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LENGTH-WEIGHT RELATIONSHIPS OF EUROPEAN EEL *Anguilla anguilla* (Linnaeus, 1758) FROM SIX KARST CATCHMENTS OF THE ADRIATIC BASIN, CROATIA

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ABSTRACT

This study presents the first references available for the length–weight relationships (LWRs) of eels from six karstic rivers in Croatia. A total of 380 European eels 13.0–76.0 cm long were collected by electro-fishing from six karst catchments of the Adriatic basin between 2004 and 2007. Eels of 34.0 cm in length dominated (over 50%) the catches, while abundance of eel smaller than 15.0 cm was very low. Value *b* of LWRs remained within the range between 2.5957 and 2.8155, which indicates a negative allometric growth. CPUE (g 100 m^{-1}) rapidly declined during the period of sampling, probably due to environmental changes, but also due to global disappearance of this species.

INTRODUCTION

European eel *Anguilla anguilla* is beyond safe biological limits (Dekker, 2003) because fisheries data indicate that the stock is at its historical minimum - 1% of the 1960 recruitment level (Maes and Volckaert, 2007). European eel recruitment has been falling by an order of magnitude per generation, while fishing yield, and presumably the continental stock, has gradually declined over several decades (Dekker, 2004). Since 2008, it has been included in the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of threatened species as critically endangered (Durif et al., 2011). Furthermore, European eel has been added to Appendix II of the CITES Red List of Endangered Species, implying drastic restrictions on trading (Maes and Volckaert, 2007). In 2009, information on freshwater recruitment, freshwater stock and fisheries reviewed by the International Council for the Exploration of the Sea (ICES) Working Group on Eels (ICES, 2009) confirmed the view that the stock is out of safe biological limits (Durif et al., 2011).

Russel and Potter (2003) stated that the biology and population dynamics of European eel is poorly understood. Therefore, monitoring and research on eel stocks throughout Europe and the biology of this species should be investigated (Yalcin-Ozdilek et al., 2006).

According to Froese (2006), the length-weight relationship (LWR) is an important indicator in fishery management and conservation. It is very useful for fisheries research because it: (i) allows conversion of growth-in-length equations to growth-in-weight for use in stock assessment models, (ii) allows the estimation of biomass from length observations, (iii) allows an estimate of the condition of the fish, and (iv) is useful for between-region comparisons of life histories of certain species (Froese and Pauly, 1998; Moutopoulos and Stergiou, 2002).

Although Dulčić and Glamuzina (2006) and Popović et al. (1984) already reported about the LWR for eel in Croatia from the River Neretva, and from the River Zrmanja and Lake Vransko, respectively, data for eel in other karst catchments are still missing.

So, the aim of this study is to report for the first time about

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the LWR of eel from six karst catchments of the Adriatic Sea drainage area.

MATERIAL AND METHODS

Eels were sampled from six karst catchments: the Rivers Jadro, Žrnovnica, Cetina and Ljuta, and the main and lateral channels of Lake Vransko (Fig 1.). Fish were caught between 2004 and 2007 by electric gear (Hans Grassl EL 63 II, 220/440 V, 17.8/8.9 A) using continuous, single pass electrofishing along the riverbanks. In order to minimize between-operator bias, the electrofishing samplings were made by the same team (Bain and Finn, 1990). The total length (TL) was measured to the nearest 1 mm, and the weight (W) was recorded to the nearest 1 g. After measuring, the fish were gently released back into the water. Heterogeneity in eel size and mass between sampling sites was analyzed by the nonparametric Friedman test. The equation $W = a\ TL^b$ was applied in order to establish the LWR, where W is the weight in grams, TL is the total length in cm, and a and b are the constants (Ricker, 1975). Catch per unit of effort (CPUE) was calculated and expressed by the mass of fish in grams caught along the 100 m of the Žrnovnica and Jadro river course (Zalewski, 1985). The statistical procedure was done by SPSS 11.0 for Windows.

RESULTS AND DISCUSSION

Between 2004 and 2007, a total of 380 specimens of eels were caught (River Jadro N=151; River Žrnovnica N=171; River Cetina N=36; River Ljuta N=1; Main Channel N=5; Lateral Channel N=16) along the riverbanks. A Friedman test showed that size (χ^2=41.538, P<0.01) and mass (χ^2=50.347, P<0.01) varied significantly among sites. Total length varied between 13.0 cm and 76.0 cm. Eel of 34.0 cm in length dominated (over 50%) the catches, while abundance of eel smaller than 15.0 cm was very low (Fig 2.). The scarcity of small eel, particularly those smaller than 15.0 cm in TL, could have resulted from low recruitment or some other changes in the river (Glamuzina et al., 2008). No eel were caught from upper flows of the Rivers Ljuta and Cetina. Extremely low density of eel in the River Ljuta could have resulted from the introduction of rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), which was the main reason for extinction of karst minnow *Telestes metohiensis* (Steindachner, 1901) (Mrakovčić et al., 2006). Dam construction and absence of fish passes (Bonacci and Roje-Bonacci, 2003) could present the main problem for eel in the River Cetina.

Value b of LWR varied between 2.5957 for eel from the River Žrnovnica and 2.8155 for eel from the lateral and main channels of Lake Vransko (Table 1). It indicated a negative allometric growth and lack of biologically optimal conditions for the oldest

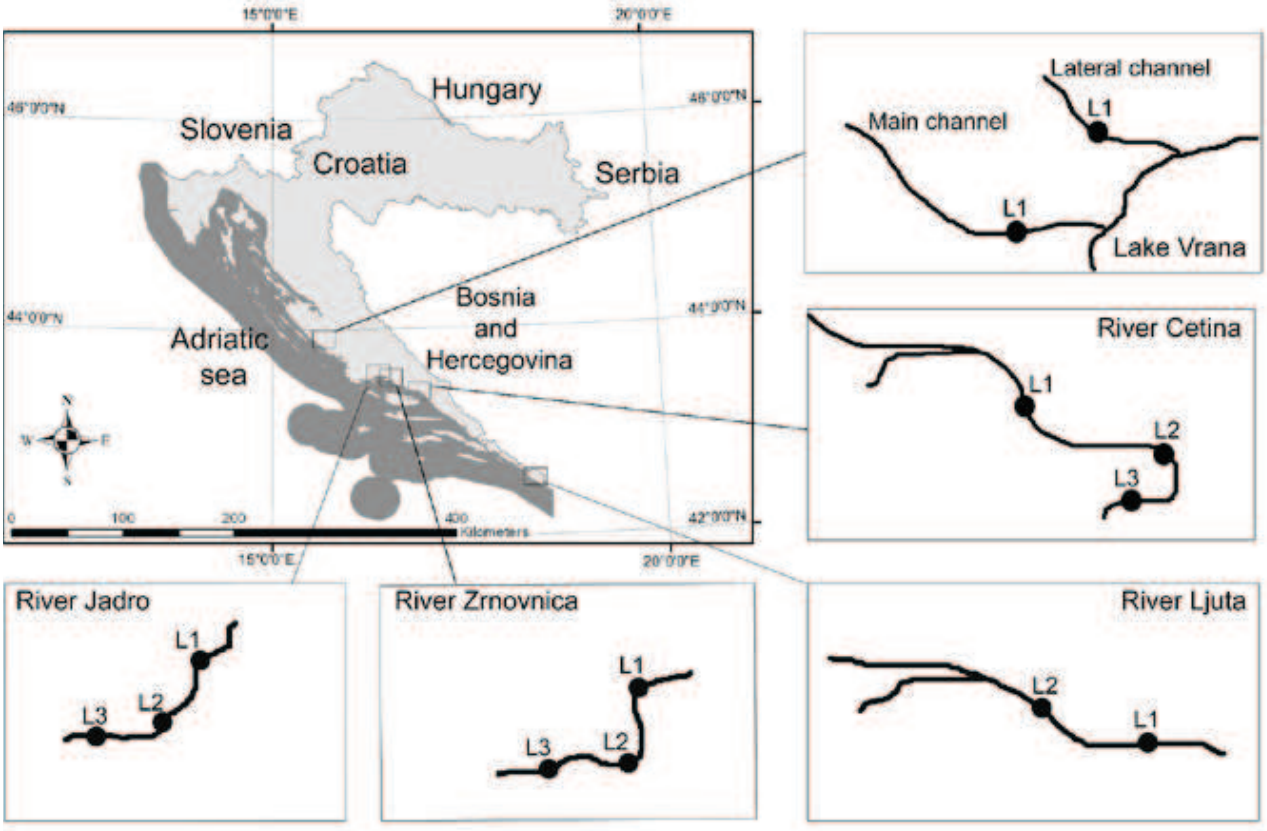

Fig 1. Study area with the location of the sampling sites

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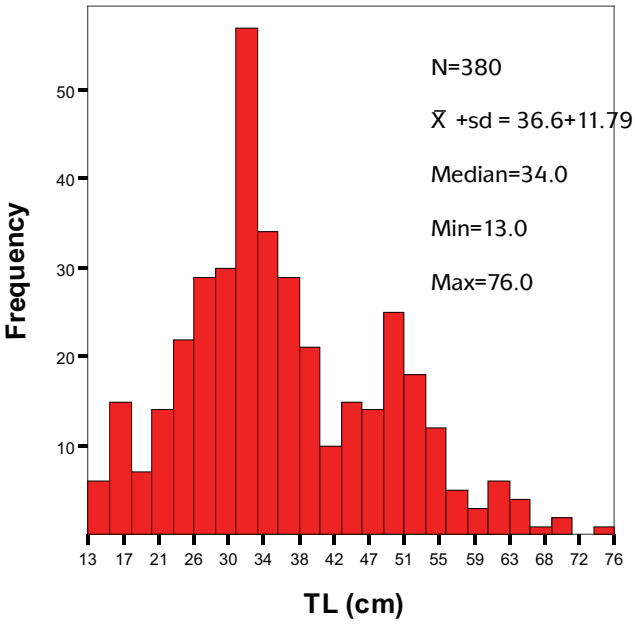

Fig 2. Size (in TL) distribution of eel in samples (n = number of specimens, X̄ +sd = mean±standard deviation)

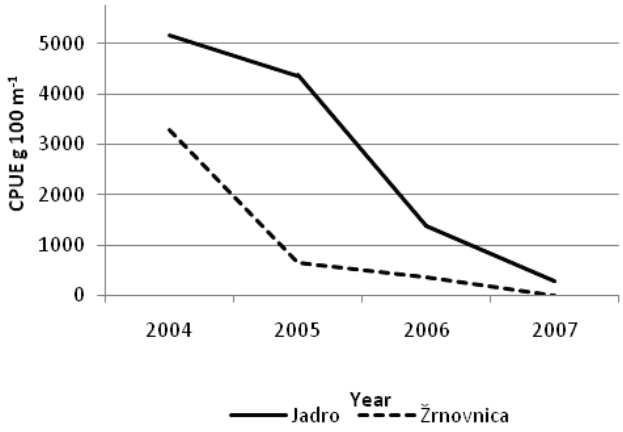

Fig 3. CPUE (g 100 m^{-1}) of eels for the Rivers Jadro and Žrnovnica between 2004 and 2007

fish. Estimated parameters of LWR should be considered only as mean values and are not representative of any particular season. Glamuzina et al. (2008) claimed that *b* value of LWRs for eel from the Hutovo Blato Wetland (2.843) had been the lowest recorded value. In this study, *b* value remained within the range of 2.5957 and 2.8155. Accordingly, this is the lowest recorded *b* value for eel. On the contrary, Dulčić and Glamuzina (2006) found high value of *b* (3.470) for eel from estuarine system of the River Neretva (the Adriatic Sea drainage area), but with only eight specimens included, the smallest one being of 25.9 cm in TL. The LWR in fishes is affected by a number of factors including habitat, area, seasonal effect, gonad maturity, sex, diet and stomach fullness, health and preservation techniques (Tesch, 1971), all of which have not been considered in this study.

In the Rivers Jadro and Žrnovnica, the overall CPUE (g 100 m^{-1}) rapidly declined in time during the sampling period (Fig 3.), probably due to environmental changes, but also due to the global disappearance of this species (Behrmann-Godel and Eckmann, 2003; Bonhommeau et al., 2008). Eel population from the Hutovo Blato Wetland showed a similar trend (Glamuzina et al., 2008). Over the past decades, the abundance of eel population has decreased dramatically (Moriarty and Dekker, 1997; Dekker, 2000; Yalçýn and Küçük, 2002; Dekker, 2004). Many factors are suspected as the cause of the decline: overfishing, limited access to upper reaches of the watershed owing to dams and other obstructions to migration, entrainment of downstream migrating silver eels in turbines of hydroelectric power plants, pollution and parasites (e.g. the nematode *Anguillicoloides crassus*) found in freshwater (ICES, 2006). As eels have been brought to the brink of extinction (Maes and Volckaert, 2007), the new data will hopefully contribute to the better understanding of this species in order to develop sound eel management plan in Croatia. Further analysis of the biological characteristics of the Mediterranean eel stocks is required (Yalcin-Ozdilek et al., 2006).

Table 1. Parameters of length-weight relationships (a, b) with confidence limits (CL), number of specimens (n), correlation coefficient (r^2) for investigated karst catchments

Parameter/catchment	n	TL range (cm)	a	b	95% CL of b	r^2
River Cetina	36	24.0-42.0	0.0081	2.6637	2.0110–3.3164	0.652
Main and Lateral Channel	21	18.0-61.5	0.0050	2.8155	2.2824-3.3486	0.849
River Jadro	151	18.0-70.0	0.0066	2.7240	2.5888-2.8592	0.911
River Žrnovnica	171	13.0-63.0	0.0106	2.5957	2.4663-2.7251	0.899
River Ljuta	1	76	-	-	-	-

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Sažetak

DUŽINSKO-MASENI ODNOS KOD EUROPSKE JEGULJE *Anguilla anguilla* (Linnaeus, 1758) IZ ŠEST KRŠKIH RIJEKA JADRANSKOG SLIVA U HRVATSKOJ

Ovo istraživanje donosi prve dostupne podatke o dužinsko-masenom odnosu (LWRs) kod jegulja iz šest krških rijeka u Hrvatskoj. U razdoblju između 2004. i 2007. godine, elektroribolovom je prikupljeno ukupno 380 primjeraka europske jegulje dužine 13,0 − 76,0 cm. Preko 50% ulova činile su jegulje dužine 34,0 cm, dok je ulov primjeraka manjih od 15,0 cm bio neznatan. Vrijednost *b* LWRs-a kretala se u rasponu između 2,5957 i 2,8155, što ukazuje na negativni alometrijski rast. CPUE (g 100 m^{-1}) naglo je pao tijekom razdoblja uzorkovanja, vjerojatno zbog promjena u okolišu, ali i zbog globalnog nestanka ove vrste.

Ključne riječi: dužinsko-maseni odnos, europska jegulja, CPUE, alometrijski rast, krške rijeke, Jadransko more

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