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Distribution of *Tylos* spp. in the Maltese Islands and population dynamics of *Tylos europaeus*

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ABSTRACT

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Two species of the oniscid genus *Tylos* occur in the Maltese Islands, *T. sardous* and *T. europaeus*, which are allopatric and restricted to just one and two sandy beaches, respectively. The dynamics of the largest locally-occurring *T. europaeus* population were investigated during the period 2001-2003. Seasonal variation in the sex ratio, length of the 5th segment of the pereion as a proxy for age, and the proportion of adults and juveniles in the population were assessed during each calendar season. The vertical distribution of male, female and juvenile individuals in the sand was determined in the field during summer 2003. Laboratory experiments were made to test sand moisture preferences. The surface activity of the isopods was studied by means of pitfall trap constellations whilst zonation on the beach was studied by sieving sand collected from quadrats placed at regular intervals along a shore-normal transect starting from mean sea-level (MSL), and counting the number of individuals in each sample. For the *Tylos europaeus* population studied, males outnumbered females in seven of eight seasonal sampling sessions, with a mean male:female ratio of 1.46, although differences between the abundances of adult males and females were only statistically significantly different during the two spring seasons. Juveniles were consistently more abundant than adults, abundances ranging between 220-450 individuals/m^3 for juveniles and between 450-3200 individuals/m^3 for adults. Males consistently exhibited larger pereion sizes than females: mean pereion length was 1.91mm (± 0.43mm) for males and 1.79mm (± 0.39mm) for females.

ADDITIONAL INDEX WORDS: *sandy beaches, zonation, sex ratio*

INTRODUCTION

The semi-terrestrial oniscid genus *Tylos* is a quasi-cosmopolitan one, typical of the upper zones of sandy shores where back-beaches are adequate (Brown & McLachlan, 1990). The ca 20 species in this genus feed mainly on algae and other wrack deposited on the shore by wave action (Hamner *et al*., 1969, Kensley 1974), with feeding taking place during the night to avoid heavy predation by diurnal predators such as birds and brachyurans (Schmalfuss & Vergara, 2000). Very few studies on the population dynamics of this genus have been carried out; existing studies concern mainly zonation, burrowing behaviour, spatial distribution and bio-ecology (Goncalves *et al*., 2005).

Tylos europaeus is known from the coasts of the Black Sea, the Mediterranean, the Azores and the Atlantic coast of Europe as far north as Bretagne (Schmalfuss & Vergara, 2000). It is a relatively long-lived isopod species with a lifespan of three to four years (Goncalves *et al*., 2005), has a specific zonation pattern on the shore, and is a scavenger (Colombini *et al*., 2005). In the Maltese Islands, the species occurs allopatrically with *Tylos sardous* and is known from just two beaches – Ramla l-Hamra and San Blas on the island of Gozo (Figure 1). Both beaches are characterised by fine sand with a median particle diameter of 0.25mm. The only existing study on *T. europaeus* populations from the Maltese Islands addresses aspects of zonation and distribution (Deidun *et al*., 2010). The aims of this study include (1) investigation of population dynamics of the species; (2) assessment of seasonal variation in sex ratio and in the length of the 5th segment of the pereion (used as a proxy for age); (3) analysis of the proportion of adults and juveniles in the population; (4) study of the vertical distribution of male, female and juvenile individuals in the sand, and (5) determination of sand moisture preferences through laboratory experiments.

METHODS

The *T. europaeus* population at Ramla l-Hamra (Figure 1) was used for this study since this is the largest such population in the Maltese Islands. Field experiments included the nocturnal deployment of pitfall trap constellations and sampling by sieving. The pitfall trap constellations used were similar to those deployed by Deidun & Schembri (2008) and were designed to study the surface activity of the isopods. A total of 14,328 *T. europaeus* individuals collected using pitfall traps were classified as adults or juveniles (defined as having a pereion length < 1 mm), sexed (for adult individuals only) and the length of the 5th segment of the

pereion was measured as a proxy for age. These measurements were collected in each calendar season during 2002-2003. Sand from quadrats placed at regular intervals along a shore-normal transect starting from mean sea-level (MSL) was wet-sieved on a 0.5mm sieve to study the distribution of the isopods on the shore. Sand from the 0-10cm, 10-20cm and 20-30cm depth strata within each quadrat was sieved separately to study vertical distribution in the sand. Choice chambers were used in laboratory experiments to test sand moisture preferences and burrowing depth for animals exposed to three sand moisture levels (1%, 5%, 20%).

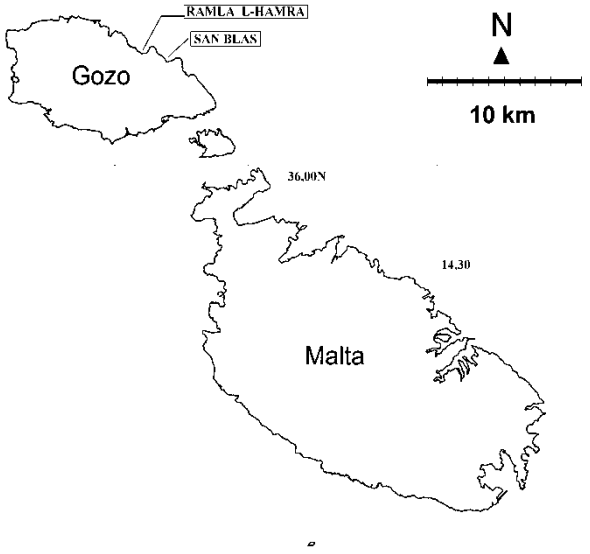

Figure 1: Location of the only two known localities for *Tylos europaeus* in the Maltese Islands.

RESULTS

For the *Tylos europaeus* population studied, males outnumbered females in seven of eight seasonal sampling sessions, the only exception being the spring 2002 season. The mean male:female ratio was 1.46±0.31. Differences in the abundances of adult males and females were only statistically significantly for the two spring seasons. Gravid females were only collected in the spring, suggesting a univoltine life cycle. Juveniles were consistently more abundant than adults, especially during the summer, with juvenile and adult abundances ranging between 220-450 individuals/m^3 and between 450-3200 individuals/m^3, respectively. The abundance of isopods collected in the pitfall traps ranged between 2 individuals/trap-constellation/hr (winter 2002) and 65 individuals/trap-constellation/hr (spring 2002). Figure 2 gives the seasonal variation in the abundance of adult male, adult female and of juvenile *T. europaeus*.

In general, juveniles and males had a more seaward nocturnal surface distribution than adults and females, with the distribution of all three classes of individual shifting towards MSL during the spring and summer months, when adults were generally distributed within a restricted zone between 3m and 7m from MSL and no juveniles were recorded upshore of 6m from MSL. In winter, a small number of juveniles occurred at a distance of up to 28m away from MSL, and generally showed a more scattered surface distribution than adults. The mean winter distances from MSL for the populations of adult males, adult females and juveniles were 6.5±1.0m, 7.75±1.0m and 10.31±5.5m respectively, whilst the corresponding summer distances were 4.5±0.5m, 5.33±0.9m and 4.86±0.7m respectively.

Juveniles dominated the 0-10cm sand depth stratum, while adult males dominated the 20-30cm depth stratum. In fact, juveniles only occurred in the 20-30cm stratum at the stations located 3m and 4m from MSL. Adult females were never found in the 20-30cm sand depth stratum. A high degree of inter-annual variation in adult abundances was observed; for example, 619 individuals and 4 individuals were collected in winter 2002 and winter 2003, respectively. A possible explanation for this result might be the anomalously cold temperatures recorded during the latter winter.

Males had larger mean pereion lengths than females: 1.91mm (± 0.43mm) for males and 1.79mm (± 0.39mm) for females. Adult male and adult female individuals exhibited a similar seasonal variation in pereion length, with a high degree of inter-annual variability. In fact, whilst in 2001/2 the highest values for pereion length for both sexes were recorded in the summer season, in 2002/2003 the highest values were for autumn. The smallest pereion lengths for juveniles were consistently recorded during the summer seasons. Table 1 gives the seasonal variation in the mean pereion length for adult males, adult females and juveniles during the sampling period.

Table 1: Seasonal variation in mean pereion length for adult male, adult female and juvenile *T. europaeus*.

Season/Year	Males		Females		Juveniles	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
Autumn 2001	148	1.78 (0.61)	109	1.58 (0.42)	511	0.38 (0.19)
Winter 2002	90	2.15 (0.33)	62	1.68 (0.39)	3	0.43 (0.09)
Spring 2002	2153	2.02 (0.54)	2643	1.85 (0.45)	161	0.87 (0.08)
Summer 2002	1209	2.23 (0.37)	801	2.17 (0.35)	1225	0.34 (0.22)
Autumn 2002	1033	1.89 (0.44)	555	1.86 (0.42)	323	0.40 (0.10)
Winter 2003	267	1.77 (0.42)	167	1.78 (0.40)	102	0.38 (0.09)
Spring 2003	1061	1.80 (0.36)	766	1.78 (0.34)	63	0,65 (0.15)
Summer 2003	538	1.62 (0.34)	316	1.62 (0.35)	22	0.10 (0.01)
TOTAL	6499		5419		2410	

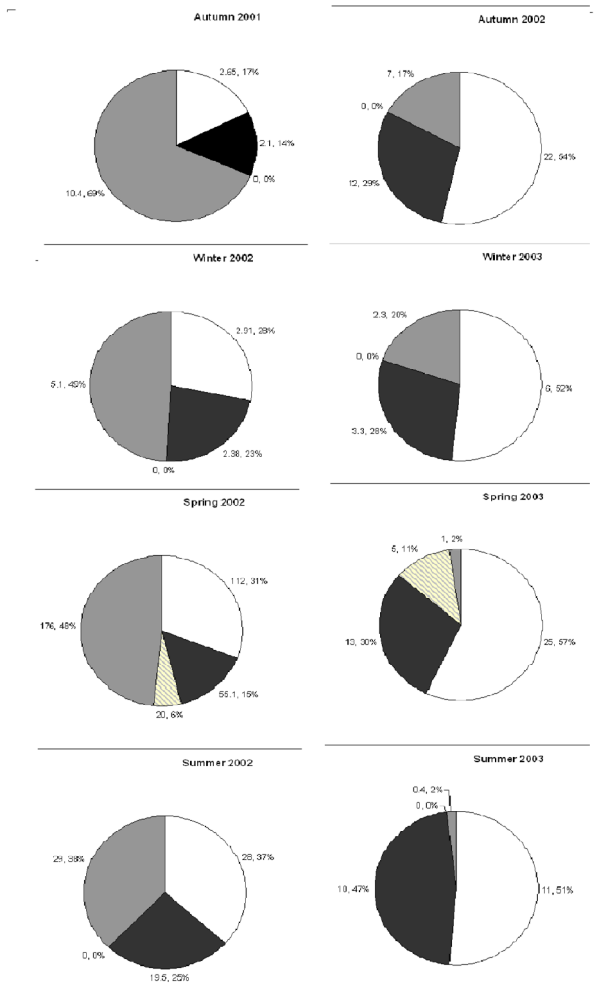

Figure 2: Proportion of adult males (white sectors), adult females (black sectors), gravid females (hatched sectors) and juvenile individuals (grey sectors) in consecutive seasonal collections spanning from Autumn 2001 (top left) to Summer 2003 (bottom right), with same-year collections grouped in the same column.

In laboratory experiments, the depth to which *T. europaeus* burrowed in the sand increased proportionately with the sand moisture content; individuals burrowed to a mean depth of 6± 2.1cm, 17±4.5cm and 21±5.1cm when placed in chambers having moisture contents of 1%, 5% and 20%, respectively.

DISCUSSION

Most species of coastal isopods typically occur at low densities (Diaz *et al*., 2005). *Tylos* seem to be an exception as they are gregarious and occur at high densities. Abundance data reported in the present study supports this, as adult *T. europaeus* population densities ranged from 450 to 3200 individuals/m^3 considering all seasons together. In addition, the animals always occurred in clusters of up to a few hundred individuals.

Pronounced seasonal variations in horizontal and vertical distribution and in abundance data were recorded in this study. Several authors (e.g. Goncalves *et al*., 2003, 2005, Marques *et al*., 2003, Williams, 1995, Colombini *et al*., 2002, Colombini *et al*., 2005) indicate that *Tylos europaeus* is capable of adjusting its distribution in response to environmental conditions or the availability of food resources. Thus, the observed variations in this study might in turn be a response of the species to these abiotic forcings, although this was not studied.

Colombini *et al*. (2005) report diurnal changes in the isopods' surface position along the shore, with the population being restricted to a narrow downshore band during the 'resting' phase (early night), and shifting to drier, less well-sorted and coarser sand upshore in the 'active' (late night) phase. This diurnal shift, along with the ability of the species to burrow to depths down to 1 metre (Brown & Trueman, 1996), might introduce noise in sampling results, which in turn might be interpreted as phenological differences. There is no consensus in the literature over the phenology of *T. europaeus*. Whilst Colombini *et al*. (2008) report that abundance remained constant between seasons and that there was no differences between age classes, others (e.g. Fallaci *et al*., 1996, Colombini *et al*., 2005) report pronounced seasonal changes in abundance. Results from the present study agree with the latter observations.

Many workers (e.g. Fallaci *et al*., 1996, Goncalves *et al*., 2005) highlight the patchy distribution of *T. europaeus*, with individuals aggregating in narrow bands on the shore. Data from the present study confirms this observation since ca 85% of the adult *T. europaeus* individuals collected during the summer 2003

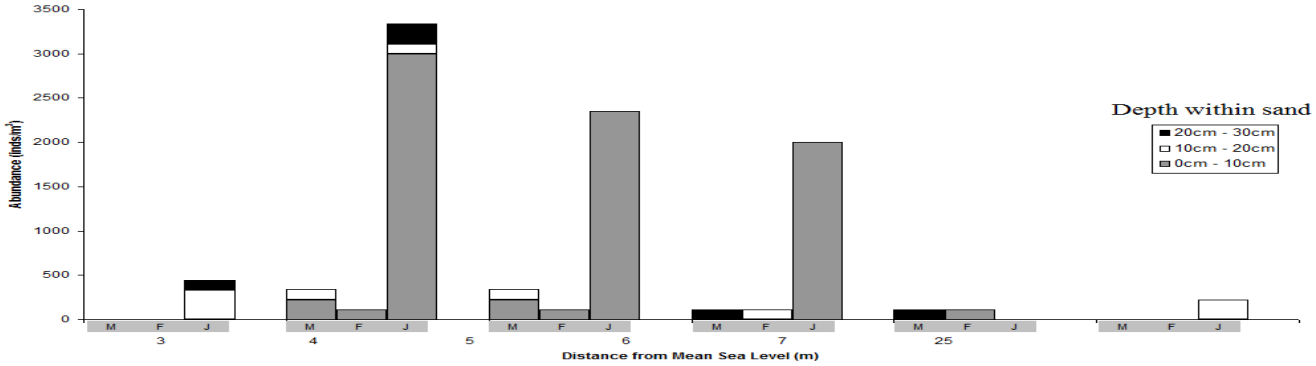

Figure 3. Variation in abundance (as individuals/m2) of male (M), female (F) and juvenile (J) Tylos europaeus with distance from mean sea-level (in m) during summer 2003.

season were found at a distance of 4-7m from MSL. Kensley (1974) and Hayes (1977) have hypothesized that this patchy distribution reflects the patchy distribution of the isopod's trophic resources. The upshore range on the shore (4.5-5.3m from MSL for the summer months) reported in this study is considerably more seaward than the values reported by Colombini *et al*. (2005) for the same season.

The *Tylos europaeus* population investigated exhibited traits, such as a male-biased sex ratio and a univoltine life cycle (gravid females were collected only during the spring seasons and the smallest juveniles were collected during the summer seasons), similar to those of *T. europaeus* populations studied on non-Maltese sandy beaches (e.g. Colombini *et al*., 2005, for a *T. europaeus* population from the Tyrrhenian coast of Italy). The shift from a male-dominated to a female-dominated population, observed in spring 2002, when there as a prevalence of females over the normally dominant male, sex has also been observed in other studies (e.g. Goncalves *et al*., 2003). In view of the timing of this, which coincides with the reproductive season, its occurrence can perhaps be attributed to differential mortality of males possibly as a result of strong competition for mates.

The observed response in terms of burrowing depth of *T. europaeus* to changes in sand moisture levels is consistent with the findings of other workers, who report sand moisture, along with pH, salinity and organic matter content (but not granulometric parameters), to be important factors in determining distribution. The present restriction of *T. europaeus* to just two beaches in the Maltese Islands may not necessarily be related to differences in granulometry (both beaches have a median particle diameter of 0.25mm). In fact, historical records of the species exist for other beaches on the Maltese Islands exhibiting different sediment granulometry (Hili, 1990); it may be that the reduction in the species' range in the Maltese Islands is related to human-mediated disturbance.

A number of studies (e.g. Goncalves *et al*., 2009) have suggested the use of *Tylos europaeus* populations as an indicator of environmental quality on sandy beaches. The stenoecious nature of the isopod (e.g. its specific sediment preferences), its wide distribution and its abundance on sandy beaches, as well as its sensitivity to climatic factors (e.g. temperature and sand moisture) as expressed through modifications in the burrowing depth, suggest that it may be useful as an indicator of natural and anthropogenic changes on sandy shorelines. For this to happen however, baseline information about the population dynamics and reproductive strategies of the species must first be compiled for those beaches where it is going to be used as an indicator.

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