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LENGTH-WEIGHT RELATIONSHIPS AND DENSITY OF BIVALVE SPECIES IN THE SHELLFISH PRODUCTION AREA OF ZARZIS (TUNISIA, CENTRAL MEDITERRANEAN SEA)

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ABSTRACT

The present work reports length-weight relationships (LWRs) for the most common and abundant bivalve species found in coastal areas of Zarzis (southern Tunisia). Systematic surveys were carried out during 2018 on soft bottom in the littoral zone down to 1 m depth. This study provides the first results about LWRs and the density levels of 6 species (Ruditapes decussatus, Polititapes aureus, Moerella pulchella, Cerastoderma glaucum, Mactra stultorum and Loripes orbiculatus) distributed among five families. A stock size assessment of these target species revealed abundance values ranging from 0.47 to 6.10 indiv. m⁻², and biomass values from 1.83 to 10.34 g m⁻². The results showed negative growth in five species and isometric growth in one species. The data presented herein are essential for the management and conservation for these species.

Key words: Mollusca, bivalvia, Length-weight relationship, Allometric growth, Zarzis coast, Tunisia

RAPPORTO LUNGHEZZA-PESO E DENSITÀ DEI BIVALVI NELLA ZONA DI PRODUZIONE DI MOLLUSCHI DI ZARZIS (TUNISIA, MARE MEDITERRANEO CENTRALE)

SINTESI

L'articolo riporta le relazioni lunghezza-peso (LWR) per le specie di bivalvi più comuni e abbondanti trovate nelle aree costiere di Zarzis (Tunisia meridionale). Indagini sistematiche sono state effettuate durante il 2018 su fondi molli nella zona litorale fino a 1 m di profondità. Lo studio fornisce i primi risultati sulle LWR e i livelli di densità di 6 specie (Ruditapes decussatus, Polititapes aureus, Moerella pulchella, Cerastoderma glaucum, Mactra stultorum e Loripes orbiculatus) distribuite in cinque famiglie. Una valutazione delle dimensioni dello stock di queste specie bersaglio ha rivelato valori di abbondanza che vanno da 0,47 a 6,10 indiv. m⁻², e valori di biomassa da 1,83 a 10,34 g m⁻². I risultati hanno evidenziato una crescita negativa in cinque specie e una crescita isometrica in una specie. I dati qui presentati sono essenziali per la gestione e la conservazione di queste specie.

Parole chiave: Mollusca, bivalvia, rapporto lunghezza-peso, crescita allometrica, costa di Zarzis, Tunisia

INTRODUCTION

The length-weight relationships (LWRs) in marine species is of a great use in fisheries biology for converting length measures into weight and ascertaining the growth characteristics related to those variables (Anderson & Gutreuter, 1983). An empirical relationship like LWR is an important piece of information in studying marine organisms. For instance, LWR allows predictions of weight from length (Pauly, 1993).

Bivalve shell growth and shape are influenced by abiotic (exogenous/environmental) and biotic (endogenous/physiological) factors. Shell morphology and relative proportions of many bivalve species are known to be affected by environmental factors, such as latitude (Beukema & Meehan, 1985), depth (Gaspar *et al.*, 2002; Derbali, 2011; Derbali *et al.*, 2011), currents and water turbulence (Fui-man *et al.*, 1999; Hinch & Bailey, 1988), and type of sediment (Claxton *et al.*, 1998; Derbali *et al.*, 2009a & b). Gaspar *et al.* (2002) have also reported that burrowing behaviour, ability and efficiency also affect the relative growth of bivalve species. In Tunisia, there have been many investigations documented on bivalve species (Tlig-Zouari *et al.*, 2010; Bellaaj-Zouari *et al.*, 2011; Derbali *et al.*, 2018). Nonetheless, the data available on morphometric relationships and stock assessment of shellfish spe-

cies are very limited. The present study is the first attempt to obtain basic information by investigating the length-weight relationships and densities levels of the most abundant bivalve species harvested along the coasts of Zarzis (southern Tunisia). Studies concerning shell morphometric relationships of the species are underpinned by basic knowledge in different fields of environmental research. Such data are valuable for establishing a monitoring and management system and can be a useful reference for studies of marine invertebrates.

MATERIAL AND METHODS

Sampling protocol and operations

Systematic surveys were carried out from February to October 2018 within the 100 km Zarzis coastal part located in south Tunisia (Fig. 1). Transects were systematically set up every 600 m in the littoral zone during low tides (up to 1 m depth). Bivalve species were collected every 50 m along each transect line from the upper limit of the tide's influence to the low water mark. Along the transects, 4 to 10 sampling stations were marked. In each one, two replicates were taken from the quadrats (0.25 m²) using a shovel. Large specimens were collected by hand and small ones using a 2 mm mesh sieve.

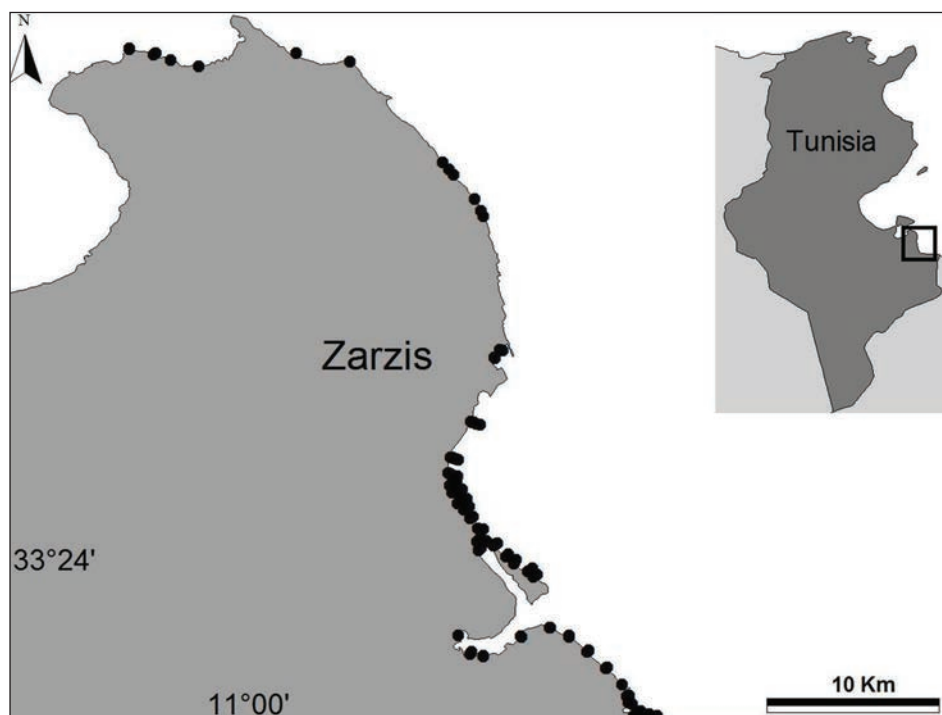


Fig. 1: Map of the study area, indicating the sampling location (Zarzis, Tunisia).

Sl. 1: Zemljovid obravnavanega območja z navedbo lokalitete vzorčenja (Zarzis, Tunizija).

Tab. 1: Descriptive statistics and morphometric relationship parameters for 6 bivalve species from the Zarzis coast (N = number of individuals; L = shell length (mm); W = total fresh weight (g); $S.D.$ = standard deviation; $S.E.$ = standard error; $(*) = P < 0.001$).

Tab. 1: Opisna statistika in parametri morfometričnega razmerja za 6 vrst školjk z obale Zarzis (N = število osebkov; L = dolžina lupine (mm); W = skupna sveža teža (g); $S.D.$ = standardni odklon; $S.E.$ = standardna napaka; $(*) = P < 0,001$).

Species	N	Lmean $\pm$ S.D (Lmin – Lmax)	Wmean $\pm$ S.D (Wmin – Wmax)	Allometric equation	Determin. coefficient (r^2)	S.E. of b	Relationship (t-test)
Family Veneridae							
<i>Ruditapes decussatus</i>	50	26.45 $\pm$ 15.00 (3.2 – 54.85)	7.05 $\pm$ 7.55 (0.01 – 32.28)	Log W = -3.378 + 2.7942 Log L	0.996 *	0.020	negative allometry
<i>Politapes aureus</i>	282	22.57 $\pm$ 8.11 (3.25 – 35.85)	2.44 $\pm$ 1.7 (0.003 – 9.57)	Log W = -3.3709 + 2.6877 Log L	0.9186 *	0.048	negative allometry
Family Tellinidae							
<i>Moerella pulchella</i>	101	6.27 $\pm$ 1.54 (2.90 – 17.20)	0.04 $\pm$ 0.04 (0.01 – 0.38)	Log W = -2.9425 + 1.8686 Log L	0.8266 *	0.086	negative allometry
Family Cardiidae							
<i>Cerastoderma glaucum</i>	452	15.89 $\pm$ 8.29 (1.50 – 35.10)	2.39 $\pm$ 2.70 (0.001 – 16.50)	Log W = -3.4484 + 2.9622 Log L	0.9708 *	0.024	isometric
Family Mactridae							
<i>Mactra stultorum</i>	31	26.91 $\pm$ 8.13 (6.6 – 37)	3.94 $\pm$ 2.70 (0.1 – 8.59)	Log W = -3.3433 + 2.6823 Log L	0.9112 *	0.156	negative allometry
Family Lucinidae							
<i>Loripes orbiculatus</i>	344	10.00 $\pm$ 3.06 (3.00 – 16.55)	0.34 $\pm$ 0.27 (0.006 – 1.37)	Log W = -3.3969 + 2.8127 Log L	0.89 *	0.053	negative allometry

During each sampling period, seawater temperature and salinity were measured near the bottom immediately after sampling using a multi-parameter kit (Multi 340 i/SET). After sampling, the materials were put in labelled plastic bags, subsequently preserved in a 7% formaldehyde solution to be used as material for data analysis.

Data analysis

In the laboratory, the preserved samples were sorted and washed to remove all adhering organisms and other debris. Specimens were identified and counted. The measurement of the bivalve shell length (maximum distance along the anteroposterior axis, L) was made to the nearest 0.01 mm, using a digital caliper. The total fresh weight (including intra-valves water, W) was measured using a toploading digital balance (precision of 0.001 g). After identification to the species level, data were pooled at sampling sites to obtain mean densities (indiv. m^{-2}) and mean biomass (g m^{-2}). Mean densities of bivalve species recorded in the study area were compared using one-way analysis of variance (ANOVA). The results are presented as means $\pm$ standard error (SE) and the significance level used in the tests was $p < 0.05$. In addition, the Spearman's rank correlation coefficient was applied to identify significant correlations between bivalves' density and biomass.

For each bivalve species, the LWRs were estimated using the equation:

$$W = a L^b \quad (1)$$

and its linear transformation:

$$\text{Log } W = \text{Log } a + b \text{ Log } L \quad (2)$$

where W = total fresh weight; L = length; a = intercept (initial growth coefficient); b = slope (relative growth rate of variables). Besides, the LWRs were determined with a 95% confidence limit of b and the significance level of r^2 . The growth type was determined using the t -test, which investigated whether slope b was significantly different from the theoretical value 3, with a confidence level of $\pm 95\%$ ($\alpha = 0.05$) (Zar, 2010). The statistical package used was STATISTICA v. 6.0.

RESULTS

Occurrence and abundance

During the studied period, 45 transects were made from the high tide point to the extreme low tide point, which corresponded to 266 sampling stations. A total of 1260 specimens were collected, belonging to 6 bivalve species distributed among 5 families (Tab.e

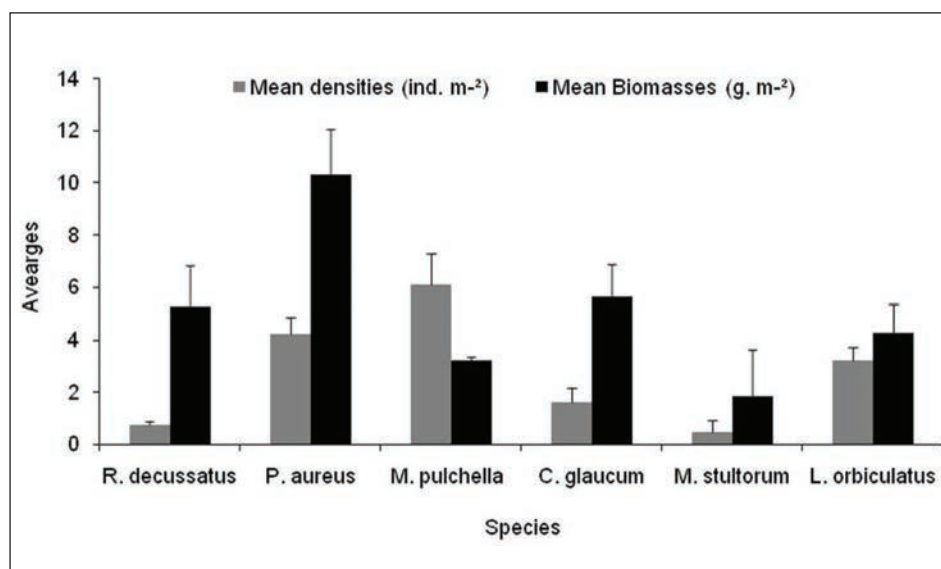


Fig. 2: Density levels of the most abundant bivalve species along the Zarzis coast (south Tunisia) and their standard errors ($\pm$ SE).

Sl. 2: Gostote najbolj razširjenih vrst školjk vzdolž obale Zarzis (južna Tunizija) in njihove standardne napake ($\pm$ SE).

1). In terms of numbers of individuals, the most abundant families were the Cardidae (35.88%), the Lucinidae (27.30%) and the Veneridae (26.35%); the least abundant were the Tellinidae and the Mactridae with percentages not exceeding 9%. The target bivalve species were encountered in various substratum types, such as muddy-sandy bottom patchily covered by meadows of *Zostera noltii* or *Cymodocea nodosa* or by mixed vegetation consisting of these two marine seagrasses.

The sample size ranged from 31 individuals, e.g., in the surf clam *Macra stultorum* (Linnaeus, 1758), to 452 individuals, e.g., in the cockle *Cerastoderma glaucum* (Bruguère, 1789). The assessment of the stock size of these target species across quadrats yielded density values ranging from 0.47 to 6.10 indiv. m⁻², with biomass values varying from 1.83 to 10.34 g m⁻² (Fig. 2). The most numerous species were *M. pulchella* (6.1 indiv. m⁻²), *P. aureus* (4.24 indiv. m⁻²) and *L. orbiculatus* (3.22 indiv. m⁻²). On the other hand, no significant variations occurred between mean values of *R. decussatus*, *C. glaucum* and *M. stultorum* (Fig. 2). This was due to fewer individuals being collected over the period of sampling.

In term of biomass, three species, *P. aureus*, *C. glaucum* and *R. decussatus*, maintained high level values (over 10.34 g m⁻², 5.64 g m⁻² and 5.3 g m⁻², respectively). Mean biomass showed significant variations of abundance ($p < 0.05$) between species, with the mean value for *P. aureus* higher ($p < 0.05$) than those of the remaining species. A Spearman's

correlation comparison indicated a strong positive correlation (> 0.9) between density and biomass for each species. The present study area has both a qualitative and quantitative importance because all the studied species together accounting for more than 491 tons. The highest temperature values were recorded in July (28°C), the lowest values in February (11°C). Salinity measurements showed an annual fluctuation between 32‰ in winter and 47‰ in summer.

Length-weight relationships

The results obtained for the length-weight relationships, along with some sample descriptive statistics are given in Table 1. The data are not representative of a particular season and were not collected during a specific period of the year. These parameters should therefore only be considered as mean annual values. In addition, the results revealed that in all encountered bivalve species determination coefficients (r^2) were high in length-weight relationships and regressions were all highly significant ($p < 0.001$). The b value of the studied samples varied between 1.86 and 2.96. For the 6 species studied, the LWRs indicated a clear prevalence of negative growth (5 species, b values = 1.86–2.81) over isometric growth (1 species, b values = 2.96). For the 5 species the growth in length was superior to weight increase, in one species the growth in length was accompanied by weight increase.

DISCUSSION

The present study provides for the first time information about densities and length-weight relationships (LWRs) of the most abundant bivalve species found on the Zarzis coast. Findings of recent research indicate that densities and biomasses varied substantially from one species to another. A stock size assessment of these target species across quadrats revealed mean density values ranging from 0.47 to 6.10 indiv. m⁻², and mean biomass values from 1.83 to 10.34 g m⁻². The highest density and biomass values were recorded for *M. pulchella* and *P. aureus*, respectively. Despite the small number of some of the studied bivalve species and the mortality of adult individuals, the littoral zone supports an extraordinary stock estimated at over 491 tons.

As follows from this study, the colonised area presents more than 5.8% of the total biomass of cockle *C. glaucum* in the Gulf of Gabes. A similar gradient was observed in the clam species *R. decussatus* and *P. aureus*, with about 86 and 166 tons or 8% and 13%, respectively, of their total biomasses in the Gulf of Gabes (unpublished data). Our sampling efforts led to an estimation of the local conditions (heterogeneity of abundance and presence of many parameters influencing the distribution). It appears that development of this population has been accompanied by major impacts at numerous levels (e.g., physicochemical, edaphic and hydrological factors of the study area). Stergiou et al. (1997) clarified that temperature and food potentials are the most important factors affecting phenotypic differences in growth patterns and maximum sizes in a variety of marine organisms. The concurrent increase in water temperatures and phytoplankton levels (unpublished data) on the Zarzis coast promotes rapid growth rates in many local bivalve species. Other mechanisms structuring bivalves populations include soft bottoms and organic matter content. The high diversity of shellfish species is particularly interesting when the relative organic matter content, depth (< 1 m) and muddy-sandy bottom are considered. In fact, these factors can provide ecological conditions able to maintain highly diverse reef communities in a coastal lagoon.

The bivalve species are more frequent and abundant in areas sheltered by seagrasses *C. nodosa* and *Z. noltei*, which cover more than 50% of muddy-sandy seabeds. The heterogeneity of the geographical distribution of the target species was found to be significantly correlated with the distribution of seagrass. This positive correlation was probably related to the main organic source provided by *C. nodosa*. The *C. nodosa* detritus is the richest in organic carbon and is the dominant source of primary organic matter. As a result, the sites colonised by it provide good conditions for the proliferation of clams as this species improves the food resources and dissolved oxygen levels. The same conclusion was reached by Vilela (1950) for natural

populations of *R. decussatus* in Portugal. Several studies have confirmed the correlation between patterns of community structure and primary production. In particular, local abundance and biomass of filter feeders was found to be correlated with both intertidal productivity and nearshore primary productivity (Menge & Olson, 1990). Other parameters such as light and tides may also contribute (da Costa et al., 2013).

All the studied species presented high determination coefficients in LWRs. In addition, the prevalence of negative and isometric growth and the absence of positive growth is a very interesting phenomenon, since these species are typical inhabitants of sandy or sandy-muddy bottoms. In practice this means that during ontogeny bivalve shells become progressively and rapidly longer than weighty. This phenomenon may be explained by the fact that the density of substrata is a limiting factor on firmer sediments, therefore the *b* values of LWRs may not exceed three in such environments.

The present observations were not in agreement with those reported in previous works by Gaspar et al. (2001) and later by Derbali (2011). These authors argued that most studied bivalve species displayed positive or isometric growth. Thayer (1975) believed that these ontogenetic changes could be related to the different lifestyles between adult individuals (more sedentary and inhabiting deeper sedimentary bottoms) and juveniles (active burrowers). For these species, the negative and isometric growth may be a reflection of their burrowing strategies or, to a lesser extent, of the burrowing difficulties associated with their globous shape.

In our study, the hydrodynamic conditions were similar across the sampling area and it might be assumed that relative growth was influenced by other parameters such as depth, sediment type, the burrowing behaviour of the studied species and their subsequent strategies to counter dislodgement and avoid predation. Indeed, Gaspar et al. (2002) found that some interesting connections between environmental conditions, bivalve lifestyles and species morphometric relationships were reported for many bivalve species.

Species of the families Veneridae, Tellinidae, Macridae and Lucinidae, namely *R. decussatus* (Linnaeus, 1758), *P. aureus* (Gmelin, 1791), *M. pulchella* (Lamarck, 1818), *M. stultorum* (Linnaeus, 1758) and *L. orbiculatus* (Poli, 1791), displayed negative allometry, which may be attributed to their shallower bathymetric distribution compared to the cockle species *C. glaucum* of the family Cardiidae. According to Gaspar et al. (2002), the negative growth and elongated shape may be an adaptive strategy to improve burrowing efficiency and depth within the substrate.

Further interesting results were detected with regard to other encountered species which, despite being deep burrowing bivalves, displayed isometric growth,

for instance, the species of the family Cardiidae; this appears to be in contradiction with other studies of these species in several other geographical areas (Ansell & Lagardère, 1980; Ramon, 1993; Gaspar *et al.*, 2001; Derbali, 2011). Disagreements reported on species morphometric relationships may be a result of environmental conditions varying between different geographical areas. In many cases, investigations were conducted in the Mediterranean and Adriatic Seas, where the habitats differ considerably from those in Tunisian waters. Therefore, Gaspar *et al.* (2001 & 2002), Tlig-Zouari *et al.* (2009 & 2010) and Derbali *et al.* (2011 & 2012) argued that these environmental conditions could potentially lead to variations within bivalve species and between localities. Moreover, the size ranges of many shellfish species from different geographical areas are highly variable, which complicates comparison among surveys.

Indeed, estimation of LWRs is necessary and important as it provides information on the condition of a population; it is also a widely applied approach in the study of the dynamics of exploited stocks and an effective tool used for basic research and management strategies in fisheries. Moreover, the parameters

affecting length-weight relationships can be used to enhance management and conservation and allow future comparisons between different populations of the same species living in similar or different ecosystems. Future studies could be conducted in many ways: i) stocks assessment should be carried out each year in order to track variations in bivalve stocks and changes in their structures, ii) the relationship between species density and abiotic and biotic parameters should be investigated in detail, iii) in future research, more consideration should be given to studies of weight of the visceral mass as opposed to those of total weight, since that analysis is also and particularly applicable to other fishery resources such as crustaceans, cephalopods, and fish.

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DOLŽINSKO-MASNI ODNOS IN GOSTOTA ŠKOLJK NA GOJIŠČU ŠKOLJK V PREDELU ZARSISA (TUNIZIJA, OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

Avtorji poročajo o masno-dolžinskem odnosu za najpogostejše in najštevilčnejše vrste školjk na obrežnem predelu v Zarzisu (južna Tunizija). Leta 2018 so opravili sistematske raziskave na sedimentnem dnu do 1 m globine. Raziskava je obelodanila prve rezultate o masno-dolžinskem odnosu in gostoti za šest vrst školjk (*Ruditapes decussatus*, *Polititapes aureus*, *Moerella pulchella*, *Cerastoderma glaucum*, *Mactra stultorum* in *Loripes orbiculatus*) iz petih družin. Gostote teh tarčnih vrst so bile v razponu od 0,47 do 6,10 osebkov m^{-2} , biomase pa od 1,83 do 10,34 $g\ m^{-2}$. Rezultati so pokazali negativno rast pri petih vrstah in izometrično rast pri eni vrsti. Pričujoči podatki so pomembni za upravljanje in ohranjanje teh vrst.

Ključne besede: Mollusca, Bivalvia, dolžinsko-masni odnos, alometrična rast, obala Zarzis, Tunizija

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