880
lDII	0,02	0,897	0,00	0,985
hDI	6,92	0,01*	6,99	0,010*
hDII	8,53	0,004**	8,62	0,004**
lA	0,03	0,855	0,03	0,868
hA	2,03	0,158	2,60	0,111
lP	5,35	0,023*	4,55	0,036*
lV	0,21	0,646	0,22	0,638

F – variance relationship; *P* values was determined by Tukey HSD Post-hoc test: *P* > 0,05 not significant, * *P* < 0,05, ***P* < 0,01, ****P* < 0,001

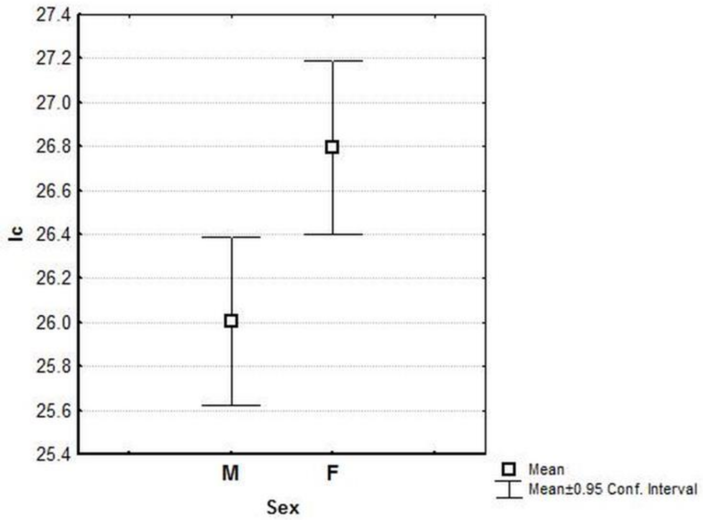

Figure 2. Box & Whisker diagram for morphometric character lc in relation to sex in European perch.

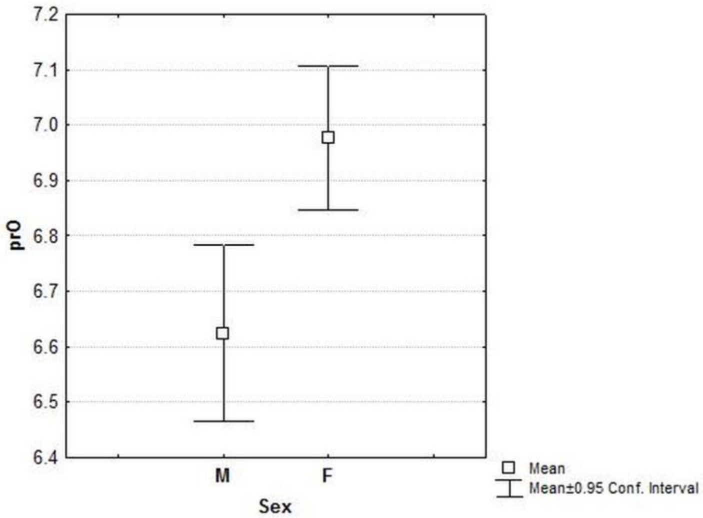

Figure 3. Box & Whisker diagram for morphometric character prO in relation to sex in European perch.

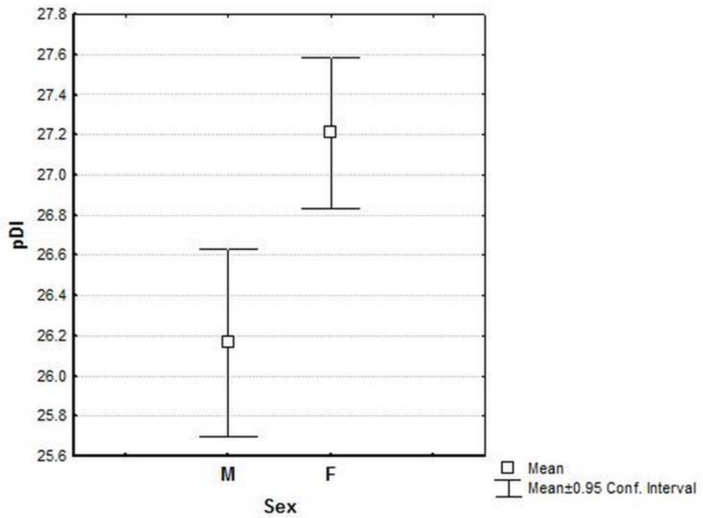

Figure 4. Box & Whisker diagram for morphometric character pDI in relation to sex in European perch.

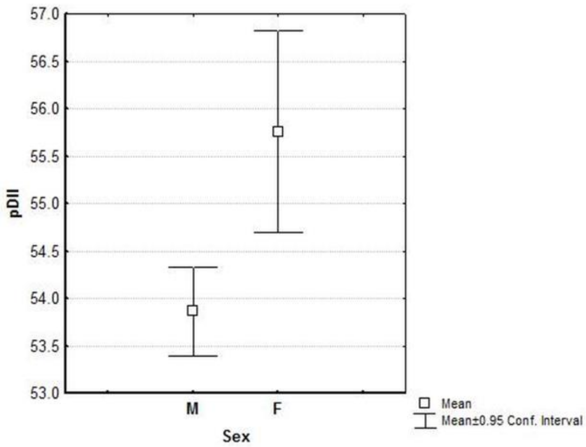

Figure 5. Box & Whisker diagram for morphometric character pDII in relation to sex in European perch.

Table 3. Morphometric variables versus Total length (TL) for male and female of European perch. Slope patterns are: + A, positive allometry; - A, negative allometry; I, isometry. *indicates significant difference of *b* value from 3 (t-test; $P < 0.05$)

Dimension	Regression parameters (Male)						Regression parameters (Female)					
	b	95% Cl of *b*	*a*	95% Cl of *a*	r^2	Slope (*b*)	*b*	95% Cl of *b*	*a*	95% Cl of *a*	r^2	Slope (*b*)
H	1.080	0.9506-1.2093	0.153	0.0530-0.2529	0.891	I	1.168	1.0308-1.3052	0.099	0.0304-0.1676	0.880	+A*
h	0.966	0.6994-1.2325	0.081	-0.0287-0.1907	0.605	I	0.959	0.8414-1.0766	0.085	0.0340-0.1359	0.872	I
lc	1.010	1.0178-1.2021	0.149	0.0784-0.2195	0.944	I	1.00	0.89612-1.1038	0.268	0.1249-0.4112	0.903	I
Oh	0.497	0.3519-0.6420	0.721	0.1859-1.2560	0.574	-A*	0.518	0.3945-0.6415	0.662	0.2425-1.0814	0.642	-A*
iO	1.128	1.0143-1.2417	0.034	0.0144-0.0536	0.920	+A*	1.065	0.9434-1.1865	0.047	0.0176-0.0764	0.884	+A*
prO	1.003	0.9482-1.2578	0.039	0.0076-0.0703	0.854	I	0.980	0.8306-1.2418	0.086	0.0048-0.1428	0.848	I
Lpc	0.834	0.6752-1.5092	0.414	0.0808-0.7472	0.762	-A*	1.088	0.9547-1.2213	0.110	0.0355-0.1845	0.871	+A*
pDI	1.070	0.8760-1.2639	0.183	0.0752-0.2908	0.908	I	0.967	0.8368-1.0172	0.396	0.2117-0.5802	0.914	I
pDII	1.029	0.9702-1.0878	0.465	0.3278-0.6022	0.973	I	1.063	0.9434-1.1825	0.402	0.1550-0.6489	0.890	+A*
lDI	1.036	0.889-1.183	0.226	0.0574-0.3945	0.852	I	1.139	1.0371-1.2409	0.133	0.0624-2.129	0.927	+A*
lDII	1.012	0.9022-1.1217	0.145	0.0646-0.2254	0.909	I	1.005	0.81096-1.1990	0.150	0.0010-0.2989	0.732	I
hDI	0.981	0.7928-1.1692	0.140	0.0047-0.2752	0.758	I	0.919	0.7994-1.0385	0.184	0.0703-0.2977	0.856	-A*
hDII	0.845	0.6999-0.9900	0.215	0.0562-0.3737	0.797	-A*	1.050	0.8873-1.2127	0.072	0.0112-0.1327	0.808	+A*
lA	0.897	0.7539-1.0401	0.165	0.0434-0.2865	0.819	-A*	1.069	0.8945-1.2434	0.068	0.0072-0.1287	0.792	+A*
hA	0.944	0.8185-1.0694	0.162	0.0581-0.2658	0.867	-A*	0.948	0.76964-1.1263	0.155	0.0119-0.2981	0.741	-A*
lP	0.886	0.7860-.9859	0.250	0.1226-0.3774	0.901	-A*	0.910	0.7944-2.0664	0.216	0.0866-0.3454	0.862	-A*
lV	0.939	0.7273-1.1506	0.201	-0.0146-0.4166	0.697	-A*	0.866	0.7778-0.9542	0.293	0.1597-0.4263	0.906	-A*

and five (Oh, hDI, hA, lP and lV) had a negative allometric relationship. Five dimension (h, lc, prO, pDI, lDII) had an isometric relationship with TL. In males, character iO had a positive relationship while seven dimensions (Oh, Lpc, hDII, lA, hA, lP and lV), a negative relationship. Nine dimensions (H, h, lc, prO, pDI; pDII, lDI, lDII and hDI) increased isometrically with TL.

Discussion

From the comparative analysis of data presented in this study and previous research conducted on European perch in Lake Skadar (Knežević & Marić, 1979; Marić & Ćirović, 2002) it can be concluded that the morphology of this species hasn't changed significantly from the time of its introduction. TL and

SL are the only characters that showed a certain degree of variability, with higher values noted compared to previous data. The higher values may be attributed to a difference in the type of sampling gear used, as in this study multi mesh size gill nets were used (EU standard EN 14757) and all cohorts were in the sample set. The specificity of the morphometric character's variable nature often creates difficulties in the precise determination of morphological adaptivity in a new environment. However, comparative analysis of available literature data (Simonović, 1995), showed that some characters have relatively constant variability, such as horizontal eye diameter, which often exhibits negative values of correlation coefficient in available literature.

When it comes to intrapopulation variability, the highest level of variability was noted in the appearance of sexual dimorphism. European perch displays sexual growth dimorphism whereby females were bigger than males (Fontaine *et al*., 1997). Research data suggest bigger body size in females, which is indicated by higher mean values in all examined morphometric parameters in female specimens (Table 1). Bigger females are favored by natural selection as bigger body size in females is often correlated with their role in reproduction, considering that the number of eggs increases along with body size in females (Lévêque, 1997). In this study both ANOVA and ACOVA, showed differences in fish size based on the sex of the species, indicated by differences in lC, prO, pDI, pDII, hDII and lP. A Bulgarian study on sexual dimorphism in a cultivated population of perch (Sirakov *et al*., 2012) also indicated larger females, as well as differences between sexes in morphometric characters: lDI, lA, hA, lP, lV; however, the cause of sexual dimorphism in this instance was not determined. Various studies on sexual dimorphism in different fish species provided different data about morphological differences between sexes. Šapošnikova, 1948 in a study on *Abramis brama*, L. reported differences between sexes in parameters hD, hA and Minos *et al*., 2008 reported that six morphometric characters (fork length, preorbital distance, postorbital distance, standard length, trunk length) were significantly different for males and females in *Pagrus pagrus* L. A study conducted on four species of genus *Sebastes* (Echeverria, 1986) also reported larger females, as well as a higher eye diameter and pectoral length in males. Aguirre & Akinpelu, 2010 in their morphological study on *Gasterosteus aculeatus* found sexual dimorphism in head morphology, which is reflected in larger head length, bigger upper lip, snout and oral region in males. Some authors consider that sexual dimorphism in head morphology and trophical structures can be the result of natural selection in relation to different ecological niche differentiation between sexes, or reproductive selection which improves reproductive success in males (Mori, 1984; Caldecutt *et al*., 2001; Kitano *et al*, 2007).

The following four of six parameters that showed sexually based differences did not show any overlap in size among males and females: lC, prO, pDI and pDII (Figures 2-5). This strongly supports our previous conclusion that females have larger heads compared to males. In addition, the analysis of growth of individual morphometric parameters versus TL showed that lC, prO, pDI and pDII have more or less isometric growth for both sexes (Table 3) and mainly depend on fish TL. All this suggests that the basis for the already noted distinctions are differences in TL (larger females compared to males). Simonović & Nikolić, 1997 noted that prO is a highly variable character in length classes where a shift from benthic to piscivorous diet occurs. According to Kottelat & Freyhof, 2007 European perch becomes piscivorous at about 120 mm SL. For a diet pattern shift to be achieved (from a benthic to a piscivorous diet) it is necessary that the morphological preconditions are satisfied (Simonović & Nikolić, 1997). According to our unpublished data the variability of prO in relation to head length is higher in females in length classes smaller than 190 mm, as well as in males larger than 210 mm. Based on the above data, a conclusion may be reached that a shift to a piscivorous diet in perch occurs at a different body length for females compared to males, which results in females shifting earlier.

Determining the sex of fish species before they reach sexual maturity would prove valuable for cultivating perch, including its artificial reproduction (Sirakov *et al*., 2012) or reproduction control. Although our research pointed out that sexual dimorphism in European perch from Lake Skadar is linked with differences in growth and size (TL), reasons for this remain unknown. In addition, we showed that females have larger heads compared to males. These findings present a basis for further research in the area which will assist in sex determination of European perch. If we managed to reveal the precise morphological characters that determine sex in immature fish, this would be of invaluable help and would be applicable to fish farming of this species.

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