Article

Scaling distribution in scorpions

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Abstract
Scorpions being solitary animals are interesting in their distribution patterns. Nevertheless, the subject of scorpion distribution has received relatively less attention than other ecological aspects of that group. It is a matter that changes continuously and moreover it is hard to define. Three different scales in distribution are introduced here: (1) Mini-distribution which describes the presence of scorpions under a single shelter or in a burrow, within a single habitat, (2) micro-distribution describing the distribution within a single habitat, and (3) macro-distribution within different habitats. Most research in scorpion distribution concentrated on the first aspect the mini-distribution. The subject is reviewed in scorpions and discussed.

Keywords mini-distribution; micro-distribution; macro-distribution; Scorpiones.

1 Introduction

Distribution of scorpions in the field is a subject that has never actually been dealt with except perhaps briefly in Polis (1990). What is actually meant by distribution? Does one mean geographical distribution? Or does one mean a local distribution. It appears to me that it is a matter of scaling. Thus the terms mini-distribution, micro-distribution and macro-distribution are introduced here to illustrate three different scales of distributions.

Mini-distribution illustrates the presence of scorpions under a single shelter or in a burrow, within a single area in a single habitat within a single zoogeographic region. Whereas, micro-distribution describes the distribution of scorpions generally in a single area within a single habitat which is located within a single zoogeographic region. Finally, macro-distribution describes the distribution in different areas within a single zoogeographic region (Warburg, Goldenberg and Ben-Horin, 1980; Smith, 1995; Warburg, 1997).

The present review will discuss and review these subjects. It will not discuss the matters of distribution of scorpions within different habitats within a single zoogeographic region, nor will it discuss the distribution of scorpions within different zoogeographic regions. These subjects will be dealt separately.

2 Materials and Methods

Six scorpion species have been found to inhabit the Mediterranean zoogeographic region in northern Israel, and in some areas up to five coexisted in the same habitat (Warburg et al, 1980). One of these is a rather rare buthid (*Androctonus bicolor* Hemprich and Ehrenberg, 1829). The remaining four species were:

Scorpio maurus fuscus (Hemprich and Ehrenberg, 1829) (Scorpionidae),
Nebo hierichonticus (Simon, 1872) (Diplocentridae),

Hottentotta judaica Simon, 1872 (Buthidae),

Leiurus quinquestriatus Hemprich & Ehrenberg, 1829 (Buthidae).

A fifth species that was studied here was a small buthid (*Compsobuthus werneri judaicus* Birula, 1905).

The field studies for macro-distribution were conducted from 1988-1996 in the two main areas within the Mediterranean region of northern Israel: Mt. Carmel and the Galillee Mts. (Warburg et al., 1980; Warburg, 1997).

For micro-distribution three areas studied were located on Mt. Carmel, one area in the Upper Galillee Mts, and three additional areas in the Lower Galillee Mts.

Mini-distribution was studied in the three different areas on Mt. Carmel.

Quantitative field sampling of scorpions (hand collection from under stones, logs and burrows) was carried out at least once monthly, only during the daytime (when scorpions hide under the shelter, or by UV lamp at night). An area of 1-2 km^2 was screened for a few hours each time. A total of 699 scorpions were collected during the study (an average of 6-7 scorpions per visit). A rough estimate would indicate that a scorpion can be found under every 10th-20th stone.

3 Improving Standard Ecological Techniques by Using a Different Approach

Several methods are in use for capturing scorpions. Each of the methods has its different advantages and drawbacks (Williams, 1968).

Collecting by UV is not useful in either a Macqui or Garrigue types of vegetation since the thick vegetation coverage does not allow sighting the scorpions. It is however most useful in deserts, sand dunes or prairie or on bark of trees.

Diurnal hand collecting from under refuges is useful as a supplement in areas where UV collection is not feasible and subject to the presence of refuges (stones, bark, burrows etc).

Pitfall traps are useful for capturing all but the burrowing scorpions who sit and wait for prey near their burrows, rarely venturing far outside. However, trapping can supplement both other two methods.

The way to assess the usefulness of capturing techniques is by using an enclosure and releasing into it a known number of scorpions. It will give one a way to evaluate the usefulness of each technique since the percentage of capture will be known for each of them. In the present study all three methods have been used.

4 Results

Plant and even better stone coverage are of utmost significance for scorpion micro-distribution in the eight different regions (Fig. 1). The plant coverage was further analyzed according to their height (Fig. 2). They were divided between woody (>50cm high), and herbaceous plant (< 50cm high).

The seasonal changes in micro-distribution were studied in four scorpion species (Fig. 3). Autumn and winter were mostly favored by *N. hierichonticus* and *C. w. judaicus*, whereas *H. judaica* preferred the winter months, and *S. m. fuscus* the autumn.

Changes in micro-distribution were studied in three different stone size categories: small, medium and large, and in four scorpion species over the year (Fig. 4). Medium and larger stones appear to be favored by all four species.

Seasonal changes in the phenology of four scorpion species are shown for Mt. Carmel (Fig. 5). The demographic changes in populations of six scorpion species in northern Israel are given in (Fig. 6). These show recent changes in number of specimens found during the years 1988-1996 (black columns) as compared to numbers found during 1974-1979.

Finally, the seasonal changes in average number of captures of four scorpion species, are shown in Mt. Carmel (Fig. 7), and for five species on the Gelillee Mts. (Fig. 8).

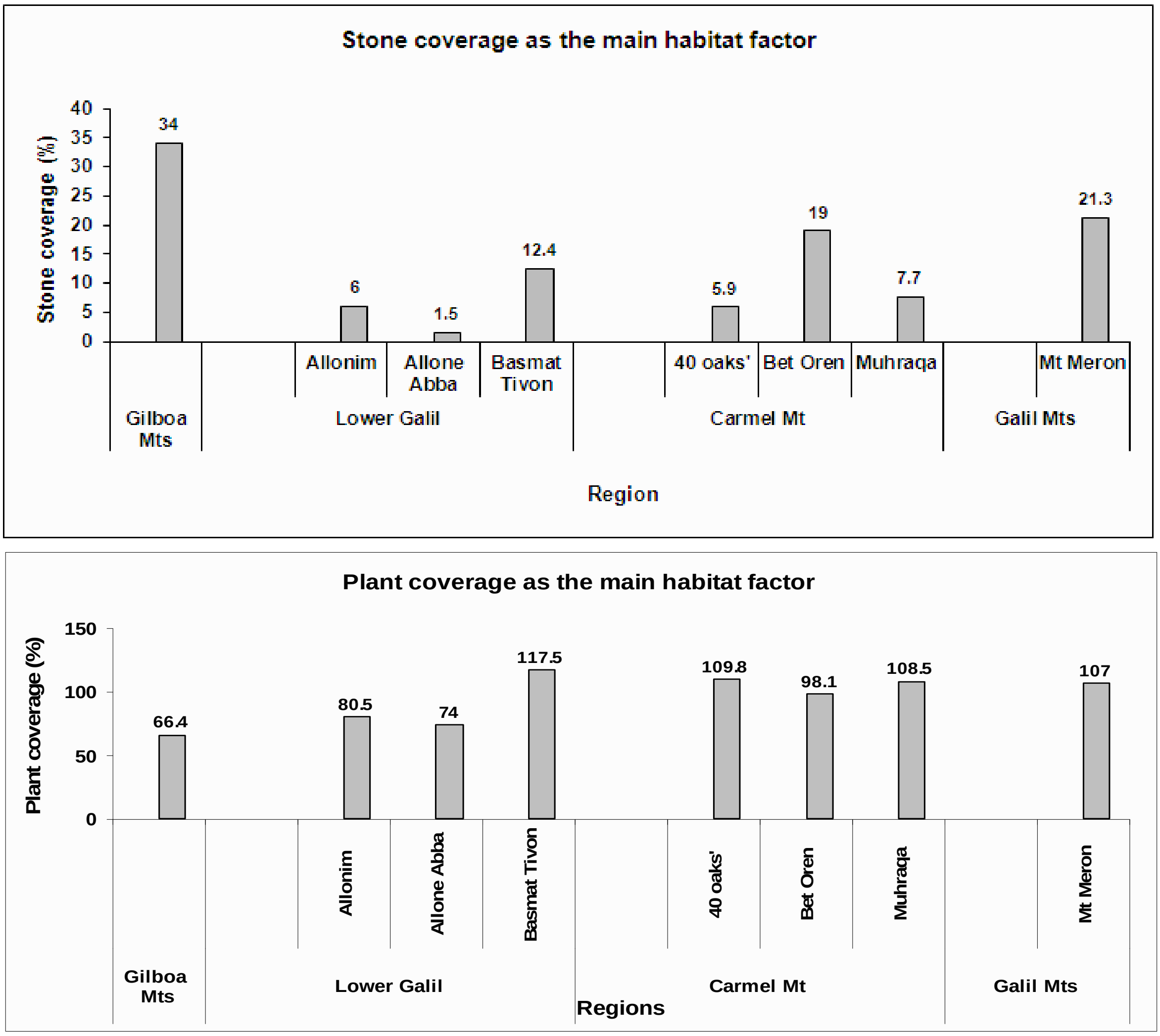


Fig. 1 Plant and stone coverage as the main factors for distribution of scorpions in the different regions.

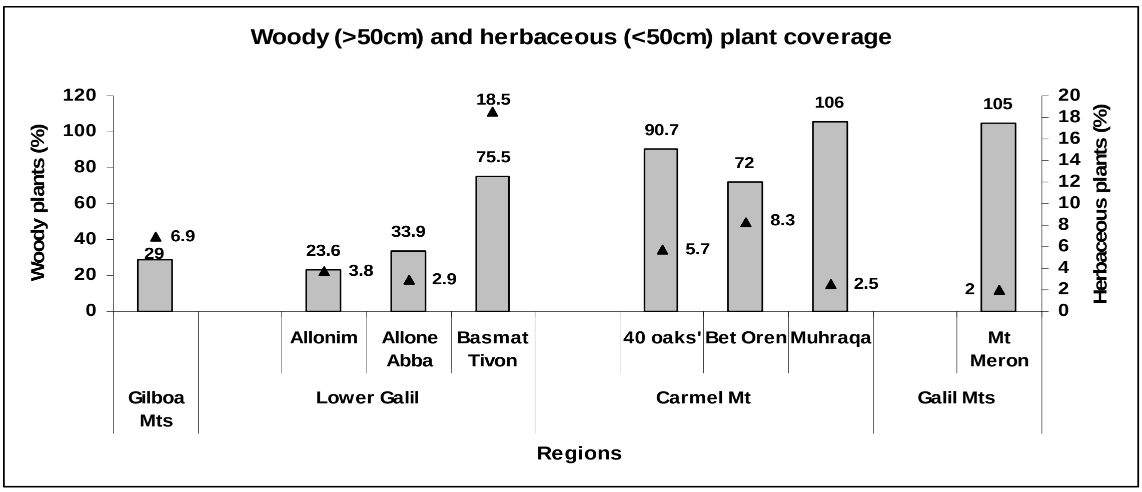


Fig. 2 Woody (columns) and herbaceous (triangles) plant coverage in the different regions.

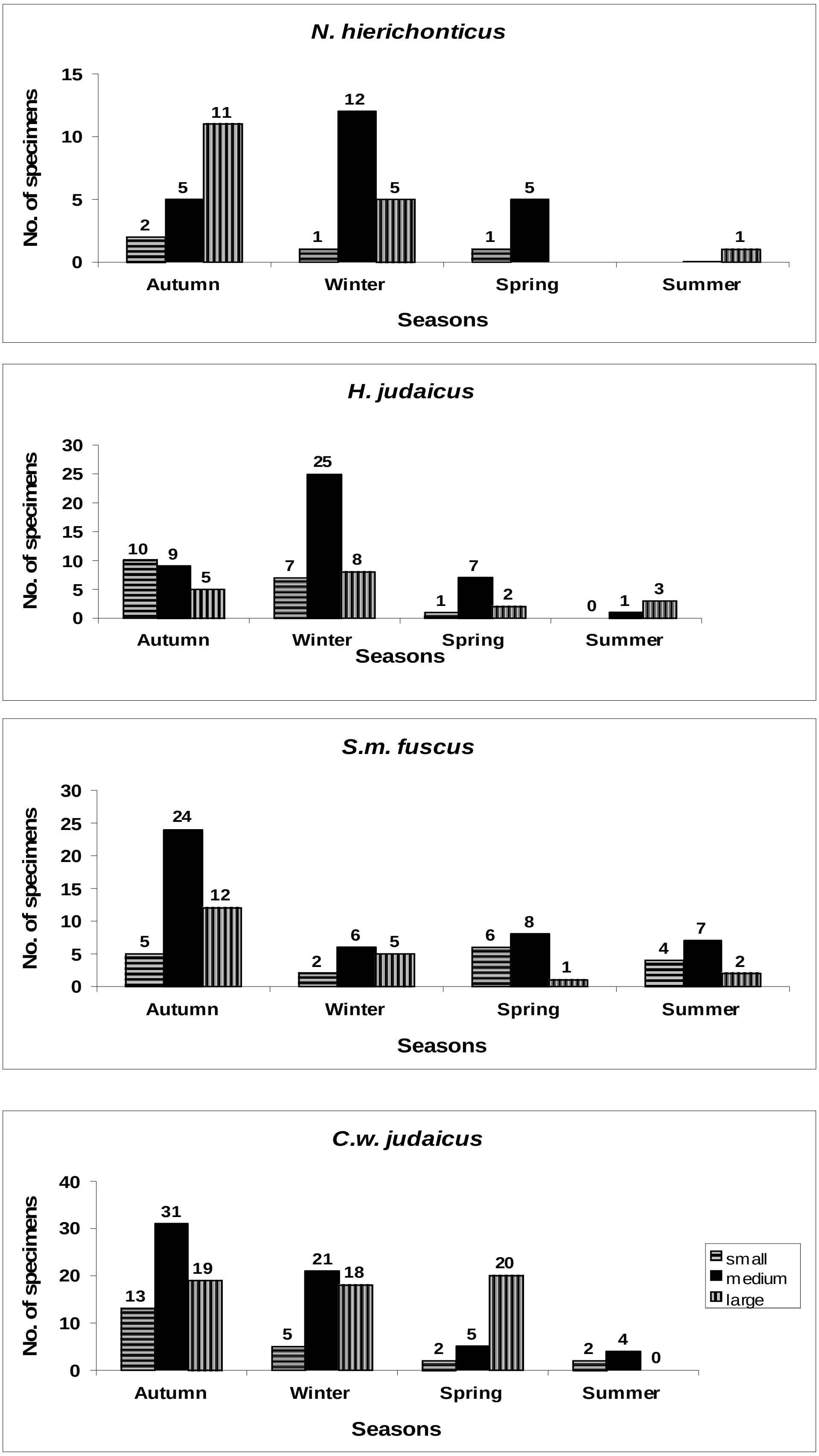


Fig. 3 Seasonal changes in micro-distribution of four scorpion species.

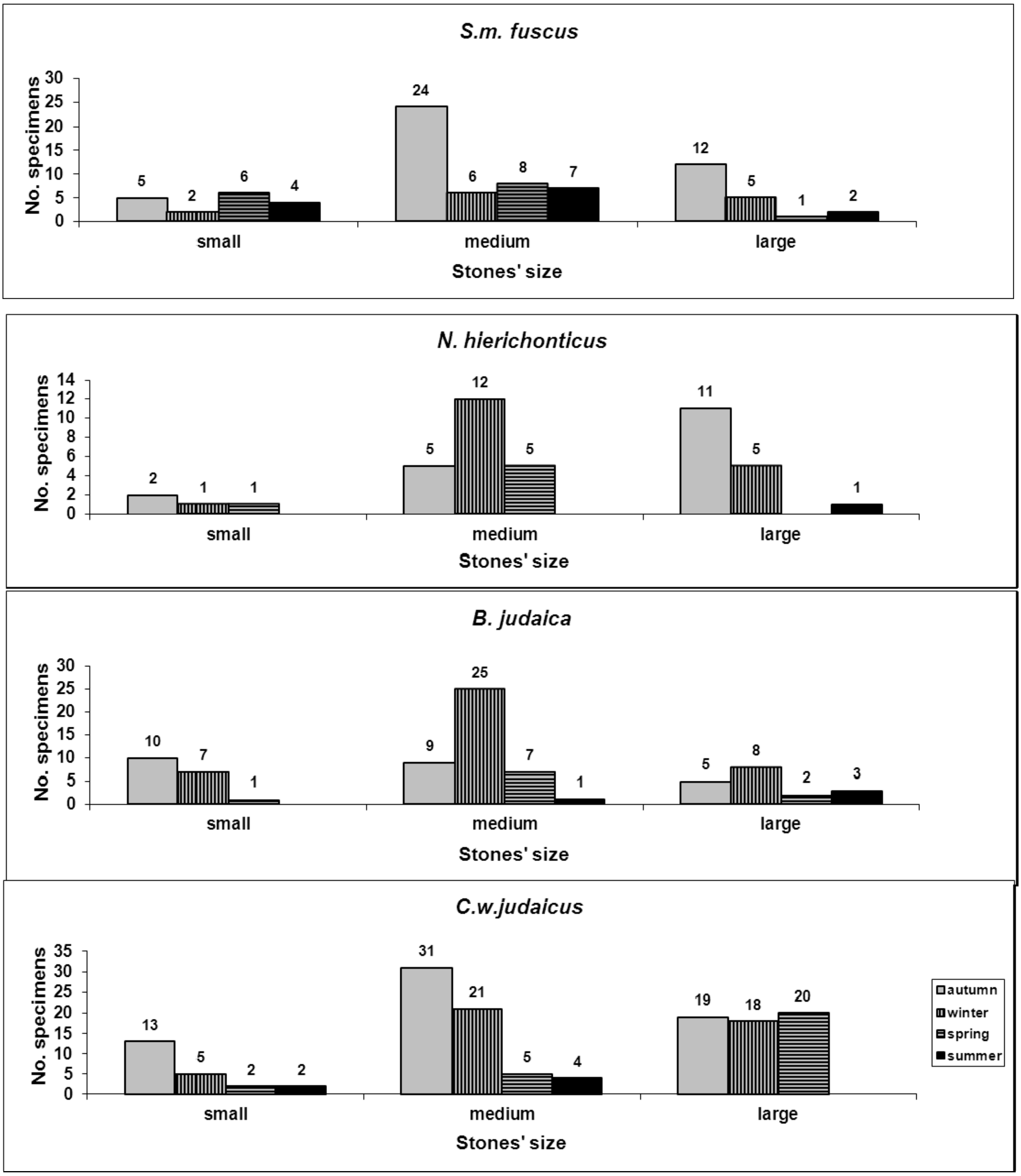


Fig. 4 Changes in micro-distribution of four scorpion species over the year.

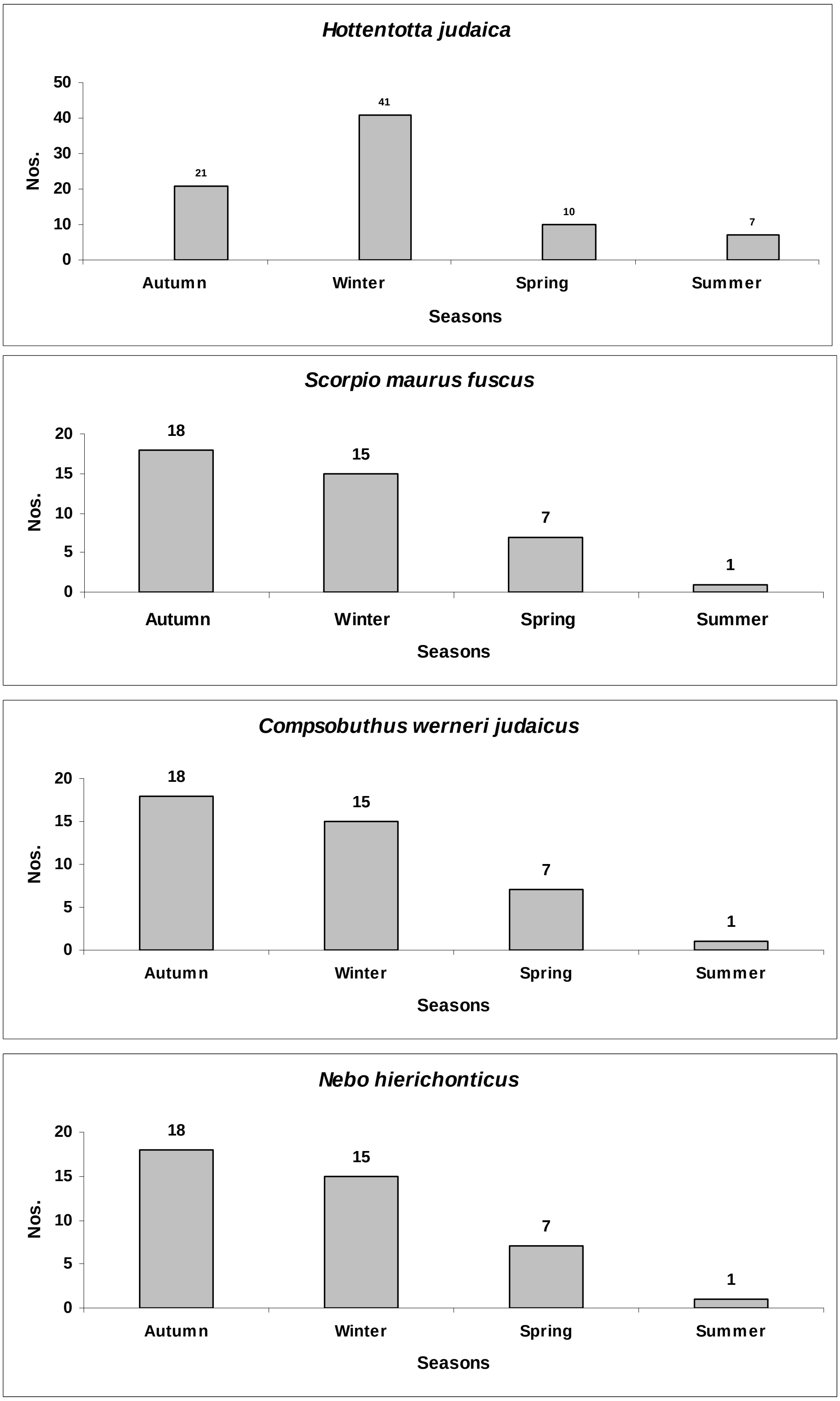
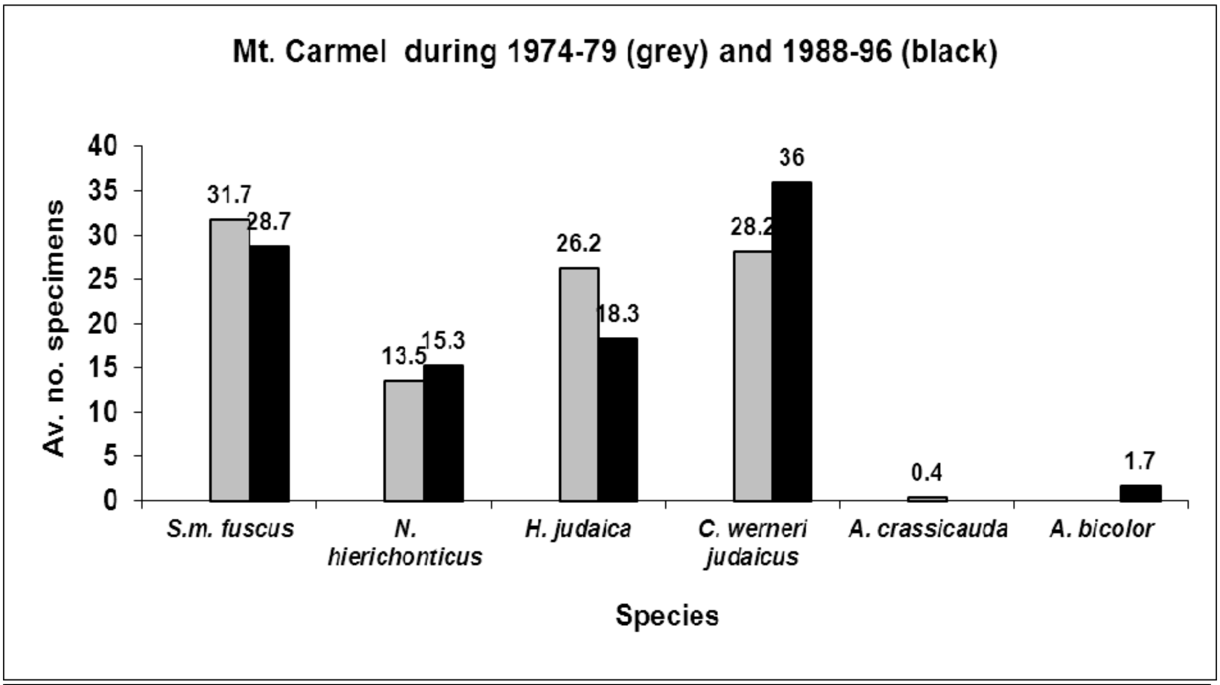


Fig. 5 Seasonal changes in the phenology of four scorpion species on Mt. Carmel.



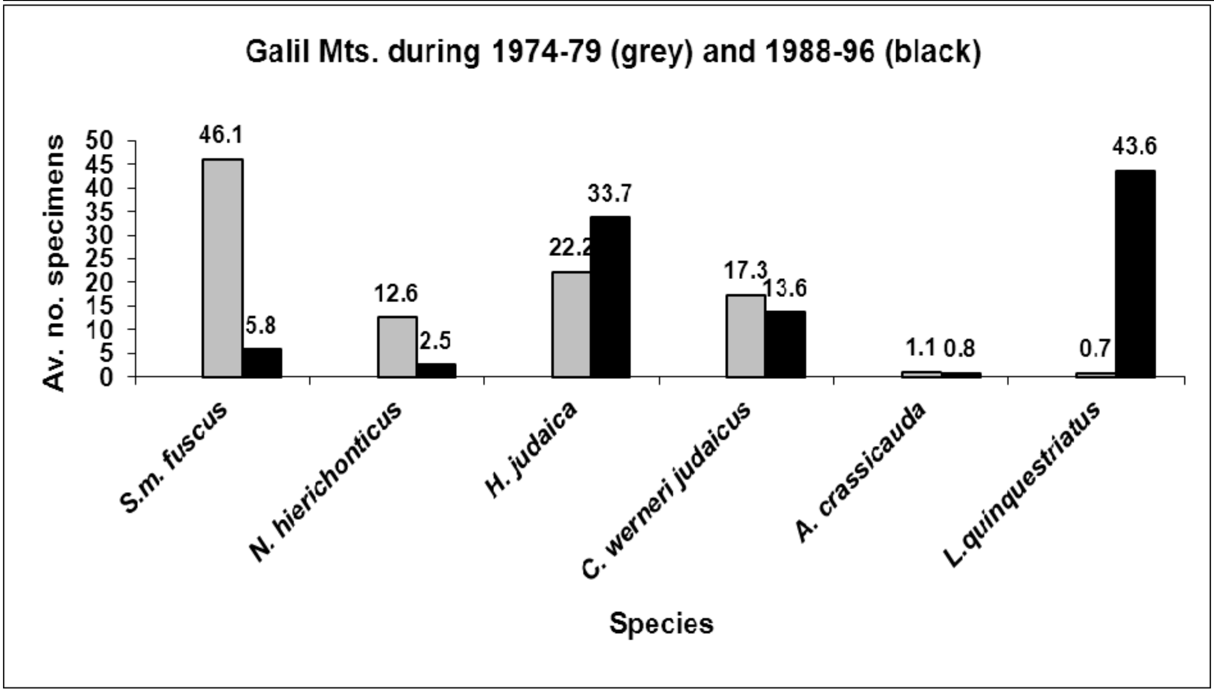


Fig. 6 Demographic changes during long-term studies on scorpions in northern Israel.

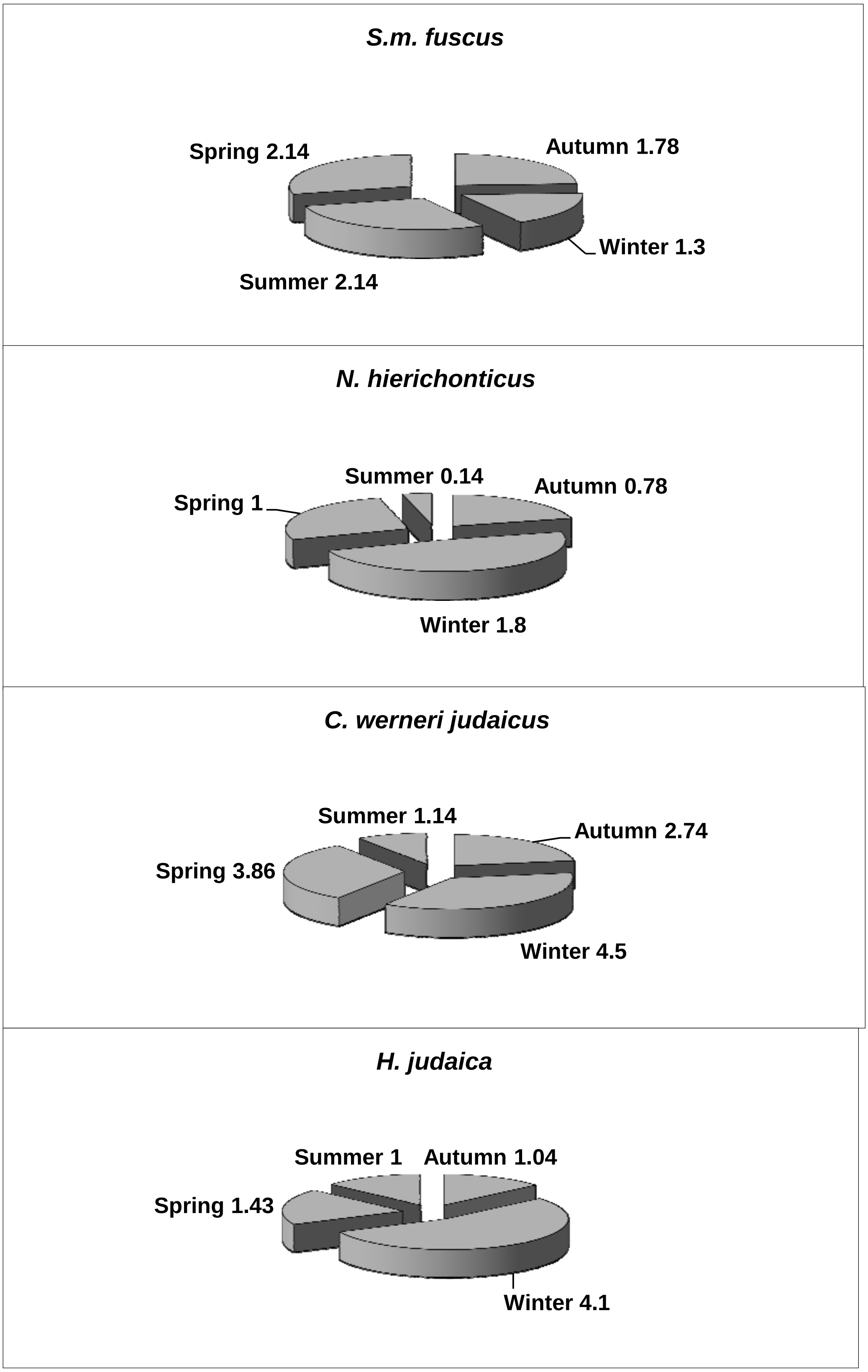


Fig. 7 Average number of scorpion specimens collected on each visit to Mt. Carmel.

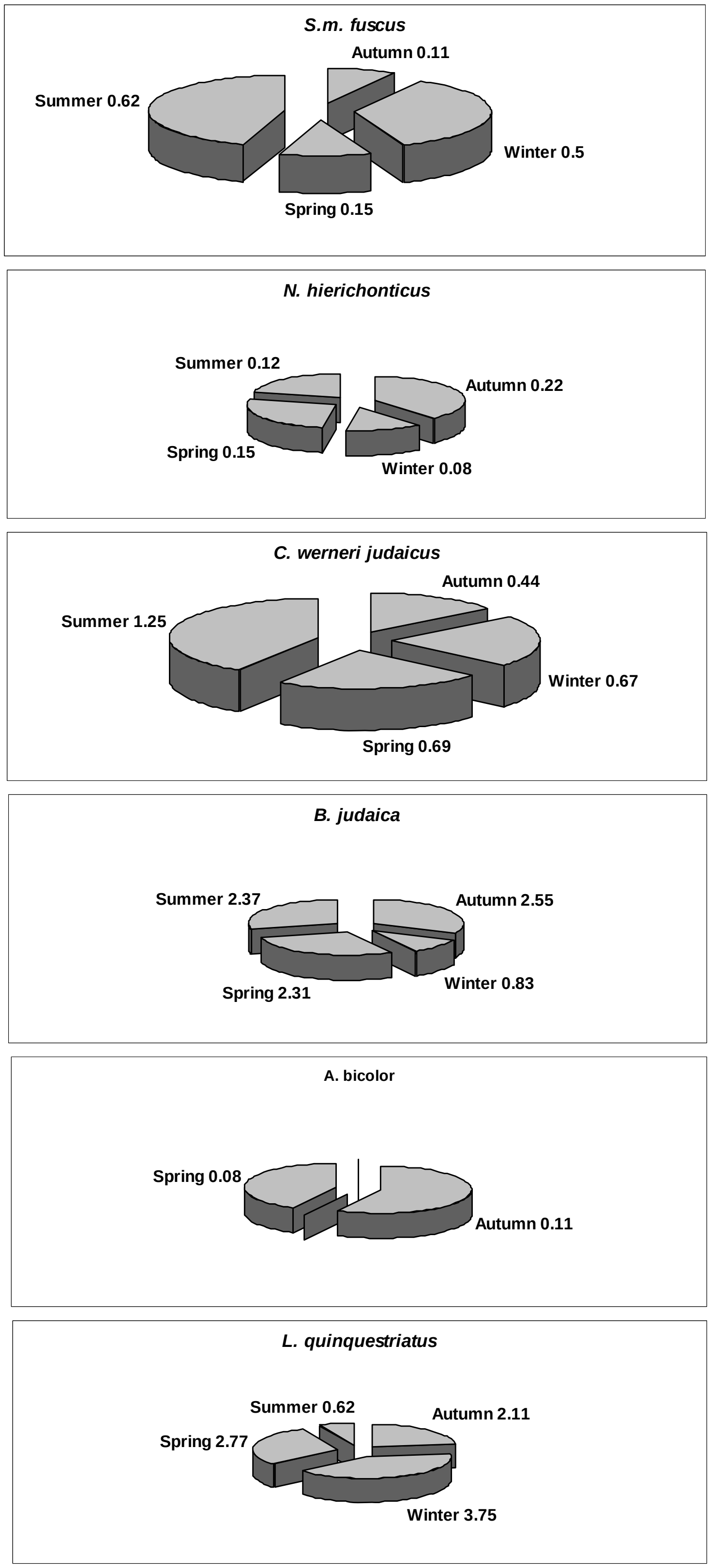


Fig. 8 Average number of scorpion specimens collected on each visit to the Galilee Mts.

5 Discussion

5.1 Mini- distribution

Toye (1970) found up to five individuals of the scorpionid *Pandinus imperator* (C.L.Koch, 1841) sharing a microhabitat. Likewise, up to 15 individuals of *Pandinus imperator* were observed together (Mahsberg, 1990).

Heterometrus fulvipes (Koch, 1837) was found to share family burrows (Shivashankar, 1994), whereas *Anuroctonus phaeodactylu*s (Wood, 1863), was found in pairs in the field (McDaniel, 1968). Finally, Zinner and Amitai (1969) described a case of 23 specimens of the buthid *Compsobuthus schmidekenichti* (Vachon, 1949), under a large stone. Shachak and Brand (1983) studying *S. m. fuscus* found them cohabiting during the breeding season.

Many studies covering aspects of mini-distribution were done on burrowing scorpions. These scorpions utilize a self-made refuge. Some of these studies are descriptive describing the burrow whereas others are concerned with functional aspects. There is no account of the distribution pattern of these burrows, nor of that of scorpion species co-habiting these burrows or their abundance there (except perhaps for Polis, Myers & Quinlan, 1986; Locket, 1993).

These studies include Main's (1956) observation on *Isomtroides* Keyserling, 1885 (Scorpionida) inhabiting spider burrows in woodland and semi-arid region. These spiders are one of its main preys.

Burrowing activities of *Anuroctonus phaeodactylus* (Wood, 1863) were studied in the laboratory as well as in nature (William, 1966). He described five steps in burrow construction: searching for suitable site, soil loosening, transporting and depositing done with the chelicerae and finally shaping the burrow. The burrow is a tunnel ending with an enlarged terminal nest. The burrows are permanent and thus occupied for longer periods of time. Pedipalp are being utilized for burrowing by the scorpionid *Cheloctonus jonesii* Pocock, 1892 (Harrington, 1978). The burrow is a simple tube (Fig. 3 therein) of 18.5cm length. Spiraling burrows have been described in *Urodacus* Peters, 1861 spp by Koch (1978). He found them to be up to 44.7cm deep. Burrows of *Urodacus yaschenkoi* (Birula, 1903) have been described by Shorthouse and Marples (1980; see Fig. 1 therein). These are spirally-shaped, deep burrows (total depth may reach 47.3cm) ending with a terminal chamber. The scorpions stay deep inside their burrows which defend them.

Likewise, in *Heterometrus xanthopus* Pocock, 1897 (Khatvar and More, 1990). They describe the architecture of the burrows as a crescent opening leading to a deep narrow passage which could be straight or tortuous and ending by a spacious circular pit.

Newlands (1972a, b) has described burrowing in psammophilous scorpions (*Opisthophthalmus* C. L. Koch, 1837). Burrowing activities have been described also in both the scorpionid *Opisthophthalmus macer* (Thorell, 1876), and the buthid *Parabuthus planicauda* (Pocock, 1889 (see Eastwood, 1978). The importance of soil hardness on burrowing in was studied in *Opisthophthalmus* Koch, 1837 (Lamoral, 1978). Finally, burrowing activity was studied in *Scorpio maurus palmatus* (Ehrenberg, 1828) in a single plot (1.200 x 55 m^2) by Rutin (1996). Burrowing activity is to some extent regulated by season.

5.2 Micro-- distribution

The distribution of scorpions could be explained by relating it to soil moisture (Warburg and Ben-Horin, 1978). There was a marked difference in temperature ranges when it was measured at the entrance or inside the burrow (see Fig. 3 therein).

The relationship between vegetation coverage and scorpion abundance was studied in *Paruroctonus measaensis* (Stahnke, 1957) (Polis, Myers & Quinlan, 1986). They found that the size (i.e. age) group is affected by the coverage. Bradley and Brody (1984) found *Paruroctonus utahensis* (Williams, 1968) is dominant species in flat grassland. The two vaejovids *Vaejovis coahuilae* (Williams, 1968), *V. russelli* studied by him, inhabit rocky cliffs and are fewer in grassland.

5.3 Macro- distribution

San Martin and de Gambardella (1967) described the different habitats in which three *Bothriurus* Peters 1861 spp occur. Abdel-Nabi, McVean, Abdel-Rahman and Omran (2004) describe morphological differences in *S.m. plamtaus* that could be related to soil texture in three different habitats.

Shehab, Amr and Lindsell (2011) describe scorpion captures in three different regions using hand collecting and pitfall traps. Cala-Riquelme and Colombo (2011) describe abundance of a single species in four habitats differing in elevation and vegetation.

To conclude, the scaling of distribution of scorpions enables better understanding of the intra- and inter-specific interactions among scorpions.

Thus, the larger the scale apparently greater number of scorpion species inhabits an area. In smaller scale, mini-distribution there are in general a larger number of intra-specific cohabitation.

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