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Distribution and allometry of the knobby swimcrab, *Macropipus tuberculatus* (Roux, 1830) (Brachyura, Portunidae) in the Strait of Sicily (Mediterranean Sea)

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Abstract: Distribution and biometric information for *Macropipus tuberculatus* of the Strait of Sicily were obtained via an experimental bottom trawl survey carried out in 2000. The species occurred with low frequency (20%) and abundance (365 specimens), showing a scattered spatial distribution, split in 2 preferential depth levels (90-160 m and 230-460 m). Males were larger and more abundant than females. The carapace length width relationship was allometric positive (b > 1), and the carapace length weight relationship was isometric (b = 3).

Key words: *Macropipus tuberculatus*, spatial distribution, allometry, Strait of Sicily, Mediterranean Sea

Introduction

The knobby swimcrab, *Macropipus tuberculatus* (Roux, 1830), is a small, right-handed heterochelic portunid crab distributed in the Eastern Atlantic Sea and the whole Mediterranean basin, but the North Adriatic Sea (Holthuis, 1987). It occurs on open-sea detritic organogenic sediments (Fanelli et al., 2007) and bathyal muddy bottoms (Massutí and Reñones, 2005). With the exception of rare findings down to 1400 m (Abelló and Valladares, 1988; Mura and Cau, 1994), *M. tuberculatus* is common from 20 m to 850 m of depth (Holthuis, 1987; Abelló et al., 1988; Ungaro et al., 1999; Fanelli et al., 2007), and represents a common by-catch of bottom trawling fleets although regularly landed only in Spain and occasionally in Italy, Greece, and Egypt (Holthuis, 1987). Different studies have been performed about its zonation pattern (González-Gurriarán et al., 1993; Fariña et al., 1997), allometry, and biological traits (Mori, 1987; Abelló et al., 1988; Ungaro et al., 1999), and the role played by *M. tuberculatus* within the macrobenthic assemblages (Fariña et al., 1997; Massutí and Reñones, 2005; Fanelli et al., 2007). As far as concerns the Strait of Sicily, only scanty information for the knobby swimcrab is available covering size distribution (15-34 mm of carapace length), smallest size of berried females (15 mm), and vertical distribution (82-750 m) (Bombace and Sarà, 1972; Pipitone and Tumbiolo, 1993).

The present note aims at deepening the knowledge on the spatial distribution (geographic and bathymetric), length structure, and allometric relationships of this species in the Strait of Sicily.

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Materials and methods

Knobby swimcrabs were gathered during an experimental bottom trawl survey (GRUND program; Relini, 2000) carried out from the 5^{th} of September to the 11^{th} of November of 2000 in the Strait of Sicily, following a depth-stratified sampling design: 10-50 m (*stratum* A), 51-100 m (B), 101-200 m (C), 201-500 m (D), and 501-800 m (E). The 1-h hauls were allocated proportionally to the strata area and conducted in daylight using a commercial stern trawler (Sant' Anna, 32.2 m overall length, 736 kW engine) equipped with a "Mazarese" gear, (codend of diamond mesh, 31 mm stretched). The bottom seawater temperature (BST; °C) was registered in each haul with a Minilog device (Vemco, 2005).

The crabs were counted, sexed, weighed (BW; 0.1 g), and the carapace length (CL) and width (CW) were measured (0.1 mm) with a calliper. Moulting condition and presence of eggs were also annotated. The "exact interpolator" (IDW, Inverse Distance Weighting) procedure within the GIS software ArcMap^{TM} 9.0 (ESRI, 2004) was employed to produce abundance (N/km^2) and BST maps.

The sex ratio (Sr), defined as the proportion of females (F) on the total sexed individuals (F+M), was computed for the overall sample and the differences from the theoretical Sr of 0.5 were tested (χ^2 test with 1 degree of freedom, df) by carapace length and by depth levels. The allometric relationships, CW vs. CL and BW vs. CL, were computed after $\log_e$ transformation ($\log_e Y = a + b \times \log_e X$). The deviation from isometry (b = 1 and b = 3 for length and weight, respectively) was checked with t-test. Homogeneity of the morphometric (CW and BW) linear regressions, carried out for males and females separately, was tested with Analysis of Covariance (ANCOVA), using CL as the covariate.

Possible differences by sex on the length (CL) frequency distribution (LFD; CL class width of 2 mm) were also studied with Kolmogorov-Smirnov two-sample test. All the computations were performed using SYSTAT 12 (©2007, SYSTAT Software Inc.).

Results

A total of 365 specimens of knobby swimcrab were collected in 47 out of the 237 hauls trawled in the investigated area, with a frequency of occurrence of 19.8%. The animals were caught from the inner shelf edge (93 m) of the B stratum (50-100 m; mean BST=16.03 ± 1.15 °C), through the C (101-200 m; mean BST=14.95 ± 0.37°C) and D (201-500 m; mean BST=13.97 ± 0.22 °C). Excluding 40 damaged specimens, 325 individual body lengths and weights were recorded.

The carapace length vs. depth plot suggested 2 discrete depth ranges of occurrence (90-160 m and 230-460 m); no specimen was caught in the A (10-50 m; mean BST=17.14 ± 1.39 °C) and E (501-800 m; mean BST=13.79 ± 0.09 °C) stratum. The horizontal distribution showed some locations of higher abundance, without any apparent relationship with the BST (Figure 1).

The CL vs. depth box-plot representation (Figure 2) indicated a fluctuation of median size and a widening of the CL distribution with the depth level, hence a $\log_e$ transformation of CL was performed. No significant linear relationship between $\log_e$ CL and depth level resulted in females ($R^2 = 0.017$; $P = 0.145$) or males ($R^2 = 0.001$; $P = 0.757$).

Only 3 specimens were in moulting conditions: 1 female (whole body; CL = 19.0 mm, CW = 29.4 mm, and BW = 2.9 g) at 346 m, and 2 males (chelipeds only) at 355 m (CL = 23.8 mm and 26.7 mm; CW = 38.6 mm and 39.6 mm, BW = 6.2 g and 7.7 g).

Eleven berried females were recovered at 158 m (1 specimen), 331-390 m (9 specimens) and 434 m (1 specimen), the former being the smallest berried female (CL = 20.4 mm, CW = 28.9 mm and BW = 3.5 g); the mean values and corresponding standard deviations of the berried females were CL = 24.8 ± 2.9 mm, CW = 36.8 ± 5.2 mm and BW = 7.8±3.4 mm.

In terms of the sex ratio (Table 1), males were consistently more abundant than females, considering both the overall sample (Sr = 0.42) and the size classes (Sr from 0.49 to 0.22); in the size classes smaller than 28 mm, however, the divergence from the 0.5 value was not significant. Considering the depth, Sr was also in favour of males (from 0.43 to 0.38), but with a significant departure only in the lowest depth level of the D stratum.

The carapace length (CL) ranged between 13-41 mm and 15-37 mm in males and females,

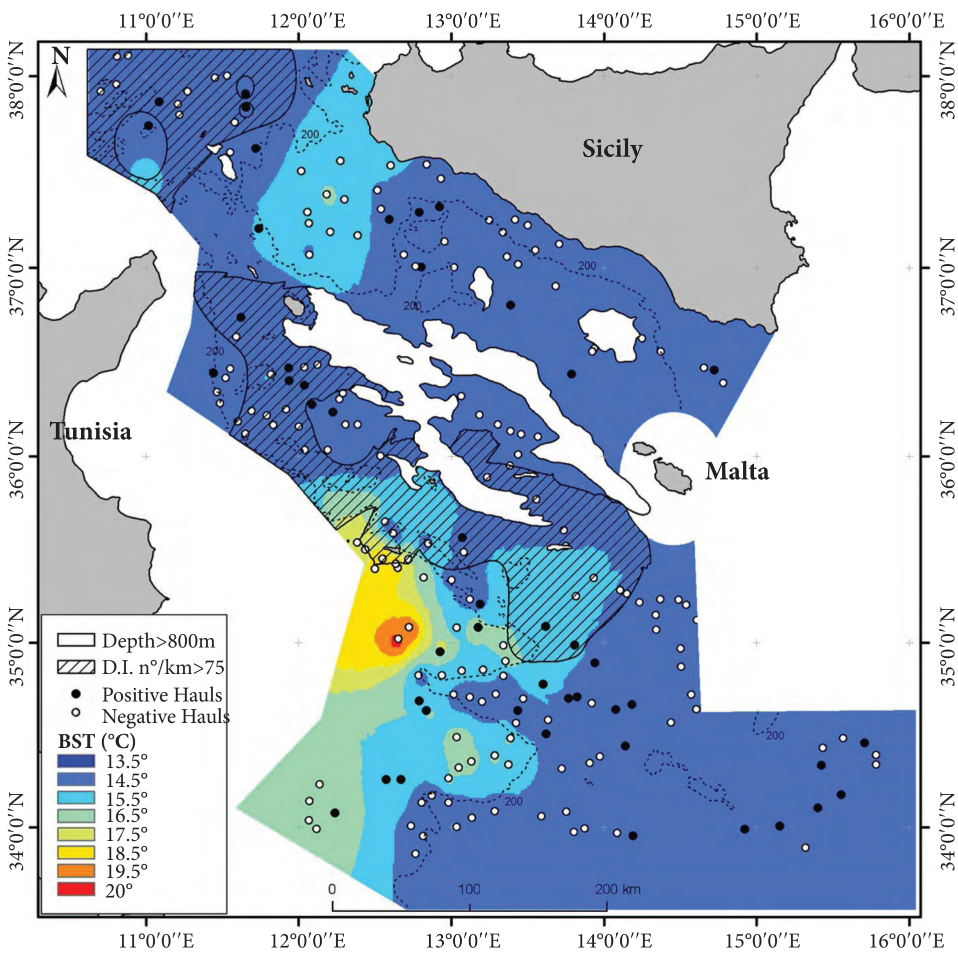

Figure 1. The area of study (Strait of Sicily) with the areas of higher abundance of *Macropipus tuberculatus* (Density Index, DI, >75 n/km^2) overimposed on the bottom seawater temperature map (BST; °C). Solid and empty dots indicate positive and negative hauls for the species, respectively. The dotted line indicates the shelf depth contour (200 m).

respectively; the former showed a bimodal LFD with a primary (around 25-29 mm) and a secondary (33-35 mm) peak, whereas the latter showed a unimodal LFD, with an irregular peak around 23-27 mm (Figure 3). Overall, male and female LFD yielded different results according to the Kolmogorov-Smirnov test (P = 0.015).

The carapace width ($\log_e$ CW) resulted linearly related to $\log_e$ CL in both sexes (Table 2), resulting in a highly significant (P < 0.01) positive allometry (b > 1) in both males (b = 1.084) and females (b = 1.067); a significant sex effect was also detected (ANCOVA; F-ratio = 6.92; P = 0.009).

Also the body weight (BW) resulted (after $\log_e$ transformation) linearly related to the carapace length (Table 2), with highly significant sex effects (ANCOVA; F-ratio = 6.732; P = 0.010); males showed a higher slope than females. However, the slight deviation from the isometric relationship (b = 3) was not significant in both males (t statistics, 1.58 vs. 1.65) and females (t statistics, 0.07 vs. 1.66).

Discussion

Present results concerning the Strait of Sicily are coherent with the distribution, biometric, and

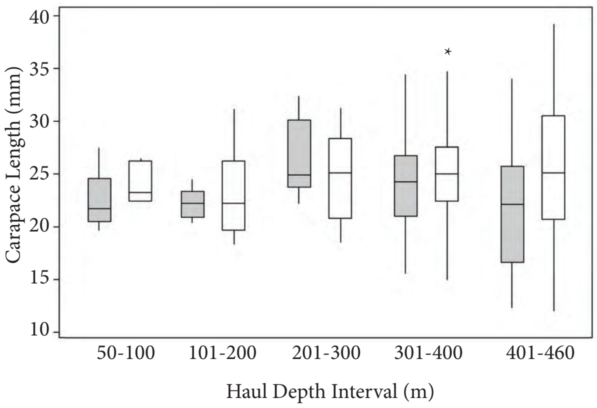

Figure 2. Box-plot representation of individual size vs. haul depth interval of females (solid box; total number = 135) and males (empty box; total number = 190) of *Macropipus tuberculatus* of the Strait of Sicily.

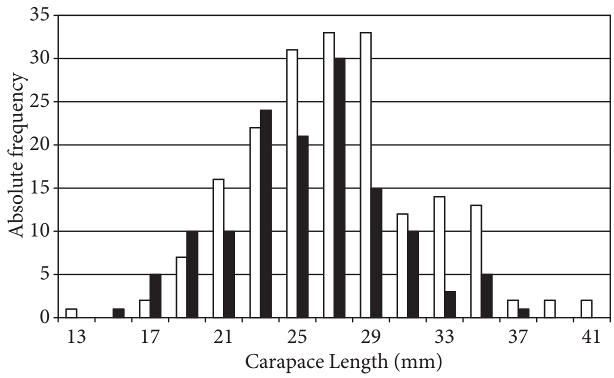

Figure 3. Length frequency distribution of females (solid histogram; total number = 135) and males (empty histogram; total number = 190) of *Macropipus tuberculatus* of the Strait of Sicily.

Table 1. Sex ratio of *Macropipus tuberculatus* of the Strait of Sicily by size and depth level. *Legenda*: n.s., not significant; *, significant ($p < 0.05$); **, highly significant ($p < 0.01$).

	Size (Carapace Length; mm) level					Depth (m) level			
	12-19	20-24	25-28	29-32	33-41	<201	201-300	301-400	401-500
N° Total	51	98	109	40	27	23	18	188	96
N° Females	25	46	45	13	6	10	6	83	36
N° Males	26	52	64	27	21	13	12	105	60
Sex ratio	0.49	0.47	0.41	0.33	0.22	0.43	0.33	0.44	0.38
χ^2 value	0	0.4	3.3	4.9	8.3	0.4	2	2.6	6
χ^2 Significance	n.s.	n.s.	n.s.	*	**	n.s.	n.s.	n.s.	*

Table 2. Allometric relationships ($\log_e$ - linear model) for males (M) and females (F) of *Macropipus tuberculatus* of the Strait of Sicily. *Legend*: Dependent, dependent variable (Carapace Width, CW, and Body Weight, BW), a, intercept, b, slope, $s.e._{a,b}$, standard error of the corresponding coefficients; Sse, standard error of the estimate; R^2, coefficient of determination; AIC, Akaike's information criterion, as index of goodness of fit. Carapace Length (CL; mm) represents the independent variable.

Dependent	Sex	a	$s.e._a$	B	$s.e._b$	See	R^2	AIC
CW (mm)	M	0.118	0.039	1.084	0.012	0.033	0.976	-751.6
	F	0.184	0.050	1.067	0.016	0.035	0.972	-515.3
BW (g)	M	-7.986	0.176	3.087	0.055	0.148	0.944	-183.75
	F	-7.735	0.176	2.995	0.056	0.125	0.956	-174.82

biological patterns already known for other Mediterranean populations of *M. tuberculatus*. The horizontal distribution is ample, but patchy (Ungaro et al., 1999), and the bimodal peaks of bathymetric distribution confirms the species preferential for the outer shelf edge, 100-150 m, and upper slope, 250-500 m (Fariña et al., 1997), likely reflecting trophic causes or burrowing or burying habits, which tend to be hampered wherever the flat bottom shape changes abruptly, such as is the case of shelf and upper-middle bottom breaks (Abelló et al., 2002) in the Strait of Sicily.

The dominance of males over females found in this study is a common feature of *M. tuberculatus*, but it is unlikely a real characteristic of the population. In fact, this pattern could be associated to a) a higher daily activity of males (Mori, 1987), or b) a reduced availability to trawling of the larger, mature, and berried females (Mori, 1987), which moreover tend to concentrate in deeper waters (Mura and Cau, 1994).

As concerns the presence of the berried females, the low percentage (8.1%) is in agreement with the November to March spawning peak reported in the literature (Holthuis, 1987; Mori, 1987; Pipitone and Tumbiolo, 1993).

The LFD found, characterised by the lack of juveniles and the presence of a secondary peak of large males, is also consistent with the literature (Mori, 1987; Abelló et al., 1990; Ungaro et al., 1999). Given the high incidence of megalopae of *M. tuberculatus* in the diets of many other crustaceans (Mori, 1987), it is more likely that the lack of small specimens reflects more a low availability to the bottom trawl than a reduced recruitment, in agreement with Mori (1987). Further, the allometric coefficients of the CL-CW relationship are very close to those estimated by Abelló et al. (1990) (1.084 vs. 1.073 for males and 1.067 vs. 1.063 for females).

Finally, it is interesting that the *M. tuberculatus* distribution does not seem related to the hydrological pattern; in fact, the species was reported in bottoms underlying all the 3 main water layers recognised in the Strait of Sicily (Grancini and Michelato, 1987): a) the Atlantic (AW; down to 50-100 m or to 150-250 m, depending on locations), with a minimum water temperature of 14-15 °C in winter; b) the Levantine Intermediate Waters (LIW, from around 200 m down to 500-700 m, with a temperature range of 13-14 °C), and c) the deep transitional (>600-700 m; 12.8 °C).

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