

Lenght-weight relationship and condition factor of silver stage of European eel, *Anguilla anguilla* (Linnaeus, 1758) from Lake Skadar (Montenegro)

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ABSTRACT

The length-weight relationship (LWR) and condition factor of the Silver stage of European eel from Lake Skadar, Montenegro were examined on 140 registered individuals. The samples were collected from October to December 2019. The aim of this study was to determine the model of growth and condition of males and females of the silver stage of European eel. LWR of females of silver European eel showed positive allometric growth ($b=3.12$) while males showed negative allometric growth ($b=2.12$). Estimates of the average Fulton's condition factor (CF) ranged from 0.166 ± 0.021 as shown for the female, to 0.173 ± 0.011 as shown for males. The results of the relationship between the condition factor and the total body length showed a slight increase of condition for female individuals while for the silver males there was a slight decrease in condition with an increase in body length. The study presented here represents an additional contribution to data of European eel from Montenegro which should be useful in the process of establishing the management plan for better protection and conservation of this important but vulnerable species. Moreover, our research provides the first references on LWR and CF for the sexes of European eel from Lake Skadar.

Keywords: Balkan, silver eel, male, female, condition

INTRODUCTION

Adult endangered European eels are distributed in freshwater and coastal regions, ranging from Subarctic environments in the Kola Peninsula and North Cape in northern Europe to subtropical environments in Morocco and the Mediterranean regions of Egypt (Tesch, 2003). The species was listed as

critically endangered (CR) by the most recent assessment published in 2020 (Freyhof & Kottelat, 2010; Pike *et al.*, 2020). Their recruitment strongly declined from 1980 to 2011 while recent analyses indicate that the trend has increased from zero during 2011–2019 but, considering the overall previous

decline in recruitment, an influence on adult stock will likely continue for at least one generation length (ICES, 2020). As catadromous fishes, European eels spend most of their lives in freshwater and only this phase of life is accessible for human observation, since no mature adults have ever been found in the open ocean (Durif *et al.*, 2009). After the growth phase (yellow phase) in the freshwater, eels undergo a second metamorphosis called ‘silvering’. This metamorphosis corresponds to physiological and morphological changes that prepare the fish for the oceanic migration back to the Sargasso Sea and reproduction there (Durif *et al.*, 2005).

The condition factor (CF) gives important data when determining the period of gonad maturation; and to verify whether it is making good use of its feeding source (Weatherley, 1972). The morphometric relationships between length and weight (LWRs) can be used to assess the well-being of individuals and to determine possible differences between separate unit stocks of the same species or between the sexes (King, 2007) as well as to describe seasonal variations of growth (Bobori *et al.*, 2010).

In the Montenegro, the European eel inhabits all rivers draining into the Adriatic Sea. There is no comprehensive study of European eels in the Montenegrin coastal region. In recent times, the number of research conducted on European eels has been increasing (Milošević & Mrdak, 2016; Piria *et al.*, 2016; Rakočević *et al.*, 2018; Kanjuh *et al.*, 2018; Milošević *et al.*, 2021; 2022; Marić *et al.*, 2022). Although the data on the length-weight relationship and condition factor for the European eel from the territory of Montenegro already exist, no studies have been conducted regarding sex. For this reason, this study had the following objectives: (1) to establish the length-weight relationship for the sexes of silver stage of European eel and (2) to

determine the condition of sexes as well as the relationship of condition with the total body length. The objectives are set to provide the first references on LWR and CF for the sexes of European eel from Lake Skadar.

MATERIAL AND METHODS

Study area

The Lake Skadar drainage basin is located between 18° 41' and 19° 47' east and between 40° 10' and 42° 58' north in a karstic area in the outer part of the southeastern Dinaric Alps. The catchment area of the lake covers 5631 km² with about 81% falling within the territory of Montenegro, and the remainder in the territory of Albania (Radulović *et al.*, 2015). According to its nutrient content, Lake Skadar is classified as oligotrophic to mesotrophic (Rakočević & Rakaj, 2015). 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”).

Sample collection

European eel specimens were caught using electric gear (Ultrasonic Inverter DC-12 V LJ-4025NP) from October to December 2019 in Lake Skadar (Montenegro). Electrofishing permits were obtained prior to fieldwork from the competent authorities of Montenegro. The data were collected within the frame of Data Collection Reference Framework (DCRF) programme (GFCM, 2018) performed in Montenegro since 2017 through support by Ministry of Agriculture, Forestry and Water Management. In total, 140 specimens were analyzed for the purpose of this study. Sacrificed specimens were individually marked and stored in a plastic bag at -20°C. After thawing, the total length (TL; ± 1 mm) and weight (W; ± 1 g) of each specimen were recorded along with the length of the pectoral

fin and eye diameter to assess the degree of silvering (Durif *et al.*, 2005; 2009). All individuals were also sexed visually by gross morphological examination in the laboratory (Frost, 1945). The mathematical function for estimation of LWRs was (Ricker, 1975): $W = aL^b$, where W is total weight (in g); L is total length (TL, in cm); a and b are the coefficients of the functional regression between W and L . The 95% confidence intervals (CIs) of the parameters and the statistical significance of the regression relationship (r^2) were estimated. The values of function parameters a and b were estimated by linear regression analysis based on the log transformed equation $\log W = \log a + b (\log L)$ (Ricker, 1975). The determination coefficient (r^2) was used as an indicator of the quality of the linear regressions. Data of Fulton's condition factor (CF) of the analyzed specimens was calculated from the W (g) and TL (cm) using the formula according to Fulton (1904).

RESULTS

The sample size, the minimum, maximum and mean lengths and weights, the values of a and b ; the coefficient of determination r^2 , and the condition factor for males and females of the silver stage of European eel from Lake Skadar are given in Table 1. The calculated allometric coefficient b among the sex varied from 2.116 for males, to 3.119 for females. LWR of females of silver European eel showed positive allometric growth (Fig. 1) while males showed negative allometric growth (Fig. 2). Estimates of the average condition factor (CF) ranged from 0.166 ± 0.021 as shown for the female, to 0.173 ± 0.011 as shown for males (Tab. 1). The results of the relationship between the condition factor and the total body length showed a slight increase in condition for female individuals while for the silver males there was a slight decrease in

condition with an increase in body length.

DISCUSSION

European eel inhabits all watercourses of Adriatic drainage in Montenegro but the main fishery area for this species is Lake Skadar for which is the third most important fish species. Since the Montenegro has limited data on population parameters of silver eel stage this study gives valuable data for this globally important fish species.

In this study the body length of examined silver European eel ranged from 30.30 to 63.50 cm while the total body weight range from 61.20 to 536 g. These results correspond available literature data. Namely, Simon *et al.* (2020) reports that the mean body length of silver eels from Lake Skadar was 40.4 cm for males and 57 cm for females, which corresponds to a mean body weight of 107 g for males and 356 g for females. The same author state fraction of silver eels in the sample from Lake Skadar was 95%, while 5% of the fish were yellow eels.

Data on length-weight relationships (LWR) and Fulton's condition factor (CF) of sexes of European eel from the Montenegro were previously lacking. Froese (2006) demonstrated through a meta-analysis involving LWR data of 1773 species that 90% of the intercept values ranged between 0.001 and 0.05. In our study, males and females showed a value within the range presented by Froese (2006). Regarding the b values our results for the females ($b=3.119$) are in agreement with Froese (2006), who reported that b values for teleost fish should fall within the expected range of 2.5 and 3.5. For the males the b value does not match this range. Carlender (1977) demonstrated that values of $b < 2.5$ or $b > 3.5$ are often derived from samples with narrow size ranges which can be the case for our study. The current length-weight

Table 1. Summary table of condition factor (CF) and estimated parameters of the length-weight relationship ($W = aL^b$) for males and females of silver stage of European eel from Lake Skadar. Shown are sample size (N); the minimum, maximum and mean values of total length (TL, in cm) observed; the minimum, maximum and mean values of total weight (in gr) observed; parameters of the relationship (a and b); coefficient of determination (r^2)

	N	TL (cm)			W (gr)			a	b	r^2	CF
		Min	Max	SD	Min	Max	SD				
Male	50	30.30	44.10	3.18	61.20	193.4	25.89	0.044	2.116	0.549	0.173±0.011
Female	90	35.70	63.50	5.87	67.20	536.00	94.88	0.001	3.119	0.851	0.166±0.021

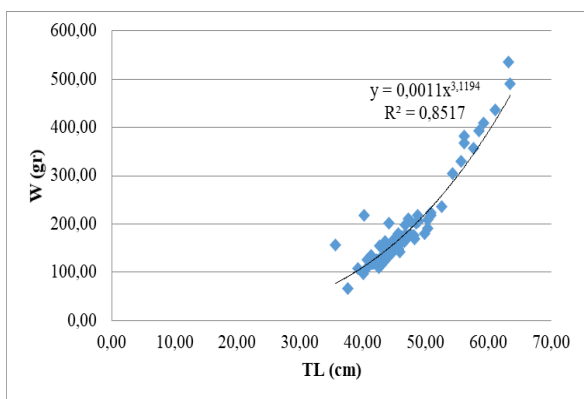


Figure 1. Length-weight relationship of silver stage female of European eel from Lake Skadar

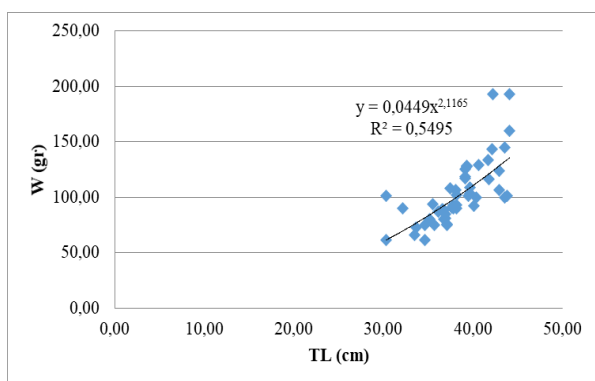


Figure 1. Length-weight relationship of silver stage male of European eel from Lake Skadar

relationship of eels in the eel management unit Drin River system is reflected by the formula $W = 0.0017 L^{2.9946}$ for males and $W = 0.0007 L^{3.2384}$ for females (Simon *et al.*, 2020). Differences in fish LWRs may be attributed to

several factors, such as number and length range of the sampled specimens, gonad maturity, diet, stomach fullness, and growth phase (Bagenal & Tesch, 1978; Wootton, 1990; Froese, 2006), but all this factor did not take in this study. Marić *et al.* (2022) report that specimens of European eel bigger than 45 cm have value of growth coefficient $b=3.25$, while the specimens lesser than 45 cm of have value of growth coefficient $b=2.54$.

The results of relationship between Fulton condition factor and total length indicates slight increase in condition for female individuals while for the silver males there was a slight decrease in condition with an increase in body length. Research of relationship between Fulton condition factor and total length conducted on European eels from Lake Skadar, River Bojana and River Sutorina showed an increasing of condition with length, proving that investigated areas are good habitats for European eels (Piria *et al.*, 2016). This statement was confirmed by isometric growth ($b=2.956$) of the same specimens obtained in the analysis of their length-weight relationship (Milošević & Mrdak, 2016). In our study LWR of females of silver European eel showed positive allometric growth, while males showed negative allometric growth. The current growth of European eels in the eel management unit Drin River system is

reflected by the von Bertalanffy growth formula with $L_t = 111.3 (1 - e^{-0.989(t + 0.073)})$ for females and with $L_t = 60.3 (1 - e^{-0.903(t + 0.107)})$ for males (Simon *et al.*, 2020).

CONCLUSION

In conclusion, females of silver European eel from Lake Skadar showed positive while males showed negative allometric growth. The smallest deviation from the ideal growth model, as well as an increase in condition with an increase in length, are shown by females. Taking in mind that subject of this paper is globally important and endangered fish species the results of this paper give valuable information about its population parameters. This is one of the first research toward understanding growing of eel in Lake Skadar. Being a species with a complicated and still not well understand life cycle (e.g. time and triggering mechanism of maturation/silvering), eel management still remain one of the top European topic in the fishery. Further analysis on larger sample will for sure put more light on the understanding of this process within the Lake Skadar water body.

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Dužinsko-težinski odnos i kondicioni faktor srebrenog stadijuma Evropske jegulje, *Anguilla anguilla* (Linnaeus, 1758) iz Skadarskog jezera (Crna Gora)

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SAŽETAK

Dužinsko-težinski odnos i kondicioni faktor srebrenog stadijuma Evropske jegulje iz Skadarskog jezera, Crna Gora je istraživana na ukupno 140 jedinki. Uzorci su sakupljeni od oktobra do decembra 2019. godine. Cilj ovoga rada je bio istražiti model rasta i kondicije mužjaka i ženki srebrenog stadijuma Evropske jegulje. Dužinsko-težinski odnos ženki je pokazao pozitivan alometrijski rast ($b=3.12$), dok je kod mužjaka uočen negativan alometrijski rast ($b=2.12$). Prosječne vrijednosti Fultonovog kondicionog faktora su varirale od 0.166 ± 0.021 kod ženki, do 0.173 ± 0.011 kod mužjaka. Rezultati odnosa kondicionog faktora i ukupne dužine tijela su pokazali neznatno povećanje kondicionog faktora sa povećanjem dužine tijela kod ženki, dok je kod mužjaka uočeno neznatno smanjenje kondicionog faktora sa povećanjem dužine tijela. Ovo istraživanje predstavlja dopunu postojećih podataka o Evropskoj jegulji iz Crne Gore koji bi trebalo da budu od značaja u procesu uspostavljanja plana upravljanja za bolju zaštitu i očuvanje ove važne i ranjive vrste. Osim navedenog, u ovom istraživanju su prvi put prikazani podaci o dužinsko-težinskom odnosu i kondicionom faktoru kod mužjaka i ženki Evropske jegulje iz Skadarskog jezera.

Ključne riječi: Balkan, srebrena jegulja, mužjak, ženka, kondicija