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MORPHOMETRICS CHARACTERS OF *ASTACUS ASTACUS* L. (ASTACIDAE) FROM THE PRACA RIVER
Morfometrijske karakteristike vrste *Atacus astacus* L. (Astacidae) iz rijeke Prače

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Abstract

In Bosnia and Herzegovina, noble crayfish (*Astacus Astacus*) can be found in the Sava River basin (rivers Bosna, Drina) and Adriatic basin (Cetina river) and it has been introduced in the Rama Lake and some accumulations in the Bosna River (Trozic-Borovac, 2011). The paper represents an overview of some morphological characteristics (W, TL, SL, CL, CW, CH), while condition indices were also calculated. The analysis of the noble crayfish was done in Prača River (Hrenovica site) in June and July 2009. The maximum-recorded length of the crayfish is 12.73 cm, and of 87 g (male) weight. We concluded that individuals vary mostly in body weight, and the least in body length. Out of the 30 analyzed specimens, males dominate (21:9) which results from the time/period of research. The values of condition index point to favorable conditions in Prača River for the existence of the species *Astacus astacus*.

Key words: Noble Crayfish, condition index, autochthonous, body weight

INTRODUCTION - *Uvod*

Globally, the family of Astacidae Latrelle (1803) is represented by three geni: *Astacus* Fabricius (1775), *Austropotamobius* Skorikov (1907) and *Pacifastacus* (1950). *Astacus* and *Austropotamobius* inhabit Europe with a total of 5 species: *Astacus astacus* (Linnaeus, 1758), *Astacus leptodactylus* (Eschscholtz, 1823), *Astacus pachypus* (Rathke, 1837), *Austropotamobius torrentium* (Schrank, 1803) and *Austropotamobius pallipes* (Lerebollet, 1858). The noble crayfish is widely spread species in Europe as a result of the autochtony of territory or introduction (Souty-GROSSET ET AL., 2006). In Bosnia and Herzegovina, the noble crayfish (*Astacus astacus)* was first registered in Bosna River (ENTZ, 1914), later in Drina River and

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Cetina River basin (KARAMAN, 1929; KARAMAN, 1961; SANDA & PETRUSEK, 2009; TROŽIĆ-BOROVAC, 2011). This species can be found in stagnant and flowing waters of Sava River basin and of Adriatic Sea basin. Due to the possibility of commercial exploitation the noble crayfish have been introduced in Ramsko Lake, where the species resides for over three decades.

The noble crayfish inhabits lowland waters, rivers, streams, canals and coastal areas of lakes. They retain in holes which they dig on the steep banks in the ground or among the underwater parts of willow and poplar roots. The noble crayfish likes warmer and slightly calmer flowing waters. These waters are rich with oxygen with little organic matter and well-developed fauna. The mean annual temperature ranger from 14°C to 15°C, while the pH of water is neutral to slightly alkaline (FALLER ET AL., 2006).

Astacus astacus can grow up to 16cm in body length. It is usually dark brown (varies from olive green to black, sometimes even blueish or reddish), while the ventral side is brown-green. Carapax is smooth with small granular tubercles. There are two pairs of postorbital tubercles where the first pair is more expressed. The edges of abdominal pleura are rounded, while the rostrum is well developed, plane with smooth edges. In the middle of the claws, on the immovable finger, there is a hollow limited with two teeth. This hollow is developed only in adult males, while in females and young individuals is poorly expressed. The species becomes sexually mature at 2-3 years of age, while the mating occurs in September and October. The male grabs the female with his claws and turns her on her back. His gonopods raise and a milky-white substance is excreted out of the genital openings, which sticks to the pereion of the female. The female carries fertilized eggs under the tail fan for the next 8-9 months after which they hatch and grow through a number of coating. They are nocturnal animals with agressive behavioural features. They are voracious and feed with smaller animals like frogs, snails, insects or carrions, also with rot and plants rich with limestone. They live in more calmer flowing rivers in shallower areas under rocks of steep banks, where between the roots of plants holes for hiding can be found.

Praca River is the left tributary of the Drina River. It rises on the northern slopes of Jahorina at 1460 meters above sea level (ASL), and flows into the Drina at Ustipraca at 329 meters ASL. The bottom of the Praca River at the sampling site is rocky and gravel. The width of the riverbed is 4-5 meters. The banks of the Praca River are covered with black alder *Alnus glutinosa* (L.) Gaertn and with white willow *Salix alba* (L.) at the sampling site. The water is clear and relatively calm.

MATERIAL AND METHODS – *Materijal i metode rada*

Specimens of noble crayfish were collected manually from the Praca River at Hrenovica investigation site in June-July 2007. A total of 30 individuals were caught with 21 males and 9 females. The measurement of the specimens was carried out in the field, after which the specimens were returned into the river.

Basic morphological characters were opserved and measured: body weight (W), total length (TL), cheliped length (SL), carapace length (CL), carapace width (CW), rostrum length (CHL), number of tubercles on carpopodite and body colour. Laboratory scale was used for measuring the weight expressed in grams, while the length and width were measured with a caliper and expressed in centimeters, after which the data was processed.

Statistical analysis of the data

Basic statistical analyses; mean value (arithmetic mean) ($\bar{X}$), variance (s^2), standard deviation (S), variance (s^2), standard deviation (S) and coefficient of variation were performed using the statistical program Microsoft Excell.

Two condition indices (adopted from Streissl, Höld, 2002) were calculated**:**

Crayfish Constant (CC):

$$CC = \frac{W}{(TL \times CL \times CV)}$$

Where: **W** – total weight, **TL** – total length, **CL** – carapace length, **CW** – carapace width (Streissl, Höld, 2002)

Fulton's Conditions Factor (FCF):

$$FCF = \frac{W}{T^3}$$

Where: **W** – total weight, **T** – total length

RESULTS – *Rezultati istraživanja*

Results of morphometric measurements of crayfish with condition index

The results of morfometric measurements are presented in tables separately for females and males, respectively.

a) **Morphometric data analysis in noble crayfish males (Table 1.) shows that:**
   - The mean value for body weight (W) is 22,57 g. The maximum body weight is 87 g (individual no.1), and the minimum body weight is 6g (individuals no.18 and no.21).
   - The mean value for body length (TL) is 7,85 cm. The longest body is 12,43 cm at individual no.1, and the shortest body is 5,54 cm at individual no.21.
   - The mean value for cheliped length is 3,34 cm. The maximum value is 6,08 cm at individual no.1, and the smallest value of 1,88 cm is at individual no.21.

- The mean value for carapace length is 4,03 cm. The longest carapace (CL) is 6,57 cm at individual no.1, and the shortest is 2,68 cm at individual no.21.
- The mean value for carapace width (CW) is 2,20 cm. The widest carapace is 3,91 cm at individual no.3, and the narrowest is 1,37 cm at individual no.21.
- The mean value for rostrum length(CHL) is 0,62 cm. The longest rostrum is 1,23 cm at individual no.3, and the shortest is 0,29 cm at individual no.19.
- The mean value for number of tubercles on the carpopodite is 23,43. The maximum number of tubercles is 35 at individual no.9, and the smallest is 15 at individuals no.1 and no.18.

Table 1. The values of morphological characters in male noble crayfish from Praca River.
Tabela 1. Vrijednosti morfoloških karakteristika kod mužjaka plemenitog raka iz rijeke Prače

	Sex	**Body weight (g)**	**Body length (cm)**	**Chelip. length (cm)**	**Carap. length (cm)**	**Carap. width (cm)**	**Rostrum length (cm)**	**Num. of tubercles**	**Body colour**
1.	M	87	12,43	6,08	6,57	3,70	0,84	15	Brown
2.	M	28	8,45	4,22	4,51	2,42	0,64	18	Fire Red
3.	M	45	10,03	4,27	5,23	3,91	1,27	27	Red – Brown
4.	M	20	8,24	3,61	4,08	2,15	0,54	23	Red
5.	M	17	7,20	3,26	3,88	2,07	0,44	22	Red -Brown
6.	M	27	8,93	3,23	4,64	2,46	1,17	21	Brown
7.	M	14	7,51	3,24	3,88	2,08	0,84	35	Dark Brown
8.	M	18	7,81	3,36	3,97	2,09	0,58	30	Red - Brown
9.	M	24	8,00	3,48	4,16	2,28	0,97	29	Dark Red
10.	M	24	8,40	3,65	4,36	2,31	0,55	22	Red - Brown
11.	M	23	8,48	4,00	4,36	2,35	0,53	30	Brown
12.	M	24	8,20	3,64	4,23	2,22	0,42	26	Dark Red
13.	M	25	8,30	3,86	4,28	2,30	0,36	20	Brownish - Red
14.	M	26	8,27	3,83	4,28	2,25	0,60	32	Red - Brown
15.	M	24	8,16	3,72	4,21	2,24	0,42	28	Brownish - Red
16.	M	7	5,98	2,08	3,03	1,52	0,33	17	Light Brown
17.	M	15	7,63	2,77	3,80	2,02	1,09	21	Dark Brown
18.	M	6	5,70	1,97	2,85	1,49	0,38	15	Brown
19.	M	7	5,87	1,97	2,79	1,50	0,29	23	Grey - Brown
20.	M	7	5,69	1,93	2,83	1,45	0,367	21	Brownish - Red
21.	M	6	5,54	1,88	2,68	1,37	0,33	17	Brownish - Red
X		22,57	7,85	3,34	4,03	2,20	0,62	23,43	

b) Morphometric data analysis in noble crayfish females (Table 2.) shows that:

- The mean value for body weight (W) is 8,66 g. The maximum body weight is 16 g (individual no.2), and the minimum body weight is 3g (individual no.6).
- The mean value for body length (TL) is 6,45 cm. The longest body is 7,71 cm at individual no.2, and the shortest body is 4,61 cm at individual no.6.
- The mean value for cheliped length is 2,17 cm. The maximum value is 2,90 cm at individual no.2, and the smallest value of 1,53 cm is at individual no.6.
- The mean value for carapace length is 3,18 cm. The longest carapace (CL) is 3,81 cm at individual no.2, and the shortest is 2,30 cm at individual no.6.
- The mean value for carapace width (CW) is 1,60 cm. The widest carapace is 1,95 cm at individual no.2, and the narrowest is 1,16 cm at individual no.6.
- The mean value for rostrum length(CHL) is 0,48 cm. The longest rostrum is 0,85 cm at individual no.9, and the shortest is 0,31 cm at individual no.6.
- The mean value for number of tubercles on the carpopodite is 21,44. The maximum number of tubercles is 25 at individual no.7, and the smallest is 19 at individual no.6.

Table 2. The values of morphological characters in female noble crayfish from Praca River.
Tabela 2. Vrijednosti morfoloških karakteristika kod ženki plemenitog raka iz rijeke Prače

	Sex	**Body weight (g)**	**Body length (cm)**	**Cheliped length (cm)**	**Carap. length (cm)**	**Carap. width (cm)**	**Rostrum length (cm)**	**Number of tubercles**	**Body colour**
1	F	9	6,79	2,28	3,30	1,79	0,34	21	Dark Grey
2	F	16	7,71	2,90	3,81	1,95	0,47	22	Grey -Red
3	F	9	6,49	2,13	3,20	1,73	0,46	22	Brown
4	F	9	7,04	2,43	3,61	1,87	0,42	22	Red – Brown
5	F	10	6,85	2,29	3,26	1,74	0,40	21	Brown
6	F	3	4,61	1,53	2,30	1,16	0,31	19	Green
7	F	8	6,40	2,05	3,00	1,61	0,42	25	Bright Red
8	F	10	7,04	2,26	3,45	1,22	0,63	21	Red – Brown
9	F	4	5,09	1,68	2,70	1,31	0,85	20	Light Green
X		8,66	6,45	2,17	3,18	1,60	0,48	21,44	

c) Statistical data analysis

Based on the obtained data, the following statistical data were calculated: minimum and maximum values, mean, variance, standard deviation and coefficient of variation. The results are shown together for all individuals, as well as separately for males and females, respectively.

Values obtained for all individuals (Table 3.) show that the average body weight is 18,4g, the average body length is 7,43cm, cheliped length 2,99cm, carapace length 3,77cm, carapace width 2,02cm and rostrum length 0,57cm. The values of standard deviations (S) range from 16,11 for body weight, 1,57 for body length, 1,02 for cheliped length, 0,88 for carapace length, 0,62 for carapace width and 0,27 for rostrum length. Values that vary the most are the body weight values as evidenced by the coefficient of variation (87,5%), and the values that vary the least are the body length values (2,11%).

Table 3. Values of some statistical parameters for all noble crayfish individuals from Praca River
Tabela 3. Vrijednosti nekih statističkih parametara za sve jedinke plemenitog raka iz rijeke Prače

	Body weight (g)	**Body length (cm)**	**Cheliped length (cm)**	**Carap. length (cm)**	**Carap. width (cm)**	**Rostrum length (cm)**	**Number of tubercles**
min	3	4,61	1,53	2,30	1,16	0,29	15
max	87	12,43	6,08	6,57	3,91	1,27	35
x	18,4	7,43	2,99	3,77	2,02	0,57	22,83
Sx	2,94	0,29	0,19	0,16	0,11	0,05	0,89
V%	87,5	2,11	3,42	2,33	3,07	4,68	21,5
S	16,11	1,57	1,02	0,88	0,62	0,27	4,91
s2	259,49	24,64	10,40	7,75	3,83	0,73	24,14

The obtained values for males (Table 4.) show that the average body weight is 22,57g, the average body length is 78,49cm, carapace length 40,30cm, carapace width 21,99cm, cheliped length 33,37cm and the rostrum length is 6,16cm. The maximum value of standard deviation is for the body weight and it is 17,59, then for the body length 16,01, for the cheliped length 10,08, for carapace length 9,01, carapace width 6,37, while the least value is for rostrum length 2,97. The values of the coefficient of variaton show that the greatest variation is in the body weight which is 77,98%, while the minimum variation is in the carapace width which is 0,29%.

Table 4. Values of some statistical parameters for noble crayfish individuals (21 males) from river Praca

Tabela 4. Vrijednosti nekih statističkih parametara za jedinke plemenitog raka (21 mužjak) iz rijeke Prače

M	**Body weight (g)**	**Body length (cm)**	**Cheliped length (cm)**	**Carap. length (cm)**	**Carap. width (cm)**	**Rostrum length (cm)**	**Number of tubercles**
min	6	5,54	1,88	2,68	1,37	0,29	15
max	87	12,43	6,08	6,57	3,91	1,27	35
x	22,57	7,85	3,34	4,03	2,20	0,62	23,43
Sx	3,84	0,35	0,22	0,20	0,14	0,06	1,25
V%	77,98	2,04	3,02	2,24	0,03	4,82	24,37
S	17,59	1,60	1,01	0,90	0,64	0,30	5,71
s^2	309,76	25,33	10,16	8,12	4,06	0,88	32,60

The obtained values for female individuals (Table 5.) indicate that the average body weight is 8,67g, the average body length is 64,47cm, carapace length 31,81cm, carapace width is 15,97cm, cheliped length is 21,73cm and the rostrum length is 4,78cm. The degree of deviation from the average value (standard deviation) is maximum for body length and it is 9,86, then for carapace length is 4,63, for cheliped length is 4,04, for body weight is 3,74, for carapace width is 2,93 and the minimum deviation is for rostrum length which is 1,65. Values of the coefficient of variation indicate that the body weight varies the most and it is 43,14%, and the carapace length varies the least which is 14,55%.

Table 5. Values of some statistical parameters for noble crayfish individuals (9 fem.) from river Praca

Tabela 5. Vrijednosti nekih statističkih parametara za jedinke plemenitog raka (9 ženki) iz rijeke Prače

F	Body Weight (g)	Body Length (cm)	Cheliped length (cm)	Carapace length (cm)	Carapace width (cm)	Rostrum length (cm)	Number of tubercles
min	3	4,61	1,53	2,3	1,16	0,31	19
max	16	7,71	2,90	3,82	1,95	0,85	25
x	8,67	6,45	2,17	3,18	1,60	0,48	21,44
Sx	1,25	0,33	0,14	0,15	0,10	0,05	0,56
V%	43,14	1,53	1,86	1,45	1,83	3,45	7,79
S	3,74	0,99	0,40	0,46	0,29	0,16	1,67
s^2	13,99	9,72	1,63	2,14	0,86	0,27	2,79

Condition index (the degree of condition)

The smallest CC is calculated for females (0,189) as well as the maximal (0,337). However, the mean value is greater for males and it is 0,28, while for females is 0,25 (Table 6). The smallest FCF is calculated for females and it is 0,026, while the greatest calculated is for males and it is 0,047. The mean value of FCF for males is 0,04, while forfemales is slightly lower and it is 0,03.

Table 6. Values for the degree of condition (condition index) for noble crayfish individuals from river Praca

Tabela 6. Vrijednosti za stupanj kondicije (kondicioni indeks) za jedinke plemenitog raka iz rijeke Prače

	CC			**FCF**		
	Min.	Max.	x	Min.	Max.	x
M	0,220	0,326	0,28	0,032	0,047	0,04
F	0,189	0,337	0,25	0,026	0,035	0,03

DISCUSSION - *Diskusija*

In many studies the number of caught males is often larger than the number of females caught. ACKEFORS (1999) divided the year into two parts, depending on the activities of females and the sex ratio. From November to June, males were the dominant sex with the ratio ranging from 6:1 (M:F) to 16:1 (M:F), whereas from July to October the sex ratio was close to 1. In the first mentioned period, the only females caught were the ones without external eggs. It is know that a small number of females captured during the period of egg carrying is a concequence of shyness of the females during that period (FALLER ET AL., 2006). This sex ratio coincides with the noble crayfish caught in Praca River where males are the dominant sex.

Many studies which were conducted on populations of *Astacus astacus* L. and *Austropotamobius pallipes* (Lereboullet) have shown that the morphological features (carapace shape, length, width and curvature) are geneticially conditioned (SINT ET AL., 2004). Generally, males are larger than females, and also the ratio of carapace length and total length is different in males and females which is a concequence of sexual dimorphism (FALLER ET AL., 2006).

The results of the research carried out on specimens of *Astacus astacus* L. from Praca River show that these are large specimens whose length ranges from 4,61cm to 12,43cm with a mean length of 7,43cm. The body weight ranges from 3g to 87g with a mean weight of 18,4g. The largest specimens of noble crayfish in Bosnia and Herzegovina are stated in the Rama Lake with the body length of 14cm (TROŽIĆ-BOROVAC, 2011).

The cheliped length of the noble crayfish from the river Praca ranges from 1,53cm to 6,08cm with mean length of 2,99cm. Statistical data on noble crayfish from river Orljava show that they are large specimens. The largest male had the body length of 13,69cm, and the largest female 11,78cm (FALLER ET AL., 2006).

By analysing the ecological and morphological characteristics of the noble crayfish *Astacus astacus* L. From river Praca, we can conclude the following:

- Given the specimens' body size and mass, one can conclude that Praca River has favourable ecological conditions for this species' egistance.
- The sex ratio is 21:9 in favor of the males.
- The values of the body weight range from 3g to 87g, with a mean value of 18,4g with this parameter having also the greatest value of the coefficient of variation.
- The body length and width are not directly proportional, ie. the individual who has the greatest total length doesn't necessarily have the greatest body width.
- Condition indexes (the degree of condition) have slightly greater values in males than in females.
- The noble crayfish is in all countries of the former Yugoslavia, as well as in the countries of Europe, in the Red Data Book and on IUCN Red List of threatened species, and their habitats are in the Habitat Directive which is one of the reasond and obligations of forming the Red Data Book and inclusion and implementation of the directived of the European Union.

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SAŽETAK

Za potrebe analize morfometrisjkih karakteristika plemenitog raka izvršen je izlov jedinki iz rijeke Prača na lokalitetu Hrenovice u periodu juni i juli 2007. godine. Analiza je obuhvatila kvanitativne parametre: ukupnu težinu (g), totalnu dužinu (cm), dužinu karapaksa, širinu karapaksa, dužinu kliješta, dužinu rostruma. Od kvalitativnih karaktera analiziran je broj kvržica na karpopoditu i boja tijela. Vrijednosti analiziranih parametara sagledani su u kontekstu statističke obrade: srednje vrijednosti, varijanse (s^2), standardne devijacije (S), koeficijenta varijabilnosti ($V_{\%}$), koeficijenta kondicije (CRAYFISH CONSTANT, ADEGBOYE, 1981, FULTON'S CONDITIONS FACTOR, RICKER, 1975).

Na osnovu mjerenja totalne dužine tijela utvrđeno je da jedinke plemenitog raka (posmatrani uzorak) dostižu 12,43 cm, a najmanja dužina tijela iznosila je 5,54 cm. Srednja vrijednost za težinu tijela (W) je 22,57 g. Najveća težina tijela je 87 g, a najmanja težina tijela je 6 grama. Potrebno je naglasiti da je kod jedinki najveće dužine konstatovana i najveća težina. Najviše variraju vrijednosti za težinu tijela, što se vidi iz koeficijenta varijabilnosti (87,5 %), a najmanje variraju vrijednosti dužine tijela (2,11 %). Odnos polova 21 M: 9 F, pokazuje izrazitu dominaciju mužjaka. Na osnovu uporedbe dužine jedinki utvrđeno je da su ženke manjih dimenzija u odnosu na mužjake, što je utvrđeno u svim dosadašnjim istraživanjima. Vrijednosti stepena kondicije (CC=0,28; FCF=0,04) ukazaju na dobro stanje istraživane populacije plermenitog raka. Utvrđene su nešto niže vrijednosti indeksa kondicije kod ženki plemenitog raka. Ovim radom su po prvi put naznačene morfometrijske karakteristike plemenitog raka sa područja Bosne i Hercegovine, koje upućuju na opća obilježja analizirane vrste. Podaci doprinose poznavanju autekologije date vrste, a sa druge strane ukazuju na opću povoljnost egzistencije ove vrste u rijeci Prači. Vrsta plemenitog raka upućuje na prirodnost i očuvanost ovog vodotoka.