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ABUNDANCE, TEMPORAL DISTRIBUTION AND ZONATION PATTERNS OF TALITRIDS ON TWO APULIAN SANDY BEACHES (SOUTHERN ITALY)

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TALITRID
AMPHIPOD
SANDY BEACH
ABUNDANCE
MEAN ZONATION

ABSTRACT. – The following paper contains a study of talitrid populations of two beach dune systems in Apulia (Lesina and Isola Varano), on the Adriatic coast of southern Italy. Two species were identified: *Talitrus saltator* and *Macarorchestia remyi*. Of the two populations, we concentrated on *T. saltator,* which is the most abundant species in the study area. However, *M. remyi* is worthy of mention, since it is the first record of an Adriatic population of the species. Bimonthly samplings were taken from August 2003 to July 2004 at Lesina and from January to December 2002 at Isola Varano. Abundances of talitrids were maximal in August at Lesina and in May at Isola Varano. Sex ratio was female biased at the two sites for *T. saltator*, whereas it did not differ significantly from equality in *M. remyi*. Mean zone level for each species was higher the shoreline in summer compared to cold months in the two localities.

INTRODUCTION

Talitrid amphipods are typical colonizers of the beach dune system. These semi-terrestrial crustaceans breathe through gills or body surface (Spicer & McMahon 1994) and the lack of carapace exposes them to a high dehydration risk; they spend the day burrowed in the sand and are active on the surface at night, moving seaward in the morning and landward after sunset, predominantly in relation to foraging. Their activity and zonation are determined by both the risk of being swept away by tides and of being desiccated by the sun (D'Elia *et al.* 2001).

The present study concerns two talitrids: *Talitrus saltator* (Montagu, 1808) and *Macarorchestia remyi* (Schellenberg, 1950). The first species, known as the sandhopper, is typical of the supralittoral of sandy shores; *M. remyi* lives in association with rotting wood carried by the sea. Italian supralittoral environments are threatened by anthropogenic impacts and natural erosion, with the consequence that these habitats are often fragmented and the associated species face the threat of local extinction. The two species studied are threatened not only by the removal of detritus and wood but also by human activities and development for tourism.

Studies on talitrid population biology, zonation and spatio-temporal distribution have been made on numerous European coasts (Colombini *et al.* 1998, Fallaci *et al.* 1999, Weslawski *et al.* 2000, Persson 2001, Anastàsio *et al.* 2003) as well as Mediterranean coasts (Scapini *et al.* 1992, Marques *et al.* 2003, Nardi *et al.* 2003, Pavesi *et al.* 2007). However, little is known about the Adriatic shores of the Italian peninsula. In the present work we study the spatio-temporal distribution, sex ratio and influence of environmental factors on talitrid populations inhabiting two different Italian supralittoral systems, located on the southern Adriatic coast of Italy. At Isola Varano, one of the sites considered in the present work, a parallel study on the coleopteran community was conducted by Chelazzi *et al.* (2005).

MATERIALS AND METHODS

Study site: Two sites in the Apulia region (southern Italy, Mediterranean climate) were studied: Lesina and Isola Varano. Both of them form part of the "Gargano National Park" (Fig. 1).

The Lesina beach and dune system (1 km wide by 20 km long) is located seaward of the Lesina lagoon, between Torre Fortore and Torre Mileto. The beach is 100 m wide and several dune belts cover the area. There is little tourist impact during the summer.

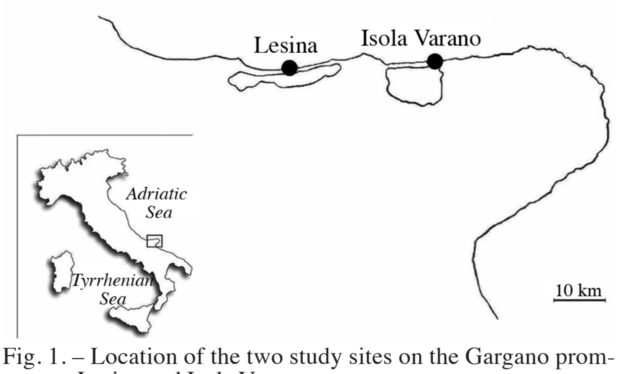

Fig. 1. – Location of the two study sites on the Gargano promontory: Lesina and Isola Varano.

Isola Varano is named after the Varano lagoon just behind it and is 10 km long. It is 700 m wide (beach dune, first and second dune belt, and an extensive retrodune), with the beach dune occupying 25 m and the first dune belt 10 m in width. This area is important for tourism during summer.

Sampling programme: Talitrids were collected from each of the two beaches every two months for a period of one year: at Lesina from August 2003 to July 2004 and at Isola Varano from January to December 2002. On each beach a continuous transect was placed perpendicular to shoreline and starting from the seaward base of the dune: pitfall trap stations were set every two metres. Tetradirectional pitfall traps were placed on the dune, since the presence of vegetation does not permit a transect in this area. Traps were labelled using the following system: trap "0"(zero) indicates the base of the dune, traps with negative numbers refer to metres toward the waterline whereas traps with positive numbers refer to the dune traps. Two replicate transects were placed 50 m apart on the two beaches. Transect length, and consequently the number of traps, varied during the year according to changes in sea level. Transects were kept active for 48 hours, with each trap left to collect for two nights.

Animals were collected the morning of the second day and fixed in 70 % alcohol. Buried arthropods were collected by sieving a volume of sand removed from a 50 x 50 cm area to a depth of 10 cm, through a 1 mm^2 mesh. The sieved sand came from a station 5 m distant from each trap station. In the laboratory, amphipods were identified to species level, sexed, and grouped in the following categories: males (identified by the presence of genital papillae), females with eggs, females with embryos (embryos up to 2 mm length, inside the marsupium), females with oostegites, and females without them. Where no secondary sexual dimorphic features were present, individuals where classified as juveniles (2 mm < length < 4 mm). Embryos outside the marsupium were also counted (length up to 1.5 mm). It was not possible to distinguish morphologically between species for the juveniles and values refer to the all species collectively. Intersex individuals, recognized by the presence of both genital papillae and oostegites, also occurred.

At Lesina and Isola Varano, penetrability and temperature of the sediment were measured at each trap station. Temperature of the sediment was measured at 3:00 p.m. at 10 cm depth with a Hg thermometer for both sampling sites. Three replicate measures were taken. Moisture and granulometry of the sand were determined from sand samples at each trap station. Penetrability was recorded as the portion, in cm, of a metallic probe that penetrated the substrate dropped from 1 m height.

Moisture was measured by drying the sediment samples for 48 h at 105 °C. Granulometric variables were determined for the Lesina samples only. These variables were: mean particle size (Mz), standard deviation (σ_I, a measure of the degree of sorting), skewness (S_{KI}, the degree of asymmetry of a frequency or cumulative curve) and kurtosis (K_G, the degree of peakedness or departure from the "normal" frequency or cumulative curve) (Folk & Ward 1957). The conductivity and pH of the sand were only measured for Lesina.

Simple linear regression was used to assess the influence of environmental factors (independent variables) on species (dependent variables) with 95 % confidence limits. These regressions were calculated for each sampling month considering the abundance of each species class and the corresponding value of each parameter for the trap station. These analyses were carried out using Statistica 6.0. Sex ratio was tested for a significant deviation from a 1:1 ratio through chi square analysis. A mean zonation value (the trap where there is the greatest probability of finding a certain class) was assessed for each month with 95 % confidence limits. Canonical correspondence analysis, using the software MVSP version 3.1, was carried out in order to obtain information on the influence of microenvironmental factors (moisture, temperature, pH, conductivity, penetrability and sorting of the sand) on each talitrid class in the different traps. Covariance analysis (Ancova) made possible to test the significance of the differences between traps location and number of talitrids, on the base of seasonal patterns, on the two study sites.

RESULTS

Microclimatic data

At Lesina the temperature of the sand reached the highest value in August (T-4: 35 °C) and the lowest in February (T+15: 8 °C). Penetrability had a maximum in June (T-8: 120 mm) and a minimum in February (T-0: 25 mm). Moisture of the sediment was maximal in October (T-28: 18 %) and least in June (T+15: 0.2 %). pH reached the maximum value in October (T-24: 9.8) and conductivity in February (T-28: 1300 µS). Mean grain size was 1.75 Φ, sorting was between 0.38 Φ, kurtosis 1.059 and skewness 0.03.

At Isola Varano the highest sand temperature was in July (T+10: 35 °C) and the lowest in January (T+2: 5 °C). The sediment showed maximal penetrability in July (T-2: 98 mm) and minimal in October (T-18: 18 mm). Sediment moisture was maximal in December (T-16: 18 %) and least in July (T+10: 0.2 %).

Fauna analysis

At Lesina and at Isola Varano, 5 989 and 21 249 talitrids respectively, were collected from pitfall traps; 506 individuals at Varano and 149 at Lesina were collected by sieving. At both study sites two talitrid species were recorded: *Talitrus saltator* and *Macarorchestia remyi*.

Monthly capture frequencies

At Lesina (Fig. 2) the maximum capture frequencies of talitrids with pitfall traps were in August (n = 1 589 ; 26.53 % of the total number) and April (n = 1 345; 22.46 %) whereas the minimum was in February (n = 277; 4 62 %). At Isola Varano the peak of maximum capture frequency with pitfall traps was in May (n = 9 346; 43.98 %) but a high capture frequency was obtained also in March (n = 6 057; 28.5 %). The lowest values occurred in October (n = 1 670; 7.9 %) and January (n = 165; 0.78 %). The capture frequency distribution was analyzed at population classes: at Lesina (Fig. 3a) *T. saltator* adult males were most abundant in August (n = 547; 32.58 %) and least abundant in February (n = 40; 2.38 %). Females capture frequency was maximal in April (n = 768; 28.3 %) and least in February (n = 115; 4.24 %). Females bearing eggs were present in August, October, April and June and had a maximum capture frequency in April (n = 28; 73.68 %; not shown). Females with embryos were present in April and August only, with n = 18 and n = 1 respectively (not shown). Maximum capture frequency for juveniles was in August (n = 478; 35.54 %) and minimum in February (n = 24; 1.78 %). Embryos outside female marsupium were high in October (n = 57; 40.43 %) and low in June (n = 36; 25.53 %) but were not found in August, December and February (Fig. 4a). At Isola Varano both male and female *T. saltator* showed peaks of highest capture frequency in March (males n = 2 761; 40.72 %; females n = 2 300; 38.17 %) and the minimum values in January (males n = 66; 1 %; females n = 97; 1.60 %) (Fig. 3b). Females bearing eggs were abundant in May (n = 1 372) and no specimens were collected between December and January. Juveniles were abundant in March (n = 990) and October (n = 547) and were absent in January; whereas embryos were abundant in May (n = 6 327) and were not found in January, March and December (Fig. 4b).

At Lesina (Fig. 5a) *M. remyi* was collected only in December, February and April. The highest capture frequency was in February with males (n = 45; 90 % of total males) females (n = 53; 88.33 % of total females) and some intersex (n = 9), for a total of n = 107 (89.91 %). At Isola Varano (Fig. 5b) male and female *M. remyi* showed the highest capture frequency in December (males n = 66; 88 %; females n = 63; 100 % females). Males were scarcely present in January, March and May, whereas females were observed only in December.

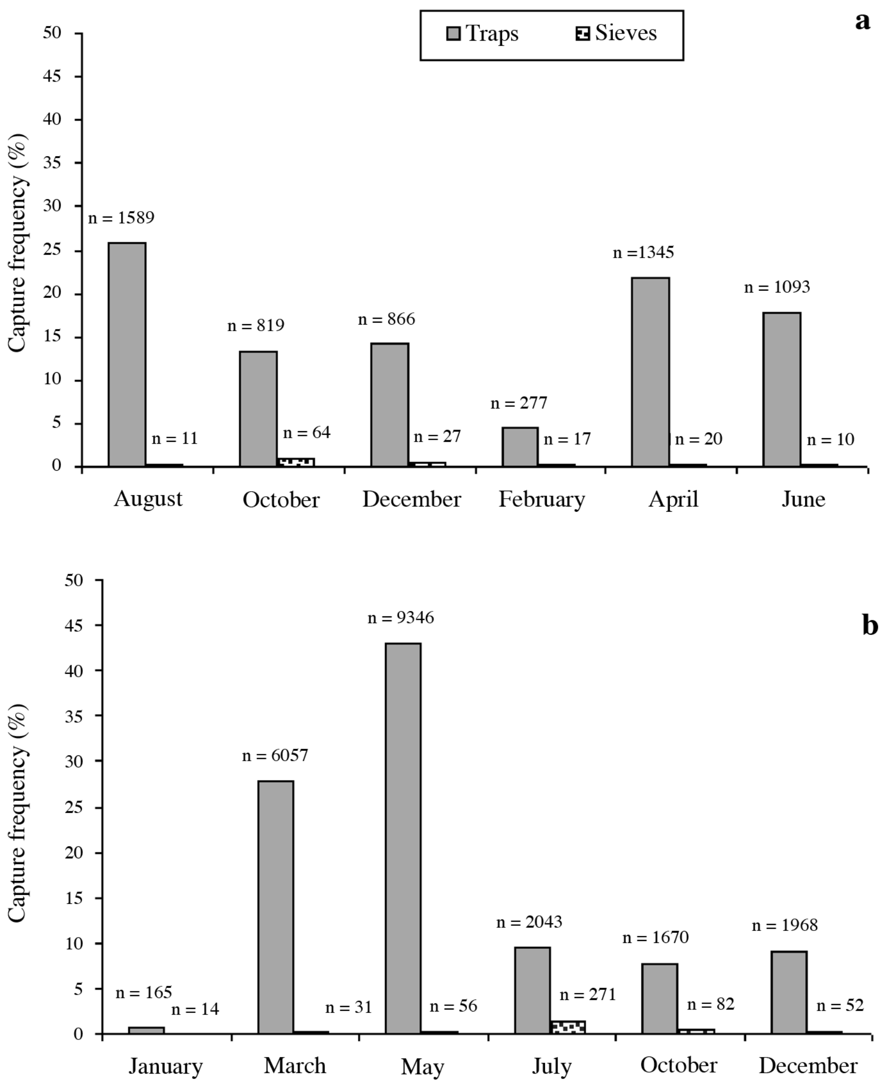

Fig. 2. – Temporal variation in capture frequency of talitrid populations at the two study sites: a) Lesina; b) Isola Varano.

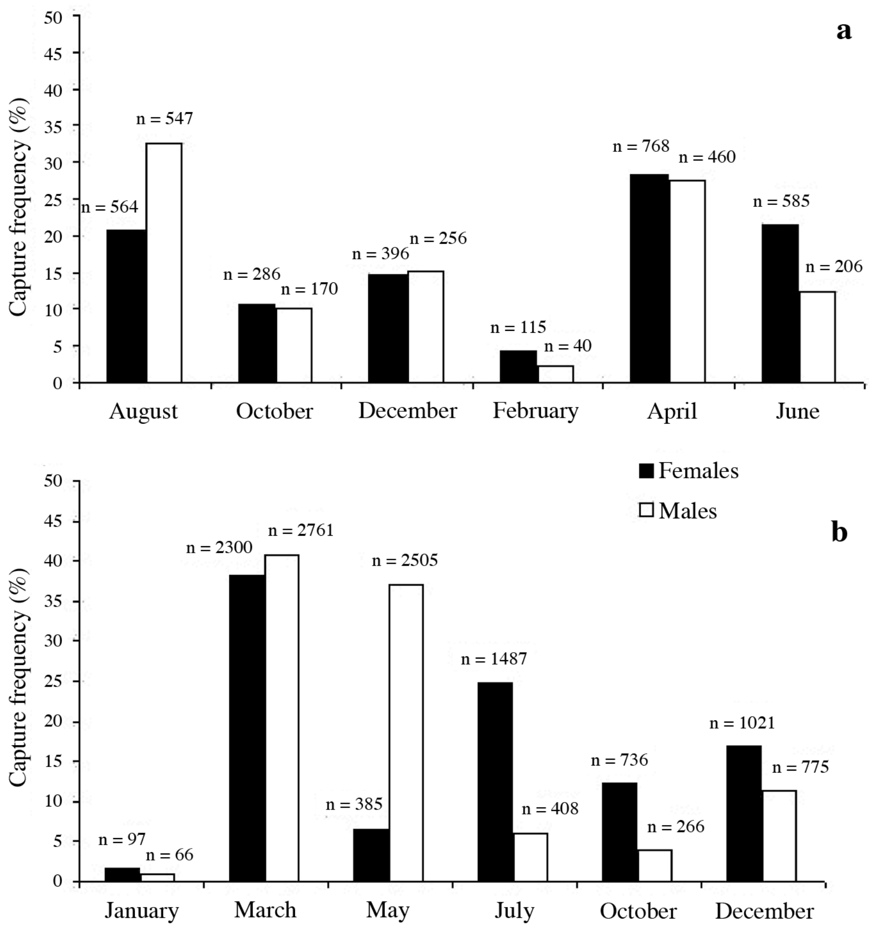

Fig. 3. – *Talitrus saltator*: Variation in number of males and females during the year at the two locations. a) Lesina; b) Isola Varano.

Spatial distribution

The mean zonation values of talitrids were analyzed for the two study sites. At Lesina (Fig. 6) talitrids had a mean zonation far from the base of the dune, with burrowed talitrids located a little nearer to the shoreline compared to the 'surface active' ones. The same mean zonation for both burrowed and 'surface active' was found in October, where juveniles in both cases were found nearer to the sea level. In December the mean zonation of active talitrids was narrow whereas burrowed talitrids were widely displaced along the beach. In February all classes were located inland and in some cases (burrowed males and females, 'surface active' males) their mean zonation level was on the dune. *M. remyi* adults had the mean zonation of 'surface active' juveniles, which were located nearer the shoreline with respect to burrowed juveniles. In April talitrids were widely displaced along the beach, with juveniles, females and females with embryos near the shoreline and females bearing eggs much more inland. In June talitrids were gathered near the shoreline, with burrowed classes a little nearer the sea with respect to the 'surface active' talitrids.

At Isola Varano (Fig. 7) talitrids are inland in January, where burrowed males and females were located on the dune. In March both burrowed and 'surface active' talitrids move in the direction of the sea, with burrowed talitrids, together with *M. remyi* males, inland with respect to surface talitrids. In May all classes gathered in a zone between 10 to 16 metres from the base of the dune, with the exception of *M. remyi* males, nearer the dune and burrowed *T. saltator* juveniles, much nearer the shoreline. In July there were two narrow zones: burrowed talitrids gathered near the sea and 'surface active' classes a few metres backwards. In October there were again two zones, but burrowed talitrids were at the base of the dune. 'Surface active' egg bearing females had a mean zonation near the burrowed talitrids and burrowed juveniles forwards, where 'surface active' talitrids were located. In December all classes were gathered near the dune, with a difference in mean zonation of a few metres between burrowed talitrids (on the dune) and, forwards, surface *T. saltator* juveniles and *M. remyi* adults.

Statistical analysis

Linear regression with $p < 0.05$ was used to assess the influence of micro environmental variables on *T. saltator* populations in each month. At Lesina (Table I), males, females with oostegites and juveniles are negatively relat-

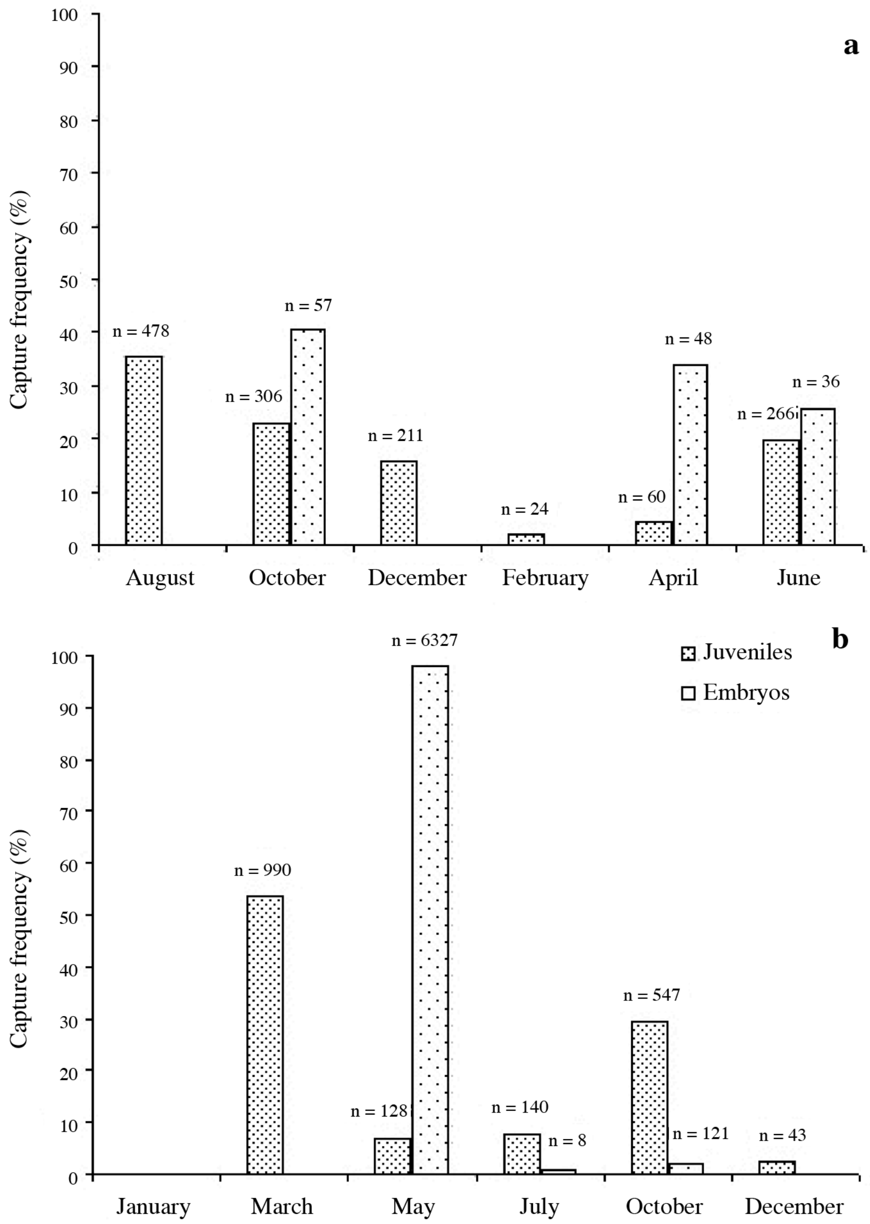

Fig. 4. – "Capture frequency" of juveniles and embryos during the sampling period: a) Lesina; b) Isola Varano.

ed to temperature during the summer, whereas the opposite condition is found in the winter, when it is positively related to males and females with oostegites. In October, penetrability values negatively influence burrowed males and positively females with oostegites. Sand moisture values positively influence talitrid classes in each time a significant relation was found: it is positively related both in June (males, females with oostegites) and August (females and females with oostegites). Even in December a positive relation was found between moisture values and juveniles. Talitrids are influenced by pH in autumn/winter, with a positive effect on males, females with oostegites and juveniles. Males, females and juveniles are positively related to conductivity during the summer (June, August) whereas it negatively influences juveniles in February.

The sex ratio for *T. saltator* was female biased in October $\chi^2 = 29.51$, $p < 0.001$; December $\chi^2 = 30.06$, $p < 0.001$; February $\chi^2 = 36.29$, $p < 0.001$; April $\chi^2 = 77.25$, $p < 0.001$; and June $\chi^2 = 181.59$, $p < 0.001$; whereas no significant difference was found for *M. remyi* (December $\chi^2 = 0.33$, n.s.; February $\chi^2 = 0.65$, n.s.; April $\chi^2 = 0.11$, n.s.).

At Isola Varano (Table II) temperature is related to 'surface active' females in January (negatively) and March (positively); to burrowed females in October (positively) and to 'surface active' males in January (positively). 'Surface active' females and juveniles (in May) and males (in January) are influenced positively by penetrability, whereas burrowed males and females are positively influenced by this variable in July. Sand moisture greatly

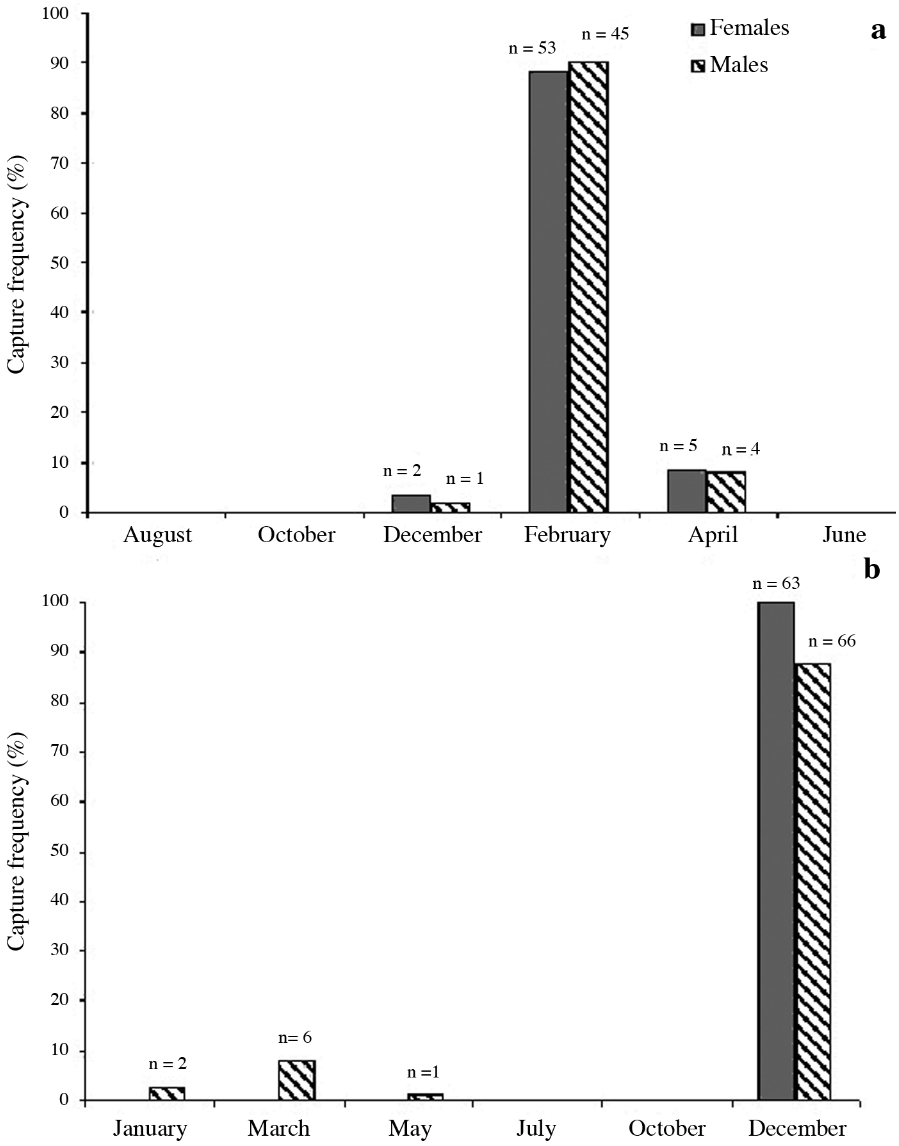

Fig. 5. – "Capture frequency" for males and females of *Macarorchestia remyi* at a) Lesina and b) Isola Varano.

influence talitrid classes (males, females with and without oostegites and females with eggs) in July. Mean grain size of the sediment positively influenced different classes in May ('surface active' males and females with oostegites and burrowed males and females) and all 'surface active' talitrid classes in July.

The sex ratio for *T. saltator* was female biased in each month (January $\chi^2 = 5.85$, $p < 0.05$; May $\chi^2 = 69.41$, $p < 0.001$; July $\chi^2 = 686.78$, $p < 0.001$; October $\chi^2 = 254.8$, $p < 0.001$; December $\chi^2 = 33.69$, $p < 0.001$) except in March ($\chi^2 = 0.353$, n.s.). No significant difference was found for *M. remyi* ($\chi^2 = 0.07$, n.s.).

Ancova analysis, used to identify significant differences in the abundance of talitrids among trap location in different sampling period, was non significant. The result permits to compare the data on the two beaches independently of the spatial or temporal variability.

Canonical correspondence analysis (CCA, Ter Braak 1986) made it possible to assess the relationships between each class of *T. saltator*, each trap on the overall samplings and the environmental factors considered. For Lesina (Fig. 8) the cumulative variance explained was 50.33 % and the 'species environment' correlation was 0.87. Moisture, conductivity and pH greatly influenced the system whereas sorting of the sediment, penetrability and temperature had minor influence. Environmental factors were highly related to axis 1 except moisture, which was associated with each axis. Sorting and penetrability varied substantially among the traps but for the shoreline stations moisture had greatest influence. Traps were located mainly on quadrants I and II (upper and lower right quadrants) of the CCA plot. Females with embryos were separated from the other populations classes in quadrant I, whereas the other classes were near to each other. Penetrability and mean size of the sediment (sigmaI) greatly influenced females, eggs-bearing females and the traps on

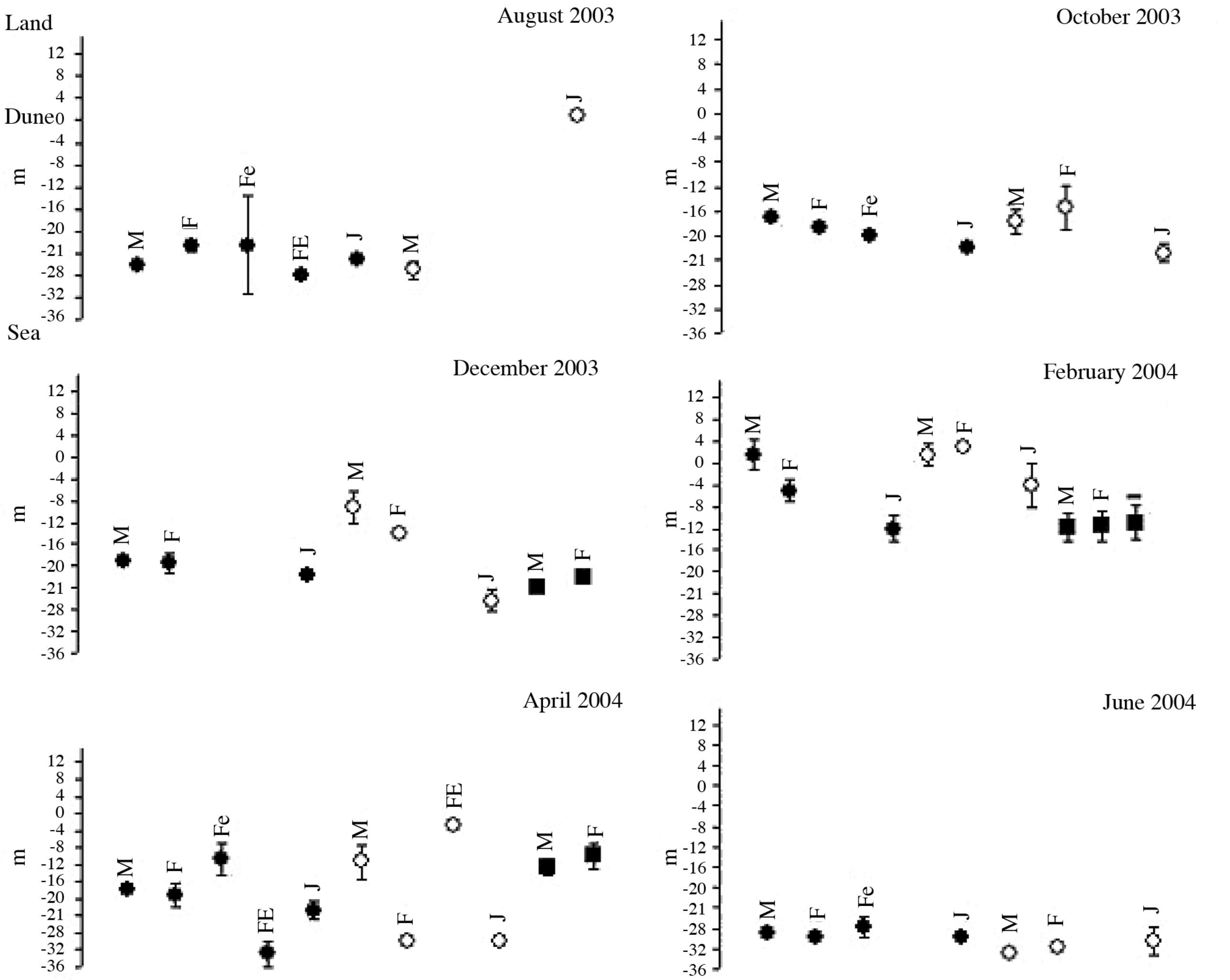

Fig. 6. – Mean zonation levels and standard deviation of *Talitrus saltator* (full circles: surface active; empty circle: burrowed) and *Macarochestia remyi* (full square: surface active) at each sampling occasion at Lesina. M = Males; F = Females; Fe = egg bearing Females; FE = Females with embryos; J = Juveniles; I = Intersex. Error bars = Standard deviation.

and near the dune. Conductivity, moisture and pH had a major influence on the traps located near the shoreline; juveniles were greatly influenced by pH.

For Isola Varano (Fig. 9) cumulative variance explained was 66.07 % and the 'species environment' correlation was 0.92. Moisture and penetrability highly varied in the system and are related to axis I; temperature is related to axis II. Traps are mainly distributed between quadrants I and II except for some traps that were near the sea, which are located on quadrant IV of the graph. Females with embryos and juveniles are on quadrant IV (upper left quadrant) and females bearing eggs on quadrant II (lower right quadrant). Females (without either eggs or embryos) and males are near the intersection of the two axes. Moisture influenced females and juveniles and mostly the traps located nearer the shoreline; penetrability had an influence on males and affected greatly the traps on the dune. Females with embryos and eggs-bearing females seem not to be influenced by a specific variable.

DISCUSSION

The capture frequency obtained from sieving sand samples compared to traps showed a much higher abundance of surface active talitrids. The temporal abundance of talitrids was similar for Lesina and Isola Varano, with the maximum peak in spring/summer in the former and in spring in the latter. It should not be forgotten that data were only collected over one year, so that variation in patterns of abundance among different years is unknown. In talitrid populations from the Tyrrhenian coast of Italy, the maximum abundance was recorded in summer at Burano (Fallaci *et al.* 2003) and Collelungo (Marques *et al.* 2003), whereas it was registered in autumn at the beach toward the Mignone rivermouth (Pavesi *et al.* 2007). Gonçalves *et al.* (2003) explained how an increase of the population density in spring is the consequence of recruitment, while the decrease in autumn results from the death of older individuals after the breeding season.

Although sand temperatures are extremely high during

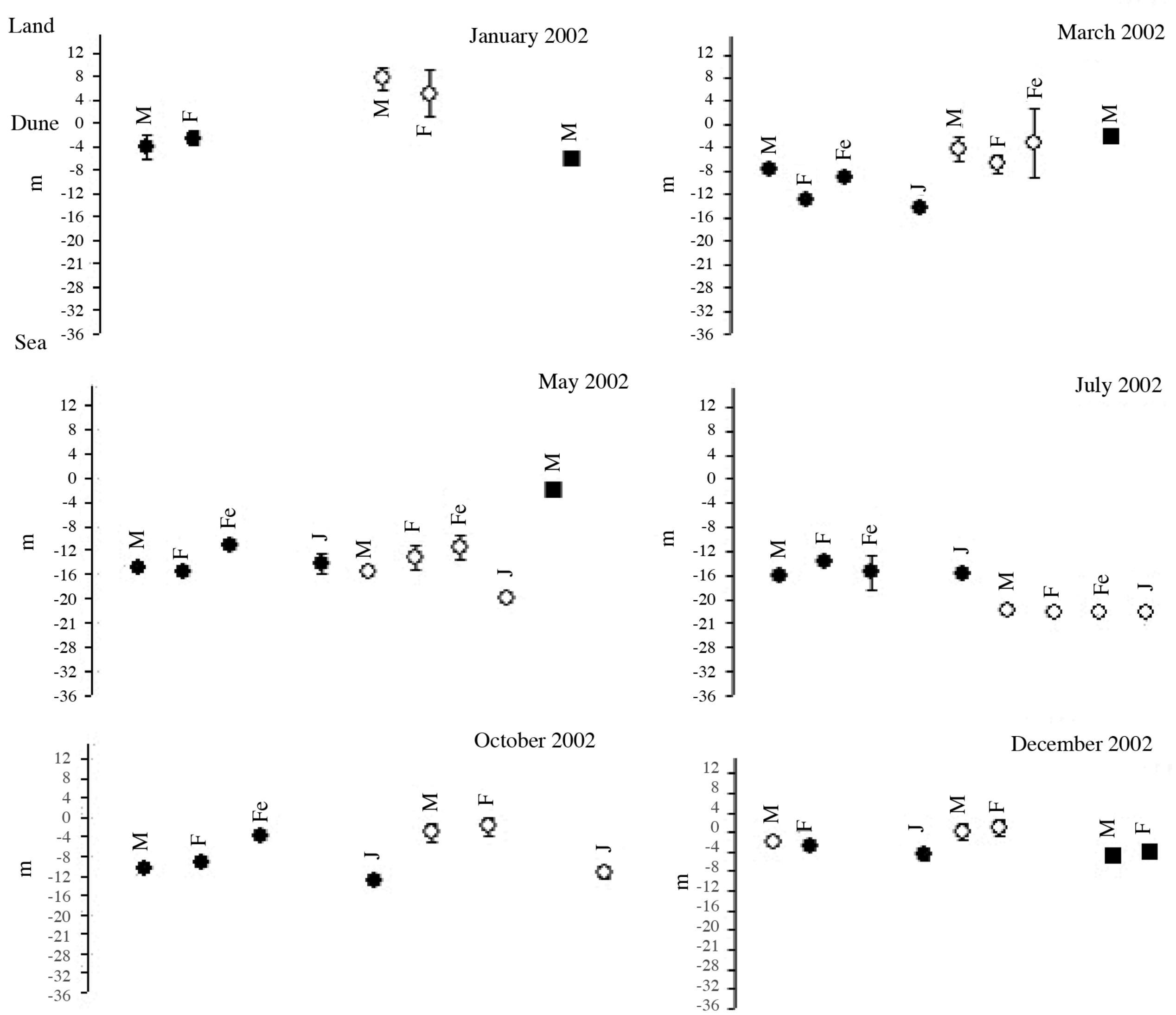

Fig. 7. – Mean zonation levels and standard deviation of *Talitrus saltator* (full circles: surface active; empty circle: burrowed) and *Macarochestia remyi* (full square: surface active) at each sampling occasion at Isola Varano. M = Males; F = Females; Fe = egg-bearing Females; FE = Females with embryos; J = Juveniles. Error bars = Standard deviation.

summer at the study sites, moisture values seem favorable for the maintenance of the population. The overall low temperature values in the winter might cause the lowest abundance of talitrids at the three sites. This has also been demonstrated in a Tyrrhenian population (Scapini *et al.* 1992) where *T. saltator* appeared to be inactive when temperatures dropped below 10 °C (winter).

At Lesina juveniles were abundant in summer: this might be a recruitment that starts in June and increases until summer, when it reaches the maximum peak. Juveniles showed the same two peaks also at Isola Varano: it seems to confirm that recruitment begins in March and a second generation starts in October**.** This is in accordance with what was found in other Italian (Tyrrhenian coasts: Fallaci *et al.* 2003, Pavesi *et al.* 2007) and European coasts (Portugal: Gonçalves *et al.* 2003; Poland: Weslawski *et al.* 2000; UK: Williams 1995), although from these data we could infer that there is a longer recruitment period on Mediterranean coasts as compared to Atlantic and Baltic ones. Climatic conditions, especially temperature, might play an important role in these differences. Of the two species *T. saltator* was predominant in the study sites. Males and females showed similar trends in abundance during the year. Sex ratio was female biased at the two sites. Along the Tyrrhenian coasts of Italy, the *T. saltator* population were male-biased at Burano (Fallaci *et al.* 2003) and Collelungo (Marques *et al.* 2003), and female-biased at Mignone (Pavesi *et al.* 2007). In Portugal it was male biased at Lavos (Marques *et al.* 2003) and female biased at Quiaios (Gonçalves *et al.* 2003). The authors explain these differences in terms of a displacement of the two sexes along the shore or in relation to reproduction activity (Marques *et al.* 2003) and death of males after copulation (Gonçalves *et al.* 2003). Differences in the characteristics of the beaches might also play a role in the sex ratio differences observed, since

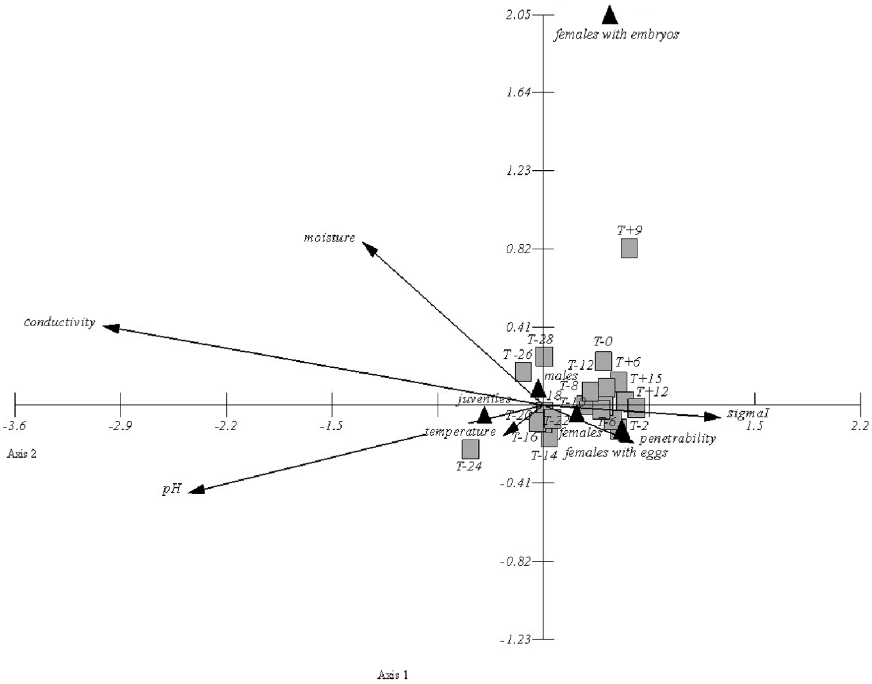

Fig. 8. – "CCA plot relating distribution and abundance of *Talitrus saltator* at Lesina to environmental variables". Species classes are presented as black triangles, traps as grey squares and environmental factors as arrows. The length of the arrows indicates the contribution of the variable to the axis.

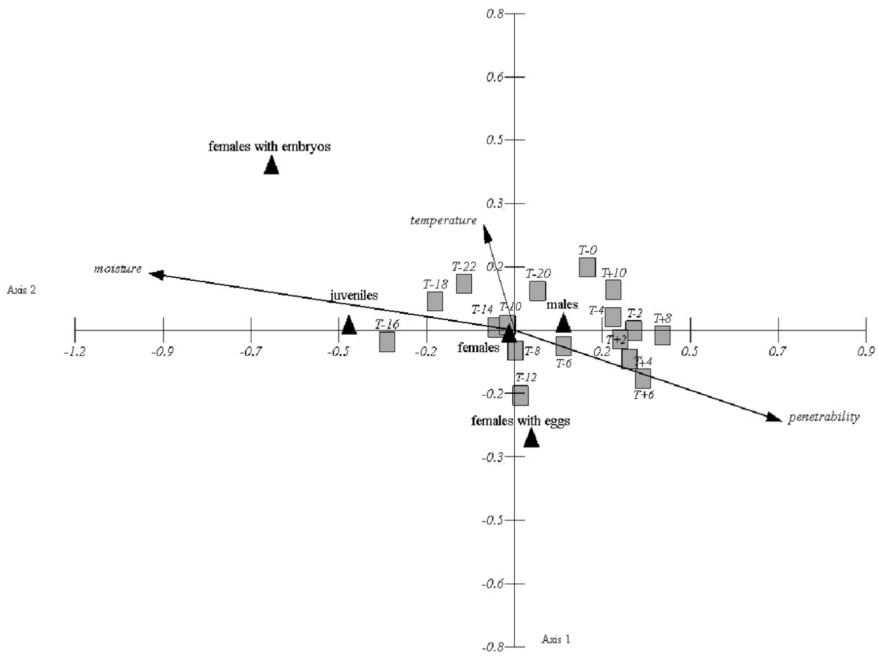

Fig. 9. – "CCA plot relating distribution and abundance of *Talitrus saltator* at Isola Varano to environmental factors". Symbols represent species classes (black triangles), traps (grey squares) and environmental factors (arrows). The length of the arrows indicates the contribution of the variable to the axis.

microclimatic factors, availability of food and selective predation might influence the biology of the populations. However, although sex ratio seems to be female biased in most talitrid populations studied, the reason is still unclear.

M. remyi was recorded at both sites, but little is known about this species. It is closely associated with wood on the beach deposited by the sea and it appears to be extremely susceptible to dehydration risk. Survival of this species is highly threatened by the removal of detritus and beached wood by human activities for touristic reasons. In fact, at both localities it was found during the winter,

Table I. – Lesina: linear regression between *T. saltator* classes and environmental factors in each sampling occasion. * = statistical significance at 0.05 %; ** = 0.01 %; *** = 0.001 %.

			Temperature	Penetrability	Moisture	pH	Conductibility	Mz
August	Traps	males	β = -0,65 R^2 = 0,36*				β = 0,88 R^2 = 0,76***	
		females						
		females with oostegites	β = 0,66 R^2 = 0,39**				β = 0,63 R^2 = 0,31*	
		females with setose oostegites					β = 0,83 R^2 = 0,66***	
		juveniles	β = -0,82 R^2 = 0,65***				β = 0,75 R^2 = 0,52**	
October	Traps	males				β = 0,54 R^2 = 0,23*		β = 0,72 R^2 = 0,48**
		females						
		females with oostegites		β = 0,65 R^2 = 0,37*				β = 0,63 R^2 = 0,34*
		females with setose oostegites				β = 0,65 R^2 = 0,35*		
		juveniles				β = 0,69 R^2 = 0,43**		
	Sieves	Males		β =-0,86 R^2 = 0,66*				
		Females						
		females with oostegites						
		females with setose oostegites						
		Juveniles						
December	Traps	Males	β = 0,65 R^2 = 0,39**			β = 0,59 R^2 = 0,31*	β = 0,59 R^2 = 0,31*	β = -0,71 R^2= 0,47**
		Females						
		females with oostegites	β = 0,69 R^2 = 0,45**		β = 0,56 R^2 = 0,27*	β = 0,74 R^2=0,52***	β = 0,68 R^2 = 0,43**	β = -0,81 R^2=0,64***
		females with setose oostegites						
		Juveniles			β = 0,68 R^2 = 0,40*		β = 0,70 R^2 = 0,45*	β = -0,71 R^2 = 0,44*
	Sieves	Males		β = 0,86 R^2 = 0,69*				
		Females						
		females with oostegites						
		females with setose oostegites						
		Juveniles						
February	Traps	Males						
		Females						
		females with oostegites						
		females with setose oostegites						
		Juveniles		β= -0,70 R^2 = 0,43*			β= -0,80 R^2 = 0,59***	β= 0,88 R^2=0,76***
	Sieves	males						
		females						
		females with oostegites						
		females with setose oostegites						
		juveniles						

when human activity is lower than the rest of the year. Smaller in total length than the other talitrid species, *M. remyi* is subject to extreme high temperatures and low moisture values. Thus its presence in the cold months indicates that favourable microclimatic conditions for its survival occur during this period of the year. From June to

Table I. – Followed.

			Temperature	Penetrability	Moisture	pH	Conductibility	Mz
April	Traps	males				β= 0,52 R^2 = 0,23*		
		females			β= 0,58 R^2= 0,29*			
		females with oostegites					β = 0,60 R^2 = 0,32**	
		females with setose oostegites					β = 0,60 R^2 = 0,32**	
		juveniles				β = 0,72 R^2 = 0,48**		
	Sieves	males						
		females						
		females with oostegites						
		females with setose oostegites						
		juveniles						
June	Traps	males			β= 0,91 R^2=0,79**		β= 0,88 R^2 = 0,74**	
		females						
		females with oostegites			β = 0,91 R^2=0,79**		β= 0,74 R^2 = 0,47*	
		females with setose oostegites			β= 0,82 R^2 = 0,61*			
		juveniles						
	Sieves	males						
		females						
		females with oostegites						
		females with setose oostegites						
		juveniles						

October it seems to disappear from the beaches, probably resisting the unfavorable period of the year by hiding in refuges.

There were differences in mean zonation level between the two species, among the different classes within a population and between burrowed and 'surface active' talitrids. These differences may take account not only of microclimatic conditions, but also of food availability, its displacement along the beach and the possible competition between classes and species for it. In summer there is a narrow distribution of the different classes and mean zonation clearly near the shoreline; burrowed talitrids are even nearer the sea, presumably because of the high daytime temperature. In Autumn the environmental conditions permit them to be displaced along the beach; probably food availability is major and widely dislocated in the area and could become the factor controlling their distribution. It should not be forgotten that these explanations are speculative and should require experimental verification. In the winter burrowed talitrids are markedly near the dune at Lesina and on the dune belt at Isola Varano: they can move far from the sea without suffering dehydration risk during the day and food availability is probably abundant in this zone of the beach. *M. remyi* is smaller with respect to *T. saltator* and its adults have the same mean zonation shown by *T. saltator* juveniles. They probably move seaward avoiding competition for food with bigger individuals. During the spring talitrids are widely displaced along the beach. Burrowed and 'surface active' adults have the same mean zonation, showing the same preferences and availability of food and microclimatic.

At Isola Varano a study on abundance and zonation of a coleopteran community was made by Chelazzi *et al.* (2005). The main difference in mean zonation between coleopterans and talitrids was that the crustaceans were, in each month, more restricted seaward in comparison to coleopterans, presumably because of the greater risk of desiccation. The authors explained the zonation patterns in terms of changes in microclimatic conditions of the eulittoral with season. Fallaci *et al.* (2003) found a significant shift toward the land for juveniles of *T. saltator* and towards the sea for the older adults on the Tyrrhenian coast of Italy. These authors also demonstrated that trends were more dependent on the age of talitrids and on the climatic conditions than on sex of the individuals. Defeo & McLachlan (2005) hypothesized that larger and dominant intraspecific competitors occupy the centre of the across and alongshore range of a species, whereas small individuals may be displaced towards suboptimal conditions at one or both extremes of the distribution range. Nevertheless, most daily excursions of talitrids between the sea and dune belt are due to trophic needs. In their movements across

Table II. – Isola Varano: linear regression between *T. saltator* classes and environmental factors in each sampling occasion. * = statistical significance at 0.05 %; ** = 0.01 %; *** = 0.001 %.

Month	Method	Class	Temperature	Penetrability	Moisture	Mz
January	Traps	males		β = 0,71 R^2 = 0,44*		
		Females	β= -0,68 R^2 = 0,42**			
		Females with oostegites				
		females with setose oostegites				
		juveniles				
	Sieves	Males	β = 0,63 R^2 = 0,36**			
		Females				
		females with oostegites				
		females with setose oostegites				
		juveniles				
March	Traps	males				
		females	β = 0,49 R^2 = 0,19*			β = 0,58 R^2= 0,30*
		females with oostegites				
		females with setose oostegites				
		juveniles				β= 0,72 R^2= 0,33**
	Sieves	males				
		females				
		females with oostegites				
		females with setose oostegites				
		juveniles				
May	Traps	males				β = 0,53 R^2 = 0,23*
		females		β = 0,62 R^2 = 0,35**		
		females with oostegites		β = 0,51 R^2 = 0,21*		β = 0,61 R^2 =0,33**
		females with setose oostegites				
		juveniles		β = 0,48 R^2 = 0,18*		
	Sieves	males				β = 0,72 R^2 = 0,48**
		females				B = 0,67 R^2 = 0,40**
		females with oostegites				
		females with setose oostegites				
		juveniles				
July	Traps	males			β = 0,80 R^2=0,62***	β = 0,86 R^2=0,72***
		females			β = 0,76 R^2=0,56***	β = 0,70 R^2 = 0,45**
		females with oostegites			β = 0,54 R^2 = 0,26**	β=0,74 R^2= 0,52***
		females with setose oostegites		β= 0,54 R^2 = 0,25*	β=0,66 R^2 = 0,39**	β = 0,73 R^2 = 0,49**
		juveniles			β= 0,87 R^2=0,74***	β=0,77 R^2=0,65***
	Sieves	males		β = 0,49 R^2 = 0,20*		
		females		β = 0,50 R^2 = 0,21*		
		females with oostegites				
		females with setose oostegites				
		juveniles				

the beach they move seaward looking for food at low tide or protection against drying up (Papi *et al*. 2007). During daytime, they burrow in the sand avoiding desiccation, predation and the possibility of being swept away by

Table II. – Followed.

			Temperature	Penetrability	Moisture	Mz
October	Traps	males				
		females				
		females with oostegites				
		females with setose oostegites				
		juveniles				
	Sieves	males				
		females	$\beta = 0{,}65$ $R^2 = 0{,}38$**			
		females with oostegites	$\beta = 0{,}63$ $R^2 = 0{,}36$**			
		females with setose oostegites				
		juveniles				

waves (Cardoso 2002). The same author also suggested that the general activity and behavior of juveniles and adults vary with the morphodynamics of the beach, which enables talitrids to adapt to different physical conditions, as already suggested by Fallaci *et al.* (1999) for sandy beach intertidal species. Scapini *et al.* (2005) reported that behavioral adaptation of these organisms is correlated not only to beach dynamics but also to frequency of human visitation, and that behavioral plasticity is the major adaptation of animals inhabiting beaches.

Linear regression performed on different classes showed that temperatures influenced males, females and juveniles of *T. saltator* at Lesina, but only females and burrowed males at Isola Varano. The positive relation during winter and the negative influence during summer suggest the dependence of the species on this environmental factor: high values of temperature limit *T. saltator* activity while, when temperature is low, it can move freely along the beach avoiding the high risk of dehydration. This factor may control recruitment, growth and the increase in density, as reported by Marques *et al.* (2003). For penetrability and moisture values, the positive relation recorded in spring/summer at Isola Varano and Lesina is related to the fundamental survival of the animals: high moisture content permits surface activity in opposition to the risk of dehydration and a favorable penetrability of the sediment helps in the possibility of burrowing of the species. Cardoso (2002) suggested that juveniles may not be affected by sediment temperature because they are more active during the day and close to the shoreline. Scapini *et al.* (1992) verified that sand temperature is the most important environmental factor influencing spontaneous activity and migration of *T. saltator*. These authors also indicated that differences between adults and juveniles are due to differences in their size.

Finally, through CCA the relationships between environmental factors, *T. saltator* classes and its abundance in the traps were assessed for Lesina and Isola Varano, and a comparison between the two sites was made. In both locations females with embryos appear separated from the other classes, suggesting that they are not influenced by the variation of environmental factors. Females bearing eggs, influenced by penetrability at Lesina, appear less influenced by this factor at Isola Varano. Sorting and penetrability highly influence the catch size and composition of dune traps.

In conclusion, in this study we highlighted the differences and similarities between populations from two sites close to each other. The two sites were sampled in different years, so that differences may reflect temporal variation rather than spatial variation. The homogeneous temporal distribution at Lesina, together with the abundance of embryos and juveniles, suggest a stability in the population. Form the great abundance of talitrids at Isola Varano, tourism activities appear not to affect the talitrids much. The presence of the species *M. remyi* on both beaches indicates the limited anthropogenic presence and the natural state of the sites. At Lesina the presence of the beetles *Scarabeus sacer* Linnaeus, 1758 and *Calicnemis latrellei* Castelnau, 1832 was also assessed in our samplings. They are strictly associated to sandy shores and seriously threatened by tourism and anthropogenic activity. Their presence gives a suggestion of the good health of the beach. At the study sites two generations per year were produced and the period of reproduction extends from spring to early autumn.

As already suggested by various studies (Scapini *et al.* 1992, Fallaci *et al.* 1999, Scapini *et al.* 2005) behavioral plasticity is a determining factor that makes talitrids well adapted to the changing and precarious environment of the beach dune system. Talitrids clearly exhibit a dynamic equilibrium with this changing environment (Gonçalves *et al.* 2003), although when conditions are extremely adverse and provoke deep environmental changes (high erosion or strong anthropogenic impact), talitrids greatly decrease in number. This decline in the populations can also lead to local extinction. Direct actions aiming to safeguard and preserve the systems that are still in good health are consequently of high priority.

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