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BIOMETRY AND POPULATION GENDER STRUCTURE OF THREE CRAB SPECIES (CRUSTACEA: DECAPODA) FROM SANDY BOTTOM IN THE NORTHERN ADRIATIC SEA

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ABSTRACT

The aim of the study was to investigate the distribution and population structure of three species of crabs (Decapoda: Crustacea), Medorippe lanata, Liocarcinus depurator and Liocarcinus vernalis for their biometric relationships. A total of 1100 specimens of three species were caught from waters off the northern Adriatic Sea in December 2013. Biometric relationships and condition factor (Fulton's coefficient index) were measured for all the studied species. Size dimorphism was also observed in M. lanata with females showing significantly larger carapace size than males without significant difference in wet weight. The studied species did not differ significantly in the results of the condition index.

Key words: *Medorippe lanata, Liocarcinus depurator, Liocarcinus vernalis*, biometry, condition factor, Adriatic Sea

BIOMETRIA E STRUTTURA DI GENERE NELLE POPOLAZIONI DI TRE SPECIE DI GRANCHI (CRUSTACEA: DECAPODA) DI FONDI SEDIMENTARI DELL'ADRIATICO SETTENTRIONALE

SINTESI

Lo scopo dello studio era quello di verificare la distribuzione e la struttura della popolazione di tre specie di granchi (Decapoda: Crustacea), Medorippe lanata, Liocarcinus depurator e Liocarcinus vernalis, per evidenziare le relazioni biometriche. Un totale di 1100 esemplari appartenenti alle tre specie sono stati catturati nelle acque al largo della costa dell'Adriatico settentrionale, nel dicembre 2013. Le relazioni biometriche e il fattore di condizione (indice del coefficiente di Fulton) sono stati calcolati per tutte le specie studiate. Il dimorfismo dimensionale è stato osservato anche in M. lanata, dove le femmine hanno dimensioni del carapace significativamente maggiori rispetto ai maschi, senza differenza significativa nel peso umido. Le specie studiate non differivano significativamente nei risultati dell'indice di condizione.

Parole chiave: *Medorippe lanata, Liocarcinus depurator, Liocarcinus vernalis*, biometria, fattore di condizione, mare Adriatico

INTRODUCTION

Measurement and analysis of biometric parameters could assist in understanding the biological and physiological status of crustaceans. One such importance has been previously shown for fecundity of *Potamon koolooense* (Rawat et al., 2016). The morphometric and allometric analyses or relation amongst different body segments is functionally significant in biology (Huber, 1985). Investigation of length-weight relationship is widely performed and used to study different aspects of animal and aquatic population such as maturity and health (Patil & Patil, 2012). In this context, the condition factor is used to study and compare the ecological and health characteristics of any species. Condition index differs from growth in that it shows weight for a given length and it is hypothesised that improved condition is achieved through increased weight at a given length (Bolger & Connolly, 1989).

Sex ratio is an assessment of animals and aquatic population condition which has been defined as an indicator of population behaviour and fecundity (Pantulu, 1961). Sex ratio gives important information on separation or disappearance of either sexes in any given ecosystem. This information may be used to investigate possible influence of the environment or human activity on the sex imbalance in the population (if any). However, the imbalance in sex ratio may be simply attributed to the natural behaviour of the population such as seasonal

migration of females for spawning (Carlino et al., 2014).

Crustaceans are the most numerous groups of invertebrates in marine ecosystem, with many species facing population decline (Bellido et al., 2011). Our study focuses on brachyuran decapods (Crustacea: Decapoda: Brachyura) since many crab species are endangered by environmental and human factors such as by-catch, where many non-target animals are also killed, causing a decline in crab populations (Bellido et al., 2011). However, many other factors can cause species declines, which are poorly studied in marine crabs.

The aim of the paper is to explore biometry of three crab species populations in the northern Adriatic Sea, namely the species *Liocarcinus depurator* (Linnaeus, 1758), *Liocarcinus vernalis* (Risso, 1816) and *Medorippe lanata* (Linnaeus, 1767), which are all characteristic for sandy soft bottoms (Manning et al., 1981; Abelló et al., 1991). Although these crabs are frequently caught in fishermen nets as bycatch (Ingle, 1997; Bergmann & Moore, 2001), they are relatively poorly studied. Information provided by this study will give valuable insight into their ecology and could facilitate future sustainable management of these species in the Adriatic Sea.

MATERIAL AND METHODS

Study area

The 67 sampling stations were distributed over the area shown in Figure 1. Stations occurred at different depths (0–30 m: 39 stations; 30–50 m: 17 stations; 50–100 m: 11 stations). Crabs of the three studied species were obtained as a by-catch of fishery nets. Sampling took place in the waters off the northern Adriatic Sea in December 2013 as a part of fishery expedition.

Studied species

Liocarcinus depurator is distributed in bottoms of the North Sea, Atlantic Ocean, Mediterranean Sea, and also in the Black Sea (Ateş, 1999). It grows up to 50 mm in width and 40 mm in length (Hill, 2007) and can be distinguished from other crabs by the curved rows of white spots on its carapace (Telnes, 2012). It is a predominant brachyuran in the by-catch in Mediterranean demersal fisheries, as deep as 200 m (Sarda & Palomera, 1981). *L. depurator* constitutes a main fraction of the cast-off species in many marine fisheries (Bergmann & Moore, 2001). Crabs often inhabit harbours with the proximity to anchored fishing vessels and feed on trash thrown off the board.

The grey swimming crab *Liocarcinus vernalis* is a crab inhabiting shallow waters. It is present in the Mediterranean Sea and from West Africa to the southern North Sea (McCarthy et al., 2005).

The distribution of benthic crab *Medorippe lanata* extends from Atlantic Ocean to the Mediterranean (Man-

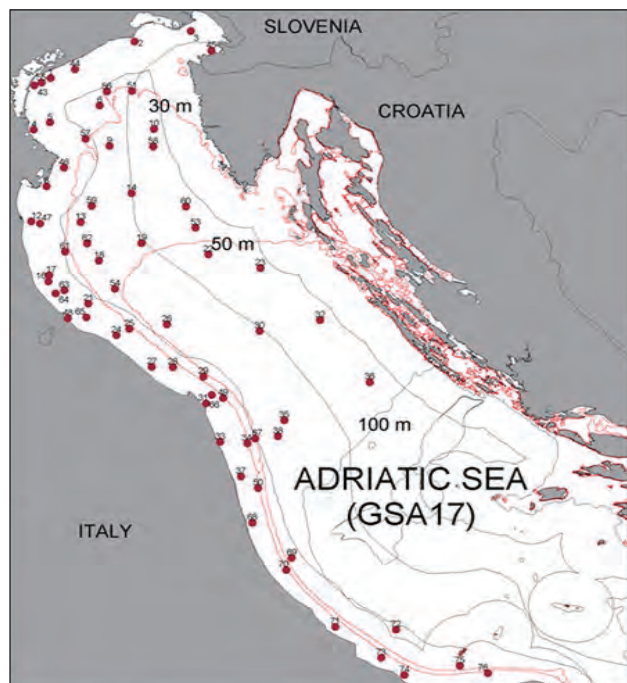


Fig. 1: The area covering the sampling stations.
Sl. 1: Zemljevid obravnavanega območja z vzorčevalnimi postajami.

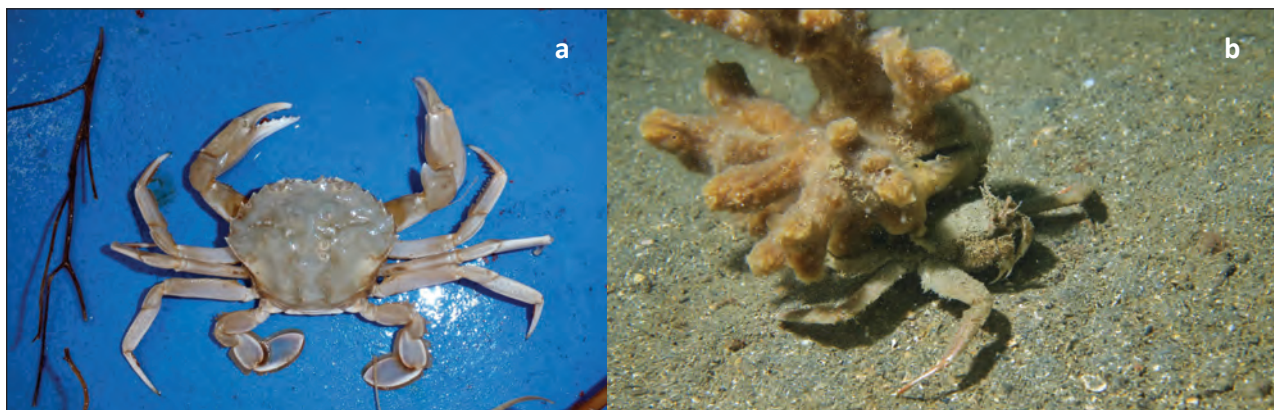


Fig. 2: The image of two studied crab species: (a) *Liocarcinus depurator* (Risso, 1816) and (b) *Medorippe lanata* (Linnaeus, 1767).

Sl. 2: Raziskane vrste rakovic: (a) *Liocarcinus depurator* (Risso, 1816) in (b) *Medorippe lanata* (Linnaeus, 1767).

ning et al., 1981) in depths from 9 to 952 m of muddy bottoms (D’Udekem d’Acoz, 1999). Carapace length in females and males has been reported to range from 10-29 and 9-29 mm respectively (Rossetti et al., 2006). This crab is subjected to trawling and eventually discarded due to the lack of commercial value (Biagi et al., 2002). Occasionally it is caught in significant numbers in trawls of fishing vessels and in squid or crab/lobster pots (Ingle, 1997).

Biometric measurements

Crab specimens were measured by Vernier calliper with accuracy up to 0.01 mm. The biometric parameters which were measured are the carapace length and width. All crabs were sexed and their wet weight was measured by using digital balance (Palmscale 8; 300g x 0.01 Capacity) (Lara et al., 2013). Due to the damage occurred during sampling, gender could not be identified in four crab specimens, all of *L. vernalis*. These crabs were excluded from analysis where males and females were compared.

Data analysis

Analysis of data was performed using SigmaPlot 13 for Windows (Systat Software Inc. CA, USA). Normal distribution of data was confirmed by the Kolmogorov–Smirnov test. The mean values of two groups (e.g. female and male) of normally distributed data were compared by a Student’s t test. The median values of two groups of data that were not normally distributed were compared using the non-parametric Mann–Whitney U test. Moreover, non-normally distributed data were subjected to Kruskal–Wallis test by ranks followed by the Wilcoxon rank-sum test. Chi-square test was performed to compare the rates. A P-value of 0.05 or less was considered as significant.

In addition, regression analysis was performed to investigate the relationship between carapace weight and length. To compare condition among species in question, Fulton’s condition factor (Fulton, 1904) was calculated as:

$$K=100W/CL^3$$

where W was weight (g) and CL carapace length (cm).

RESULTS

Overall survey of the studied populations

All specimens of crabs were collected from 32 sampling stations. The number per station varied from 1 to 92 specimens. Out of 922 crabs, 451 individuals were *L. vernalis*, 317 *L. depurator* and 154 *M. lanata* (Tab. 1).

Except for *M. lanata*, the number of males in other species was higher than that of females (Tab. 2). The sex ratio in all species (except for *M. lanata*) was found to be significantly different from 1:1 (chi-square test).

Tab. 1: The number of analysed males (M) and females (F) per crab species.

Tab. 1: Število analiziranih samcev (M) in samic (F) raziskanih vrst rakovic.

Species	Sex	Number of individuals
<i>Liocarcinus depurator</i>	M ♂	192
	F ♀	125
<i>Liocarcinus vernalis</i>	M ♂	301
	F ♀	150
<i>Medorippe lanata</i>	M ♂	68
	F ♀	86

Tab. 2: Sex ratio in population of examined three crab species. Significant difference from 1:1 ratio was indicated by chi-squared test. Legend: 1 - Regardless of gender in the whole population, 2 - P-values indicate significant difference from hypothetical ratio of 1:1.

Tab. 2: Delež samic in samcev pri treh raziskanih vrstah rakovic. Signifikantni odklon od razmerja 1:1 smo preverjali s Hi- kvadrat testom. Legenda: 1 - Delež vrste ne glede na spol, 2 - P-vrednost kaže signifikantni odklon od hipotetičnega razmerja med spoloma 1:1.

Species	Ratios in the population					Chi-square test	
	N Females	N Males	Proportion of population ¹	% Females	% Males	χ^2	P-Value ²
<i>L. depurator</i>	125	192	34.4	0.39	0.61	6.75	0.009
<i>L. vernalis</i>	150	301	48.9	0.33	0.67	25.35	<0.001
<i>M. lanata</i>	86	68	16.7	0.56	0.44	1.35	0.25

No effect of depth was found on the distribution of the studied crabs.

Wet weight

Wet weight was compared among the three studied species (Fig. 3). Non-parametric analysis revealed significantly higher wet weight in males than in females of *L. vernalis* (Mann–Whitney *U* test: $U=18377$, $P=0.012$). The males of *L. vernalis* were also significantly larger than males of *L. depurator* and *M. lanata*. The difference among females across species was not significant (Wilcoxon rank-sum test: $P=0.63$).

Carapace width-carapace length relationships

Liocarcinus depurator

Carapace length was on average larger than carapace width in *L. depurator*. Carapace width ranged

from 13.7 to 29.0 mm in males and 14.7 to 27.2 mm in females. Carapace length ranged from 11.2 to 42.3 mm in males and 17.9 to 39.4 mm in females. No statistically significant differences were found between females and males of *L. depurator* in carapace width and length. There was a significant correlation between carapace width and length for males and females combined (Fig. 4).

Liocarcinus vernalis

Carapace length was on average larger than carapace width. The latter ranged from 10.5 to 26.5 mm in males and 14.7 to 27.2 mm in females. Carapace length ranged from 14.8 to 43.1 mm in males and 14.0 to 37.3 mm in females. No statistically significant differences were found between females and males of *L. vernalis* in carapace width and length. There was significant correlation between carapace width and length for males and females combined (Fig. 5).

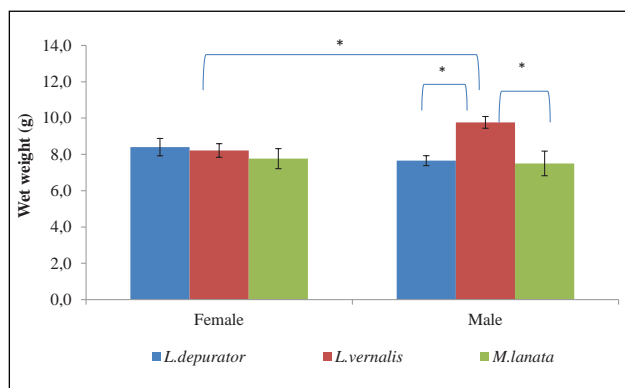


Fig. 3: Comparison of wet weight among different species and between genders within species. Asterisk indicates a statistical difference (* $P<0.05$).

Sl. 3: Primerjava mokre teže pri različnih vrstah in spolih. Zvezdica označuje statistično razliko (* $P<0.05$).

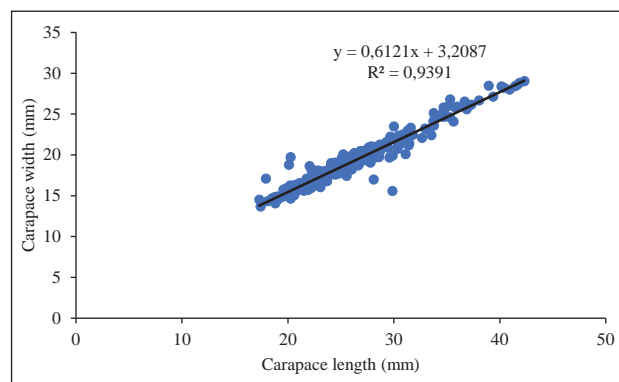


Fig. 4: Scatterplot and relationship between carapace width and length in *Liocarcinus depurator* ($t=69.2$; $P<0.001$).

Sl. 4: Razpršeni diagram in odnos med širino in dolžino karapaksa pri vrsti *Liocarcinus depurator* ($t=69.2$; $P<0.001$).

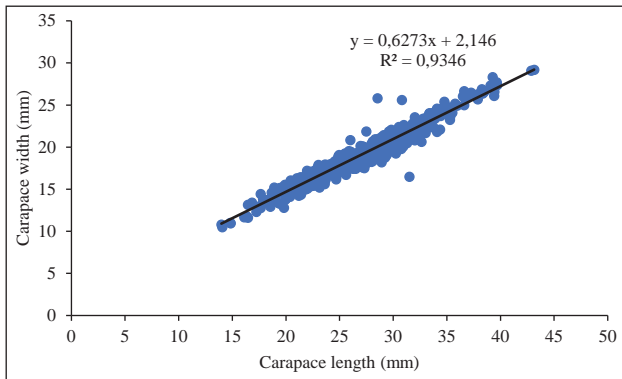


Fig. 5: Scatterplot and relationship between carapace width and length for the whole population of *L. vernalis* ($t=79.6$; $P<0.001$).

Sl. 5: Razpršeni diagram in odnos med širino in dolžino karapaksa pri vrsti *L. vernalis* ($t=79.6$; $P<0.001$).

Medorippe lanata

Carapace length was on average larger than carapace width. Carapace width ranged from 7.0 to 17.35 mm in males and 7.8 to 17.3 mm in females. Carapace length ranged from 10.0 to 35.5 mm in males and 12.7 to 37.8 mm in females. Carapace width, length and height in females of *M. lanata* were significantly greater than those of males (Mann-Whitney U test: $U_{width}=2126$, $P_{width}=0.01$, $U_{length}=2107$, $P_{length}=0.008$, $U_{height}=1967$, $P_{height}<0.001$) (Fig. 6).

There was significant correlation between carapace width and length for males and females combined (Fig. 7).

Fulton's condition index

The differences between males and females in condition index were not statistically significant (Mann-Whitney U test) within and between any of the species (Tab. 3).

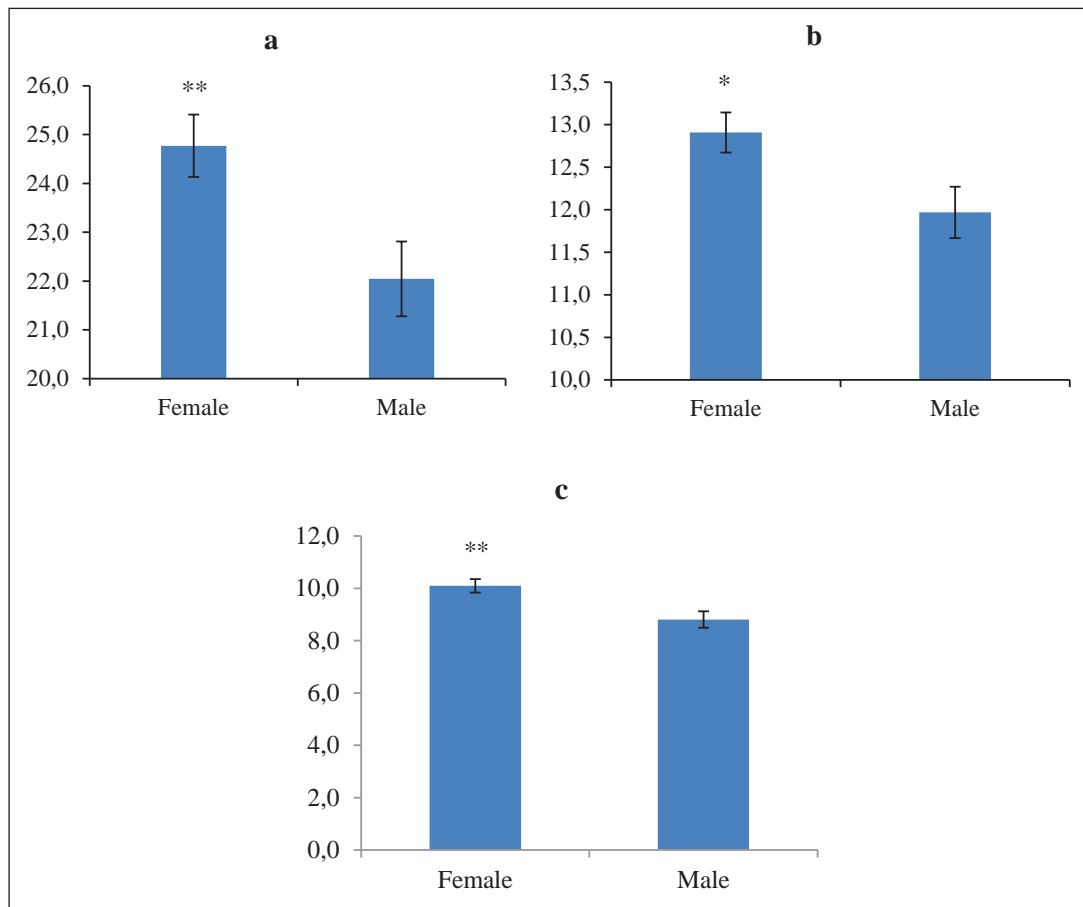


Fig. 6: Carapace width (a), length (b) and height (c) of females ($n=86$) and males ($n=68$) of *M. lanata*. Asterisk indicates a statistical difference (* $P<0.05$; ** $P<0.01$). Values (in mm) represent means \pm standard error (SE).

Sl. 6: Širina (a), dolžina (b) in višina (c) karapaksa pri samicah ($n=86$) in samcih ($n=68$) vrste *M. lanata*. Zvezdica označuje statistično razliko (* $P<0.05$; ** $P<0.01$).

Vrednosti (v mm) predstavljajo povprečje in standardni odklon (SE).

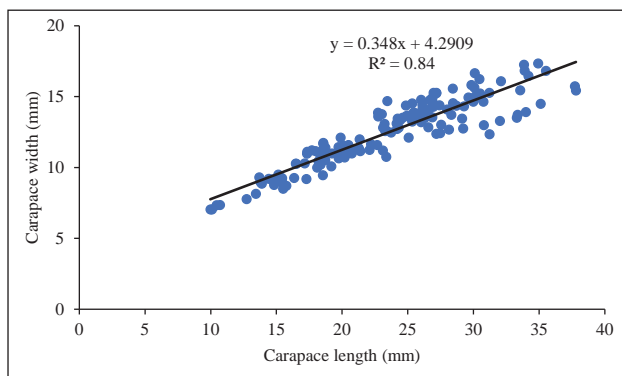


Fig. 7: Scatterplot and relationship between carapace width and length for the whole population of *M. lanata* ($t=28.1$; $P<0.001$).

Sl. 7: Razpršeni diagram in odnos med širino in dolžino karapaksa pri vrsti *M. lanata* ($t=28.1$; $P<0.001$).

DISCUSSION

Crab populations

L. vernalis and *L. depurator* were caught in higher numbers, which could be a possible indication of their dominance in the ecosystem of the northern Adriatic Sea. These two species represent 70% of all collected individuals. *L. vernalis* has also been shown previously to be one of the dominant species in Spanish Bay of Cadiz (Drake et al., 1998). One reason for dominance could be the environmental conditions such as depth. It has been shown that *L. depurator* density is highest at depths between 51–100 m in Iberian Peninsula (Rufino et al., 2005). However, in this study *L. depurator* and *L. vernalis* distribution was not affected by depth. Other factor affecting population could be the impact of predators which could not be controlled and measured in this study.

The maximum density of *L. depurator* was reported to occur in depths below 100 m (Rufino et al., 2005) corresponding to this study's range of depths. The distribution of *L. vernalis* has been reported to occur in regions as deep as 130 m in the Mediterranean Sea (Koch & Đuriš, 2016) and the maximum recruitment of *M. lanata* has

been found within 20–100 m depth (Abelló et al., 1988) which corresponds to the depth range in this study.

Higher ratio of males to females is evident in both studied *Liocarcinus* species. This is in agreement with Sartor et al. (2006) who reported higher vulnerability of males to fishing and sorting operations compared with females. One alternative explanation to the higher ratio of males to females may be the migration of females to other regions for spawning during the sampling period as shown previously for Atlantic blue crab *Callinectes sapidus* (Carlino et al., 2014).

Biometry

Males of *L. vernalis* were significantly larger than females, however this was not associated with significant differences in carapace dimensions between males and females. No other scientific report was found to confirm sexual dimorphism in *L. vernalis*. The weight of females of *M. lanata* were found to be larger than that in males numerically, however, the difference was not statistically significant. The sexual dimorphism is observed in *M. lanata* at carapace level with the dimensions of carapace being significantly larger in females. Sexual dimorphism in size of chelae was reported previously in *M. lanata* (Rossetti et al., 2006). The range of carapace length of *L. depurator* in this study was close to that reported previously by Ungaro et al. (2000).

Strong relationship between carapace width and length is observed for all species in females and males. The relationship between carapace width and length is used to indicate health and physiological conditions within the population (Bolger & Connolly, 1989).

Fulton's condition index

The condition factor is used as an indicator of health and biomass which is found to change in response to crabs' alterations in weight. This may occur under different feeding, growth and physiological conditions (Bolger & Connolly, 1989). Condition index of *L. depurator* in this study is similar to those obtained by Aydin (2018). No significant difference in this parameter between female and male of all studied crabs could

Tab. 3: Fulton's condition index of the studied crab species. Values represent means \pm standard error (SE).

Tab. 3: Fultonov kondicijski indeks pri treh vrstah rakovic. Vrednosti predstavljajo srednjo vrednost in standardni odklon (SE).

Species	n (total)	Total	Female	Male	Gender effect	
		Mean \pm SE	Mean \pm SE	Mean \pm SE	P-value	U-test
<i>L. depurator</i>	298	50.4 \pm 2.5	51.0 \pm 3.0	49.8 \pm 2.0	0.46	15499
<i>L. vernalis</i>	442	55.7 \pm 2.4	57.6 \pm 2.9	53.9 \pm 1.9	0.31	27559
<i>M. lanata</i>	149	55.8 \pm 3.8	51.7 \pm 3.6	59.9 \pm 4.1	0.06	4954

indicate that there were no environmental, nutritional and physiological effect on body condition between both sexes.

The information on the biometry and population profile of three species of crabs in northern Adriatic Sea can be useful in the future studies to evaluate and monitor any changes in the population of crabs. Further, the obtained data in this study could be helpful when performing research on various crab predators in the shallow area of the northern Adriatic Sea such as sharks and rays.

The specimens which are killed as bycatch in fisheries provide a valuable source of data for studying the ecology of such species. Thus, it is important to obtain as much as possible data regarding these crabs and other

organisms due to the collateral damage imposed by fisheries. Further studies are needed to study how environmental and human factors may affect crab populations and their biometrical features in northern Adriatic Sea. One such environmental effect could be the seasonal change in water quality and/or temperature. The knowledge in population structure and biometry can be used to adjust regulation leading to protection of crabs and overall benthic fauna in the region.

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BIOMETRIJA IN SPOLNA STRUKTURA PRI TREH VRSTAH RAKOVIC (CRUSTACEA: DECAPODA) IZ SEDIMENTNEGA DNA SEVERNEGA JADRANA

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POVZETEK

Cilj raziskave je bil raziskati razširjenost in populacijsko strukturo treh vrst rakovic (Decapoda: Crustacea), Medorippe lanata, Liocarcinus depurator in Liocarcinus vernalis ter biometrične meritve. V decembru 2013 je bilo v severnem Jadranu ujeto skupno 1100 primerkov, ki so pripadali trem vrstam. Avtorji so opravili biometrične meritve in izračunali Fultonov kondicijski indeks za vse tri vrste. Pri vrsti M. lanata je bila izražena spolna dvoličnost, ki se je kazala v večjih karapaksih samic, čeprav ta ni bila signifikantna v telesni teži. Raziskane vrste se glede kondicijskega indeksa niso statistično razlikovale.

Ključne besede: *Medorippe lanata, Liocarcinus depurator, Liocarcinus vernalis*, biometrija, kondicijski indeks, Jadransko morje

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