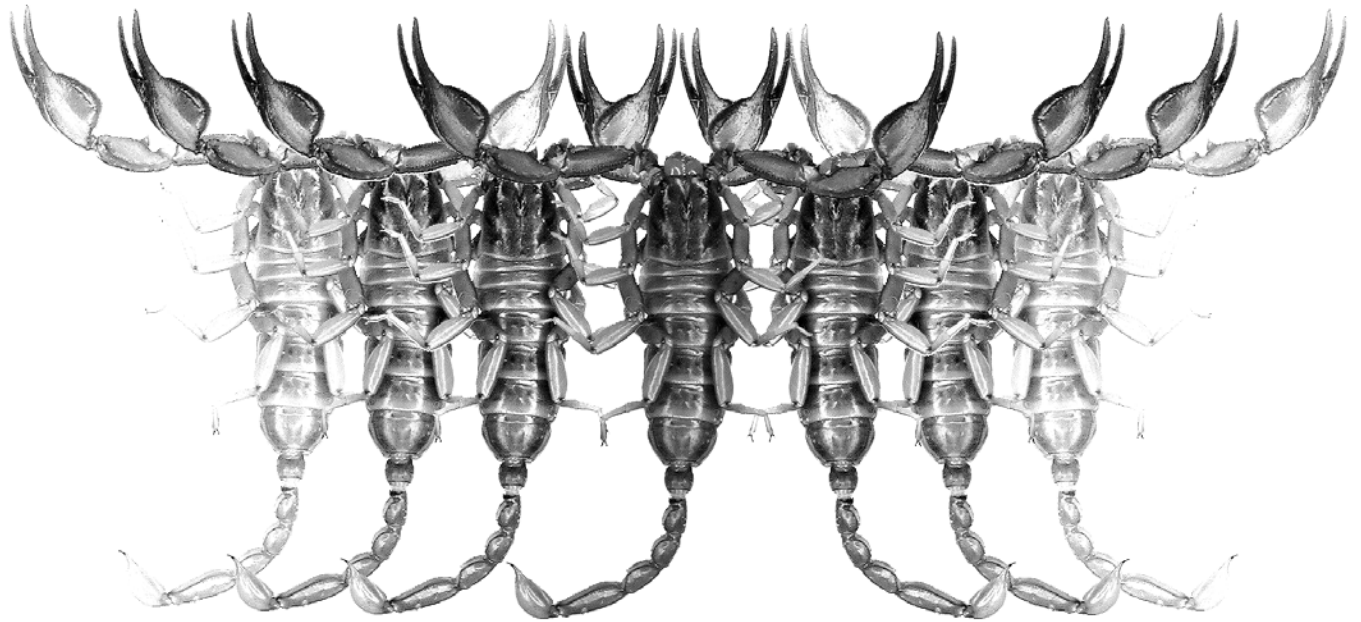


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**The Effect of Insularity on the Seasonal Population
Structure of *Mesobuthus gibbosus* (Scorpiones: Buthidae)**

Dimitris Kaltsas, Iasmi Stathi and Moysis Mylonas

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The effect of insularity on the seasonal population structure of *Mesobuthus gibbosus* (Scorpiones: Buthidae)

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Summary

We compared the population structure of *Mesobuthus gibbosus* from autumn to mid-summer at two similar phrygic ecosystems, one in continental Greece (Thessalia, near Volos city) and one in insular Greece (eastern Crete). Data were collected monthly using the capture-recapture method. At both sites, density was low during the cold period and increased towards summer. During the samplings, only a small percentage of each population was present. Population density and co-occurrence of scorpions with scorpions or other animals was higher in Crete than in Volos, probably due to the higher inter- and intraspecific competition in Volos. The population structure of the studied species depends on the interspecific competition, the seasonal fluctuations of which influence the intraspecific relations of scorpions, which is reflected in the higher degree of sociality of the insular population.

Introduction

Scorpion ecology has proved to be an important scientific field for the understanding of the function of arid and desert ecosystems. Nevertheless, the studies on the population structure of scorpion species are few and most of them refer to species from southern North America, especially vaejovids of California and Baja California, such as *Smeringurus mesaensis* (Polis, 1980a; Polis & McCormick, 1986), *Paruroctonus utahensis* (Bradley, 1986), *Paruroctonus boreus* (Tourlotte, 1974), *Paruroctonus baergi* (Fox, 1975), *Serradigitus gertschi* (Toren, 1973; Due & Polis, 1985), and *Serradigitus littoralis* (Due & Polis, 1985). Apart from three studies, which contain data on population structure of scorpion species (Zinner & Amitai, 1969; Shulov & Levy, 1978; Warburg et al., 1980), there is lack of such studies on species of the Mediterranean region.

Mesobuthus gibbosus is the only Buthidae species on the Balkan Peninsula. It is distributed throughout the southern part of the Balkan Peninsula (Albania, Bulgaria, FYROM, Greece, Montenegro), as well as in Turkey (Fet & Lowe, 2000). It is brownish-yellow with slim pedipalps. Adults may reach 8.5 cm in total length (Kinzelbach, 1975). It is nocturnal (Kinzelbach, 1975), aggressive and probably the most venomous of European scorpions (LD₅₀: 0.4 mg/ for mice and 2.4 mg for rats) (Lebez et al., 1980).

Insularity, in terms of the biology of island biota in relation to population dynamics, has attracted the interest of biologists since Darwin (Blondel & Aronson,

1999). Syndromes of traits have been identified in relation to the geographical context of islands (Whittaker, 1998). Collective differences in population structure in islands and mainland have been termed as “the island syndrome” (Adler & Levins, 1994). The aim of our study was to find out if insularity influences the population structure of *M. gibbosus*. In order to do this, we compared the structure of a continental and an insular population of *M. gibbosus*, a species widely distributed in continental and insular Greece.

Materials and Methods

The study was conducted in two similar arid phrygic ecosystems, one in insular south Greece (Toplou, eastern Crete) and the other in continental central Greece (Alykes, near Volos city) (Fig. 1, Table 1). At both sites there are no other scorpion species.

Samplings were conducted monthly from October 2001 to June 2002 at Crete and from October 2003 to June 2004 at Volos, by searching for scorpions within the study sites under stones. The capture-recapture method was used. Mature individuals were marked with enamel paint on a specific segment of the mesosoma or/and the metasoma (Fig. 2). Immature scorpions were not marked because of their small size and their high molting rate. After applying Equal Catchability Test (Leslie et al., 1953), we used the Jolly-Seber (Jolly, 1965) method to estimate population parameters using Ecological Methodology (Version 6.1). We chose the Jolly-Seber method because both populations were open

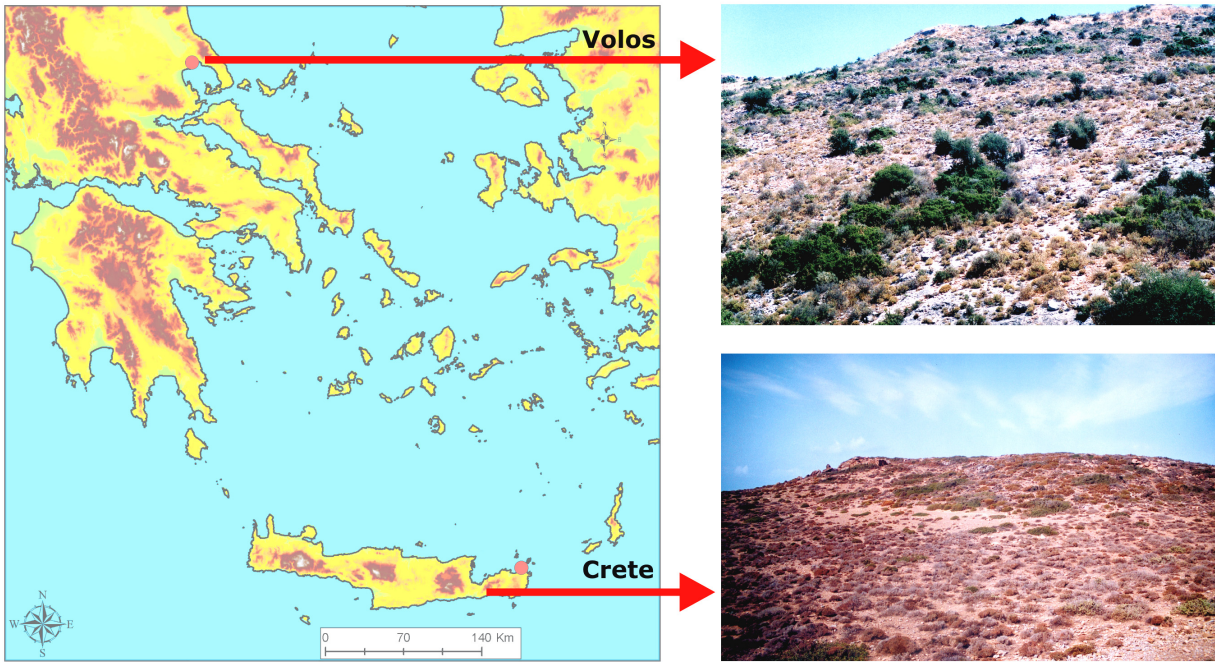


Figure 1: Map showing the location of the two study sites in Greece.

Study Site Characteristics	Toplou (Crete)	Alykes (Volos)
Coordinates	35° 14' N; 26° 14' E	39° 20' N; 22° 6' E
Area	27000m ²	25500m ²
Elevation (approximately)	200m	130m
Substrate	Limestone	Limestone
Dominant Plant Species	<i>Phlomis lanata</i> , <i>Thymus capitatus</i>	<i>P. fruticosa</i> , <i>T. capitatus</i>
Annual Precipitation	350mm (55.3% during winter)	500mm (36.4% during winter)

Table 1: The main characteristics of the two study sites.

and thus constantly changing because of births, deaths, immigration, and emigration (Krebs, 1989).

Results

Monthly captures and sex ratio

In Crete, 234 mature and 56 immature individuals were captured, whereas in Volos the respective numbers were 203 and 66 (Fig. 3). In total, 170 mature scorpions were marked in Crete and 149 in Volos, whereas 75 recaptures were made in Crete and 111 in Volos. The average number of captures per sampling was 32.22 ± 4.82 in Crete and 29.89 ± 10.75 in Volos. There was a gradient of the sex ratio per sampling in favor of males towards warmer months (Table 2), whereas few (Crete) or no

males (Volos) were observed from November to February.

Co-occurrence of scorpions under stones was observed in Crete only during winter (38.63% of the total captures during winter). Most often, two and sometimes even more individuals were co-occurrent. There was one observation of four scorpions under the same stone (in December) and two observations of five co-occurrent individuals (January and February). In Volos, only four times, two scorpions (and never more) were found under the same stone (14.81% of the total captures during winter). Co-occurrence of scorpions with other animals was also more frequent in Crete (19.83% of the total captures) than in Volos (4.53% of the total captures). Generally, the biodiversity was much higher in Volos than in Crete (Table 3).



Figure 2: A scorpion marked in the first somite of the mesosoma (November 2001 in Crete).

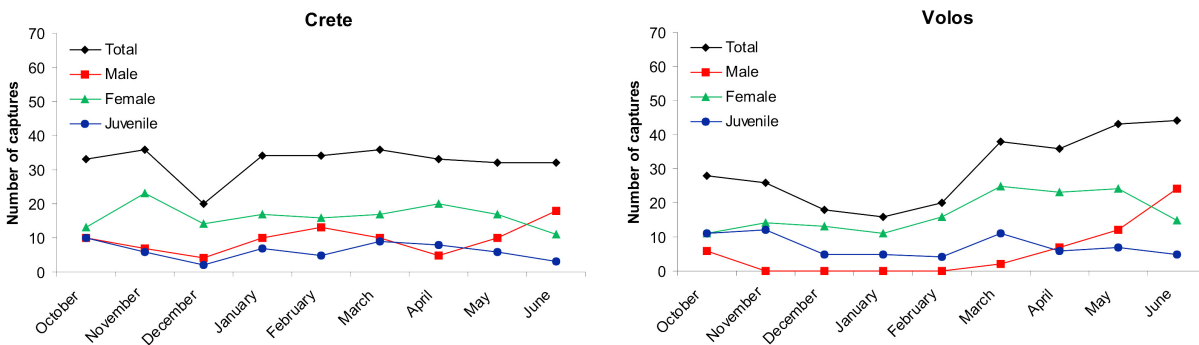


Figure 3: The number of monthly captures in Crete and Volos.

Estimation of population parameters

Equal Catchability Test resulted in an underestimation of 2.09% in Crete and 0.315% in Volos, which showed that catchability at both sites was equal between samplings, so we applied the Jolly-Seber method in order to estimate population parameters (Figs. 4, 5, 6).

Based on Polis (1980a) of both populations (Fig. 7, which is the percentage of the population which appears on the surface.

Discussion

Generally, it is known for many scorpion species, that mature individuals are more active during the warm period of the year and immatures are more active during the cool period (Shorthouse, 1971; Anderson, 1975; Fox, 1975; Koch, 1977; Polis, 1980a, 1984). The numbers of captures on *M. gibbosus* (Fig. 3) show that juveniles were generally more active than males during the cold period only in Volos (sex ratio: 0 ♂: 2.08 ♀: 1 juv.) and their activity decreased slightly towards summer at both

Sampling	Crete	Volos
October	1.00 ♂: 1.30 ♀: 1.00 juv.	1.00 ♂: 1.30 ♀: 1.00 juv.
November	1.17 ♂: 3.83 ♀: 1.00 juv.	0.00 ♂: 1.17 ♀: 1.00 juv.
December	2.00 ♂: 7.00 ♀: 1.00 juv.	0.00 ♂: 2.60 ♀: 1.00 juv.
January	1.43 ♂: 2.43 ♀: 1.00 juv.	0.00 ♂: 2.20 ♀: 1.00 juv.
February	2.60 ♂: 3.20 ♀: 1.00 juv.	0.00 ♂: 4.00 ♀: 1.00 juv.
March	1.11 ♂: 1.89 ♀: 1.00 juv.	1.00 ♂: 11.5 ♀: 5.50 juv.
April	1.00 ♂: 2.50 ♀: 1.60 juv.	1.00 ♂: 2.86 ♀: 1.29 juv.
May	1.67 ♂: 2.83 ♀: 1.00 juv.	1.71 ♂: 3.43 ♀: 1.00 juv.
June	6.00 ♂: 3.67 ♀: 1.00 juv.	4.80 ♂: 3.00 ♀: 1.00 juv.
Total	1.68 ♂: 3.00 ♀: 1.00 juv.	1.00 ♂: 2.92 ♀: 1.35 juv.

Table 2: Sex-ratio per monthly sampling at both sites.

sites. Females were the most abundant from autumn to the end of spring, when the activity of males increased, as the reproductive period of the species began at both sites (the sex ratio in June was 6 ♂: 3.67 ♀: 1 juv. in Crete and 4.8 ♂: 3 ♀: 1 juv. in Volos) (Table 2). Our results on the variation of the activity of males and females agree with the results on *Paruroctonus boreus* (Tourtlotte, 1974) and *Smeringurus mesaensis* (Polis, 1980a).

Taxon	Crete	Volos
Coleoptera	7	16
Chilopoda	9	14
Araneae	3	10
Gastropoda	2	9
Orthoptera	8	8
Reptilia	1	3
Amphibia	1	1
Mammalia	3	1
Total	34	62

Table 3: The number of species belonging to various taxa in the two study sites.

Population density at the two study sites (Fig. 4) had the same pattern of variation throughout the year: low during winter, intermediate in autumn and the beginning of spring and increasing towards summer. This pattern is common in many scorpion species (e.g. Zinner & Amitai, 1969; Hibner, 1971; Bacon, 1972; Tourtlotte, 1974; Fox, 1975; Polis & Farley, 1979; Polis, 1980a). The population density of *M. gibbosus*, as estimated, was

similar to that of other scorpion species in chaparral habitats of Mediterranean type ecosystems, such as *Compsobuthus weneri* (Zinner & Amitai, 1969), *Serradigitus gertschi* (Toren, 1973) and five sympatric species in northern Israel (Warburg et al., 1980). The densities of these species are much lower than the densities of desert species (Polis, 1990). Polis (2001) reported that the average density of desert scorpion species is 0.321 ± 0.35 individuals/m², which is more than 31 times greater than the maximum density of *M. gibbosus* in Crete, although the reproductive period of the species was not included in our study.

The density of the population in Crete was higher compared to the population in Volos. Biodiversity of all animal taxa examined, except mammals, was higher in Volos, indicating higher interspecific competition in comparison to Crete, which was proved by the fact that co-existence of scorpions with any other animal(s) under stones in Crete was 4.06 times higher than in Volos. The above are an indication of possible territoriality of *M. gibbosus* in Volos. Scorpion and nonscorpion predators may influence the activity of scorpions (Polis et al., 1981) if competing for e.g. the inhabitation of the same type of shelter, such as scolopendromorph Chilopoda (*Scolopendra cretica* in Crete; *S. cingulata* in Volos). This reasonably led to an increase of intraspecific competition (co-occurrence of scorpions under stones in Volos: 3.83 times lower than in Crete), because co-occurrence and tolerance among individual scorpions bypasses the impediment of competition (Mahsberg et al., 1999; Mahsberg, 2001). Increased territory overlap is generally more common in insular populations compared to mainland populations (Blondel & Aronson, 1999) and is a phenotypic reaction norm in response to higher island densities (Adler & Levins, 1994).

The proportion of marked scorpions per sampling (a, Fig. 5) in Crete was higher than in Volos, except for

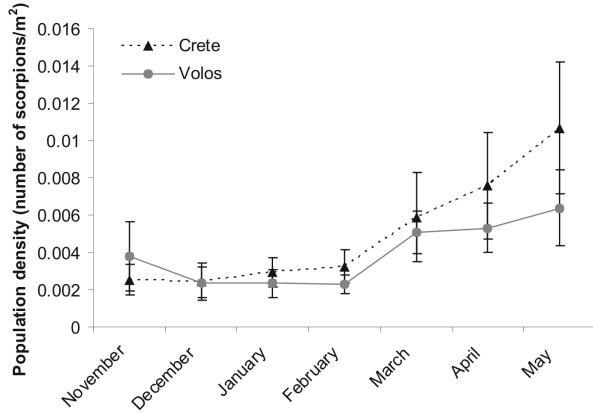


Figure 4: The population density at the two sites.

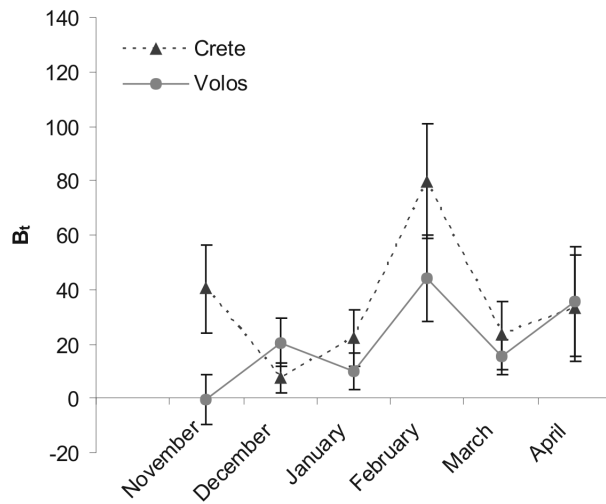


Figure 5: The proportion of marked scorpions per sampling.

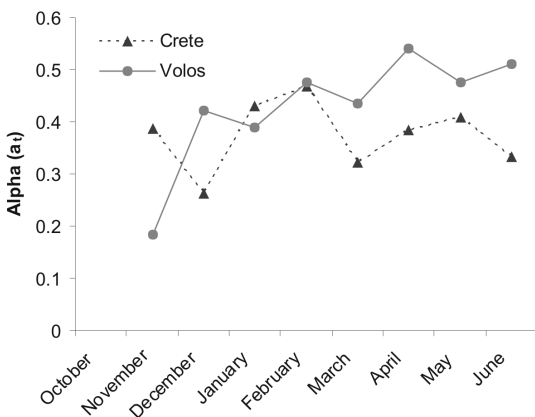


Figure 6: The number of new animals joining each population from one sampling to the next.

the samplings in December and spring (many unmarked individuals captured). This was due to the generally higher number of immigrations into the study site of Crete (B_t , Fig. 6). From the beginning of the warm period of the year towards summer (March–June), competition was possibly decreased, because of decreased temporal overlap in activity under stones with other invertebrate species (Fox, 1975; Maury, 1978; Polis, 1980a, b, 1990; Polis & McCormick, 1986, 1987). In Volos, competition was possibly too high for that to happen, and as the samplings proceeded, the frequency of recaptures increased. The latter leads us to the conclusion that population density was higher in Crete during winter, because more males were active (not even one in Volos) (Fig. 3). In spring, the two parameters were higher and their increase was more abrupt in Crete due to more new adult incomers.

The percentage of the population which appeared on the surface (R.S.D.) was higher in Crete until spring and from then on it was higher in Volos (Fig. 7). The R.S.D. in Volos during winter was caused only by females, because no males were active. In spring, as stated above, there were many more immigrations and abrupt increase in population density in Crete than in Volos. Nevertheless, the number of captures of mature individuals was not much different in the two sites (Fig. 3), which caused the gradual decrease of R.S.D. in Crete. In Volos, R.S.D. varied little in very low values (14.81–28.37%) and in Crete it was higher, but generally low ($R.S.D._{max}=43.8\%$ in November). Low levels of surface activity are characteristic of all scorpion populations that have been analyzed (Bacon, 1972; Toren, 1973; Tourtlotte, 1974; Polis, 1980a; Bradley, 1982, 1983).

Even though the mechanisms of population increases on islands are not fully known (Blondel & Aronson, 1999), species depauperization, increased population density (“density inflation”) and increased niche breadth are proved to be common characteristics of insular populations (Blondel et al., 1988; Blondel & Aronson, 1999). The comparison of the two populations indicates that insularity influences the population structure of *M. gibbosus* in Crete, because of the different level of competition. The lower level of density-depressing factors, such as competition and possibility of predation, is a principal factor differentiating island from mainland populations (Adler & Levins, 1994). The insular population in Crete was denser and showed a much higher degree of sociality and tolerance in co-occurrence with other animals compared to the continental population. This is probably another case of “density compensation”, as described by McArthur et al. (1972). Population density depends on competition and varies accordingly. In two very similar ecosystems in altitude, vegetation, geological formation and habitat, apart from the climatic conditions which may vary, the differences

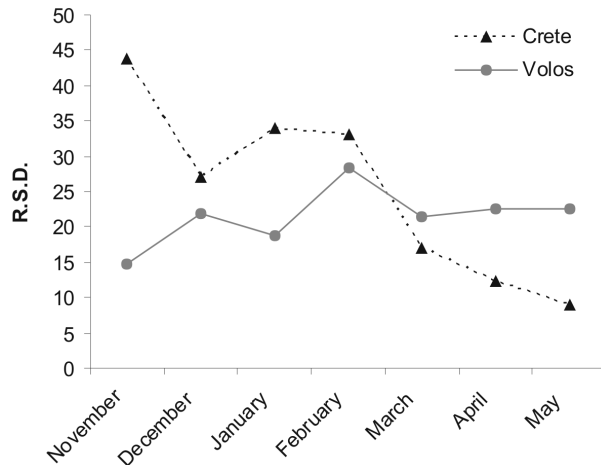


Figure 7: The Relative Surface Density per sampling in the two study sites.

in the seasonal population structure were caused by the biodiversity of the sites, which probably caused different implications in the intraspecific relations of individuals, sexes and age-classes. An explanation to this is (at least a small) niche enlargement of the *M. gibbosus* population in Crete and therefore the availability of extra resources, as a result of fewer competitors. According to Adler & Levins (1994), population density is predicted to increase with island isolation and to decrease with island area, as islands more closely resemble a mainland. In our case, Crete is a large island (8265km²); however, the studied population of *M. gibbosus* presents typical characteristics of insular populations. Based on our conclusions, we expect insularity (in terms of the island syndrome) to occur more intensely in sufficiently isolated, smaller islands, but not so small that they can not support persistent populations (Whittaker, 1998), because lower population density makes species more prone to stochastic extinction on small islands (Ricklefs & Lovette, 1999).

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