LENGTH-WEIGHT GAIN OF EUROPEAN CRAYFISH *ASTACUS ASTACUS* (L.) IN THE AREA OF THE UPPER COURSE OF THE ZETA RIVER, MONTENEGRO

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Abstract - This paper presents the results of studying length-weight gain using exponential regression analysis. The gain was analyzed in the Slano, Krupac, and Liverovići Reservoirs and in the Zeta River. Comparing growth at different localities, we found different weight gains. The greatest weight gain exists in the population from the Slano Reservoir. Growth in the first year of life is much more intensive in this area than in populations from the literature we compared it to.

Key words: Crustacea, *Astacus,* length-weight relationship, regression analysis, Nikšić region, Montenegro

INTRODUCTION

The species *Astacus astacus* is found in 28 European countries, and it was introduced into England, Spain, Liechtenstein, and Cyprus (C u k e r z i s, 1988; H o l d - i c h *et al.,* 1999). Outside Europe it can be found only in Morocco, and today it lives in just six rivers and five lakes (B e n a b i d and K h o d a r i, 2000). When compared to the period before the plague, the populations are reduced to only 10% today (W e s t m a n *et al.,* 1990; S k u r d a l *et al.,* 1999). In Europe, due to such status, *Astacus astacus* is listed as "vulnerable" by the IUCN Red List of Threatened Species, together with *Austropotamobius palipes* and *Austropotamobius torrentium* (B a i l l i e and G r o o m b r i d g e, 1996).

European crayfish or noble crayfish (*Astacus astacus*) is one of the rare species of freshwater crustaceans that have been used for commercial purposes and as human food for a long time (P l a n č i ć, 1946). Great demand in the previous century influenced the abundance as well as the range of this species in Europe by reducing them to a considerable extent. This reduction was affected significantly by different diseases, especially crayfish plague (W e s t m a n *et al.,* 1990; S k u r d a l *et al.,* 1999).

In Montenegrin waters, European crayfish has been exploited intensively in the last two decades. Statistical data kept by the users (concessionaires) of this species show that it is intensively fished only in waters of Nikšić Polje. These data show that the greatest quantities were fished in the Zeta River and the three reservoirs of the impounding type: the Krupac, Slano, and Liverovići Reservoirs.

The aim of this paper is to examine the growth of European crayfish *Astacus astacus* from four different ecosystems, i.e., the Zeta River and the Slano, Krupac, and Liverovići Reservoirs, and ascertain respective differences in growth, if there are any, by using standard statistical methods (regression analysis).

MATERIAL AND METHODS

Populations of European crayfish were investigated in the Zeta River and the Slano, Krupac, and Liverovići Reservoirs. Sampling for the purpose of this paper was done using the technique of night fishing with an LPG lamp and a hand net in each lake and in the river. Material was collected in the period of July 2004 - June 2005.

Examined material:

Research on growth of European crayfish in the Krupac Reservoir was based on 85 male specimens and

79 female specimens, whereas in the Liverovići and Slano Reservoirs and Zeta River, it was based on 100 male specimens and 100 female specimens.

Regression analysis showed that the exponential regression method is appropriate for such research.

The linear regression line fitted to the given data (weight-y and length-x) with n data points (x_1, y_1), (x_2, y_2), . . . , (x_n, y_n) has the following form: $y = mx + b$ where:

$$m = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \qquad b = \frac{\sum y - m(\sum x)}{n}$$

$$\sum xy = x_1 y_1 + x_2 y_2 + \ldots\ldots + x_n y_n \; ; \qquad \sum x = x_1 + x_2 + \ldots\ldots + x_n ;$$

$$\sum y = y_1 + y_2 + \ldots\ldots + y_n ; \qquad \sum x^2 = x_1^2 + x_2^2 + \ldots\ldots x_n^2 ;$$

$$q = Ar^t$$
$$\log(q) = \log(Ar^t)$$
$$\log(q) = \log(A) + t \log(r)$$

The expression log (q) is a linear function of t with deviation m= log (r) and point of intersection b = log(A)

(S t a n k o v i ć *et al.,* 1992).

Description of Locality

The Nikšić Polje is located at the site of a former large lake from the glacial period. It has an area of around 65 km². The polje is 13.5 km wide on average and around 18.5 km long. It is the biggest karst polje in Montenegro and has a latitude of 42.53° north and altitude of around 600-630 m. In 1960 several impounding reservoirs were built on former fields through which streams and rivers flowed, and the abundant springs, water sources and numerous sinking streams were dispersed (V l a h o v i ć, 1975; H r v a č e v i ć, 2004).

Table 1 shows basic morphometric data of the examined ecosystems, Table 2 contains data on fauna of the bed.

RESULTS

Based on individual data on length and weight, length/weight regressions for all four ecosystems were calculated, in addition to the relevant correlation index (Table 3).

Table 1. Morphometric characteristics of examined ecosystems

|	Krupac	Slano	Liverovići	Zeta River
altitude	620	621	732	600-630
aquatic ecosystem length	2.50 km	4.37 km	3.00 km	15 km
aquatic ecosystem width	2.62 km	3.37 km	0.50 km	7-25 m
water depth	7.00 m	11.00 m	1.00 m	0.2-5 m
area	5.20 km²	8.89 km²	0.74 km²	0.4km²
volume	42,101,000 m³	111,277,000 m³	9,000,000 m³	
minimum elevation	612 min. elevation	606 min. elevation	719 min. elevation	
vegetation - biofouling	70-80%	80%	50%	70%
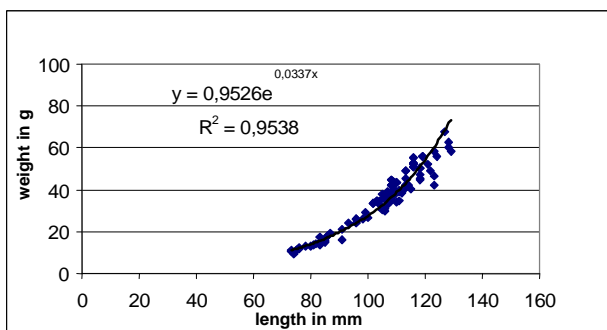
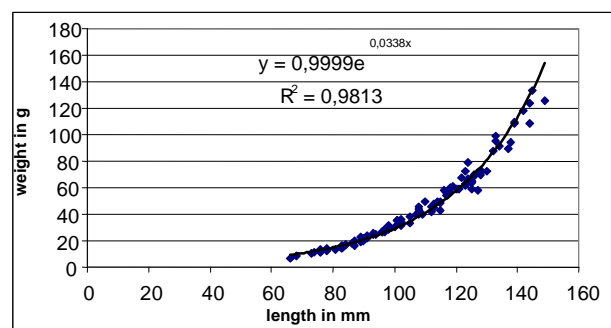Fig. 1. Regression in females in the Slano Reservoir.

Fig. 2: Regression in males in the Slano Reservoir.

The smallest crayfish specimen analyzed was 23.5 mm long and weighed 0.3 g. The specimen was caught in the Zeta River. The biggest specimen was 144 mm long and weighed 109 g. That specimen was caught in the Slano Reservoir.

The index of regression obtained in the Slano Reservoir shows that for every mm of length, weight increases by 0.9999 g in males and by 0.9526 g in females. The correlation index equals 0.95 in male crayfish and 0.96 in females (Figs. 1 and 2).

Based on the shown regression indexes, we note that male crayfish in the Krupac Reservoir gain 0.4043 g in weight for every mm of length, while female crayfish gain 0.7843 g. The correlation index equals 0.92 in males and 0.87 in females, which means that this index is considerably lower than in males and in all other examined ecosystems (Figs. 3 and 4).

In the Liverovići Reservoir, the male gains 0.4587 g in weight per 1 mm of length, while the female gains 0.4117 g. The correlation index equals 0.91 in females and 0.93 in males (Figs. 5 and 6).

In the Zeta River, the situation is rather different, the male gaining 0.6331 g in weight per 1 mm of length, the female only 0.2842 g which resulted from the fact that the specimens of small dimensions are also present in this sample. The correlation index equals 0.96 in males, while in females it equals 0.94 (Figs. 7 and 8).

DISCUSSION

It is known that the growth of crayfish happens through a number of moults, and these are more frequent in young specimens (up to six times in the first year of age) than in older ones (R e y n o l d s, 2002). In adult crayfish, moulting is more frequent in males than in females. While the females carry eggs (spring) they do not moult, and moulting occurs only late in summer (early autumn), which is when the males moult for the second time in that year (S k u r d a l and T a u g b ø l, 2002). This is the reason why the male crayfish grows faster and is bigger than the female crayfish. Such dynamics of growth is manifested in the fact that no females were found among specimens measuring over 140 mm in length. Moreover, in sizes ranging from 120 to 140 mm the percentage of females is less than 15%, and males are also much more frequently found in sizes ranging from 100 to 120 mm (R a j k o v i ć, 2004). Gain in size during moulting varies to a great extent. The number of moults and increase in length during one moulting depend on the temperature and available food (A b r a h a m

Table 2. Fauna of the beds of examined ecosystems

Locality	Date	Groups-species							Total ind/m^2
		Epheme-roptera	Chiro-nomida	Pleco-ptera	Simulidae	Tricho-ptera	Oligo-chaeta	Isopoda	
Krupac	12.07.2002	-	89	-	-	-	1023	222	1334
	29.11.2002	-	289	-	-	-	2023	356	2668
	12.03.2003	-	844	-	-	-	1222	-	2066
Slano	12.07.2002	-	373	-	-	-	866	-	1244
	29.11.2002	-	1889	-	-	-	1800		3689
	12.03.2003	-	844	-	-	-	1222		2066
Liverovići	12.03.2003	-	133	-	-	-	133		266
Zeta									
Jugovići	24.04.2002	40	40	-	40	-	40	-	160
Gračanik		106	74	16	-	4	61	-	261
Rastovnik		804	449	82	351	73	24	-	1783
Vidrovan		139	163	163	102	16	90	-	673
Miločani		212	41	24	-	8	-	-	285
Duklo Polje		208	90	53	-	-	457	-	808
	12.03.2003								
Gračanik		50	8	8	-	-	8	-	74
Miločani		151	33	41	8	-	16	-	249
Brezovič-ki Bridge		-	65	24	-	37	16	-	142

Table 3: Length – weight regression for all four ecosystems and the relevant correlation index

Localities		G	E
		Sex	
SLANO	y	$0.9999e^{0,0338x}$	$0.9526e^{0,0337x}$
	R^2	0.9813	0.9538
	Correl.	0.95	0.96
KRUPAC	y	$0.4043e^{0,0434x}$	$0.7843e^{0,037x}$
	R^2	0.9678	0.9005
	Correl.	0.92	0.87
LIVEROVIĆI	y	$0.3668e^{0,0443x}$	$0.4117e^{0,0429x}$
	R^2	0.9619	0.9694
	Correl.	0.91	0.90
ZETA - BREZ.BRIDGE	y	$0.6331e^{0,0387x}$	$0.2842e^{0,0474x}$
	R^2	0.9657	0.9292
	Correl.	0.96	0.94

R^2 - deviation of the value of points from exponential curve. If R^2, i.e., the deviation, is smaller, then the correlation index is higher.

s s o n, 1966, 1972). Uneven weight gain at the examined localities is probably a consequence of differences in these factors, primarily in the quantity of available food. Greater weight gain in the Slano Reservoir can be attributed to lower competition because it was found that this lake there has the smallest number of crayfish (informa-
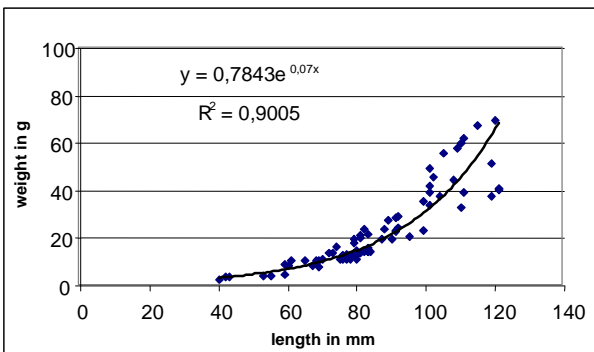

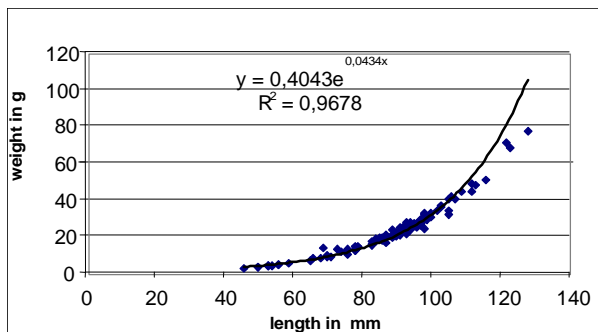Fig. 3. Regression in females in the Krupac Reservoir.

Fig. 4. Regression in males in the Krupac Reservoir.
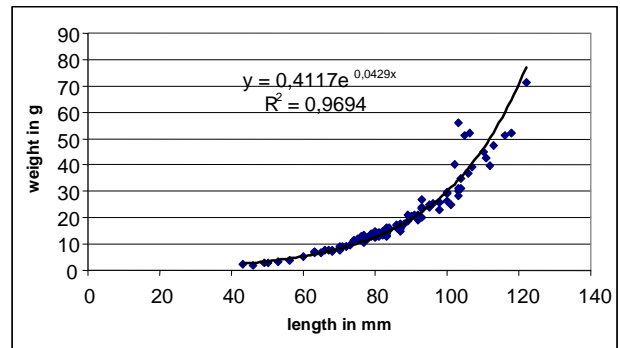

Fig. 5. Regression in females in the Liverovići Reservoir.
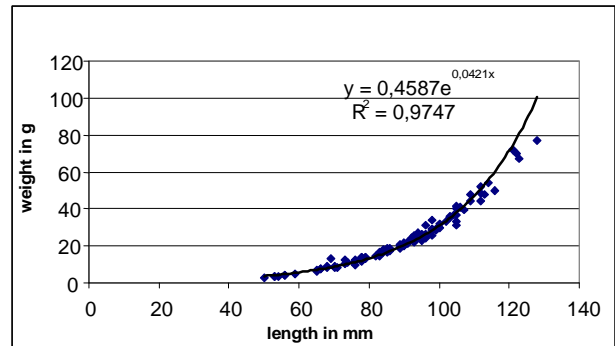

Fig. 6. Regression in males in the Liverovići Reservoir.

tion provided by the concessionaire – statistical data). In previous research, they were not found in this lake owing to the small number of them in it (R a j k o v i ć, 2004). To judge from morphological characteristics, all of the examined ecosystems provide optimum conditions for crayfish. However, the fauna of the bed of the Slano Reservoir offers somewhat better conditions, which can account for the best weight gain there, whereas the poorer weight gain in the Zeta River is a consequence of a great number of crayfish.

Generally, the growth rate is slower when the females carry eggs, and the number of moults decreases as the crayfish becomes older, adult and mature crayfish moulting once or twice a year. Adult males moult for the first time in mid-spring or early summer, depending on the temperature, and females are still carrying eggs or the young in this period. The second moulting phase occurs in late summer or early autumn, and at that time the female crayfish also moults. (A b r a h a m s s o n, 1966, 1972). This can be seen especially nicely in the specimens from the Zeta River. Growth in the Krupac Reservoir differs from growth in the Zeta River, but this is probably a consequence of the fact that females of main-
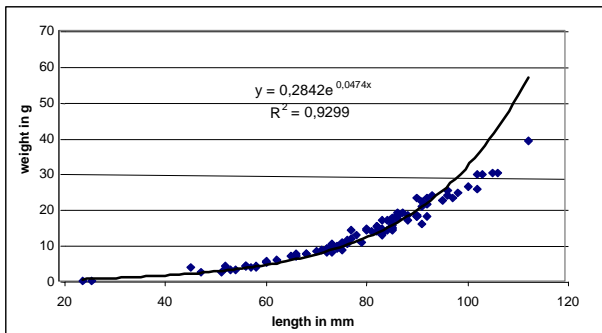
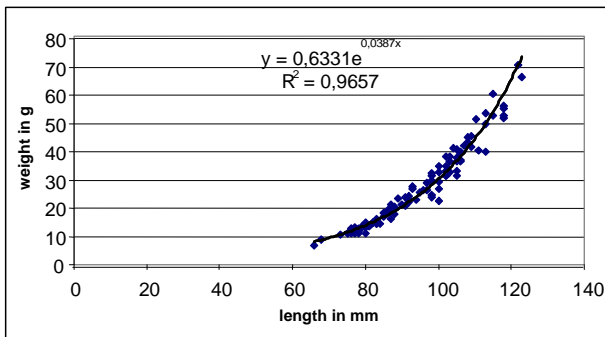Fig. 7. Regression in females in the Zeta River.

Fig. 8. Regression in males in the Zeta River.

ly small dimensions were analyzed, i.e., a very small number from this sample were sexually mature. In the Liverovići and Slano Resevoirs, no major difference was found between male and female crayfish. In the former, the number of females which probably reproduced is less than 20% and the males have small dimensions (around 20% are longer than 100 mm) (R a j k o v i ć, 2004), so that the difference in moulting was not manifested to a considerable extent.

Size (total length) of noble crayfish at the age of 0+ is assessed at 15-23 mm. In the second year, it is 25-48 mm; in 2+, it is 50-70 mm; and in 3+, it is 60-80 mm (A b r a h a m s s o n, 1966, 1971, 1972; C u k e r z i s, 1984, 1988; A p p e l b e r g, 1986; W e s t m a n *et al.*, 1992 ; W e s t m a n, 2000). However, under favorable conditions, noble crayfish can reach 95 mm in total length after the summer (3+) (G y d e m o, 1989). The data given by R a j k o v i ć (2004) show that crayfish grow faster in the first year, i.e., they are bigger than those mentioned in the literature. At five examined localities, no young crayfish specimen smaller than 20 mm was found. For instance, at the Brezovički Bridge – Zeta River locality, crayfish specimens having a length of 19.8 –

29 mm were found. Based on these comparisons we can assume that the crayfish from waters around Nikšić grow faster than those mentioned in the literature.

CONCLUSION

Based on the results presented in this paper and information from the available literature, the following conclusions can be drawn:

By applying regression analysis, an exponential correlation was established between length and weight of the crayfish body.

The correlation index in all examined length-weight relations is positive and ranges from 0.87 to 0.96. The lower correlation index in females than in males is legitimate considering the fact that increase of reproductive products causes weight to change without major influence on length.

Weight gain in males is different at different localities. It is highest in Lake Slano, where it equals 0.9999 g, and lowest in the Krupac Reservoir, where it equalls 0.4043 g. This is a consequence of differences in available food and in the numbers of crayfish at these localities.

The smallest weight gain in females was found in the Zeta River, where it equals 0.2842 g per mm of length. This is probably a consequence of great abundance of *A. astacus.*

The growth of young specimens (up to 30 mm) in the first year of age is greater than that found in information mentioned in the literature.

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ДУЖИНСКО-ТЕЖИНСКИ РАСТЕЊЕ РИЈЕЧНОГ РАКА *ASTACUS ASTACUS* (L.) У ПОДРУЧЈУ ГОРЊЕГ ТОКА РИЈЕКЕ ЗЕТЕ, ЦРНА ГОРА

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У раду су приказани резултати дужинско-тежинског растења речног рака, базирани на експоненцијалној регресионој анализи. Раст је анализиран на узорцима из акумулација Слано, Крупац, Ливеровићи и из ријеке Зете. Упоређујући раст по локалитетима утврђен је различит прираст тежине. Највећи прираст је код популације из акумулације Слано. Резултати које смо добили показују да у првој години ријечни ракови брже расту односно да су крупнији у односу на литературне податке. На пет истраживаних локалитета није пронађен рак мањих димензија од 20 mm, осим на локалитету Брезовачки мост – ријека Зета гдје су констатоване јединке дужине 19,8 mm – 29 mm.

По морфолошким карактеристикама сви испитивани екосистеми пружају оптималне услове за живот ријечног рака док у фауни дна акумулација Слано пружа нешто боље услове, па то може бити један од разлога бољег прираста, док је слабији прираст тежине у ријеци Зети последица велике бројности ракова. Раст јединки у акумулацији Крупац се разликује од раста у другим екосистемима што је вјероватно последица већег присуства женки које су углавном мањих димензија. У акумулацијама Ливеровићи и Слано није нађена већа разика у расту између мужјака и женки. Број женки које су се вјероватно размножавале у Ливеровићима је мањи од 20%, с једне стране, а мужјаци су малих димензија (око 20% већих од 100 mm).