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On the Ecology of the Iulid Millipede *Symphyoiulus impartitus* (KARSCH) in a Mediterranean Pine Forest of Greece

(Diplopoda: Iulida)

by

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Abstract: *S. impartitus* is one of the dominant species of the millipede community of a mediterranean pine forest in Greece (Sophiko, Peloponnese), and exhibits a particular preference for *Pinus halepensis* litter. Since no data exist on the ecology of the species, in the present paper its phenology, biomass and horizontal distribution into various microhabitats (litter types) of the forest of Sophiko are studied. Quantitative litter sampling was carried out from October 1984 to Oct. 85 in monthly intervals. Laboratory experiments on behavioural preference of microhabitat were also effectuated.

According to the field data, the appearance of the species is restricted to the rainy season, while aestivation occurs during the rest of the year. Peaks of density and biomass are observed mainly in December (40 ind., 570 mg [dry weight] per m^2 of litter). *Pinus halepensis* litter is the microhabitat preferred by the species. Field data, reinforced by laboratory experiments suggest that the ecological character of the species rather than competition is the major factor to determine the horizontal distribution and the microhabitat of the species. Further investigations are necessary.

1. Introduction:

According to literature data (CHOTKO & STRIGANOVA 1975, ARPIN et al. 1986, DAVID 1986), pine forests are habitats avoided by most European Iulid millipedes due to the chemical composition and mechanical nature of pine needles. The species under consideration was found to be one of the dominant species of the millipede community of a mediterranean pine forest (*Pinus halepensis*) in Sophiko (KARAMAOUNA 1987). According to the recent revision of ENGHOFF (1990) *S.impartitus* is confined to Greece and Asia Minor. Until now no data on its ecology exist.

In the present work, an attempt is made to investigate the ecology of the species in the pine forest of Sophiko with a twofold approach: (1) monthly quantitative sampling in litter during an annual cycle, (2) laboratory experiments. Likewise, its phenology, biomass and horizontal distribution to the different microhabitats (litter types) were studied. Interest is focused on the factors which determine the microhabitat preference of the species: does this preference reflect competitive interactions within the millipede community or does it arise primarily from the ecological character of the species?

2. Study Area:

The study area is described in detail in previous works (KARAMAOUNA 1987, 1990). The area is situated in the north-eastern part of Peloponnese near the village Sophiko, about 20 km from Korinthos, on a calcareous hill, the soil being of the "terra-rossa" type. The climate is semi-arid mediterranean, characterized by a prolonged dry season from May to September or October.

The tree layer of the forest consists of *P. halepensis*, while the shrub layer consists of *Quercus coccifera*, *Phillyrea media* and *Arbutus unedo*. The forest floor is covered in a mosaic pattern by four litter types (A_o): *Q. coccifera* (29 %), *Ph. media* (11 %), *A. unedo* (10 %) and *P. halepensis* litter (50 %). The profile of all types of litter is moder. According to my field observations, these litter types constitute the microhabitats where *S. impartitus* can be found during the daytime.

3. Methods:

3.1. Sampling and Extraction Techniques:

These techniques were described in detail previously (KARAMAOUNA 1987, 1990). Quantitative sampling was carried out from October 1984 to Oct. 85. Every month 5 samples, 625 cm^2 each, of each litter type were collected. Totally, 232 samples were taken. Berlese-Tullgren funnels were used for the extraction of millipedes. Mean biomass (dry weight) of immatures, subadult and adult females, as well as subadult and adult males was estimated from the individuals collected by the funnels. For the estimation of density and biomass per m^2 of litter, the cover of the forest floor by each litter type was taken into consideration.

3.2. Laboratory Experiments: Behavioural Microhabitat Preference:

The microhabitat preference was investigated by allowing the individuals to choose between different microhabitats, i.e. between the four litter types of the forest of Sophiko. Individuals and litter (L and F layers) have been collected at Sophiko in December, the month of greatest appearance of the species, few days before the experiment. In Table 1 some important physicochemical parameters of the litter are presented. Litter was dampened to minimize moisture differences. Big leaves and pine needles were cut into pieces, and placed in an aluminium circular tray (25 cm diameter, 5 cm depth). They were arranged in four different sectors (2 cm thick) equally spaced and separated by sand. A thin layer of moistened plaster of Paris at the bottom of the tray helped to keep high moisture during the experiment. 15 individuals were released in the center of the tray. After 3 days the individuals found in each sector were recorded. Similar experiments, concerning behavioural food preference of millipedes, have been carried out by several scientists (BARLOW 1957, PEDROLI-CHRISTEN 1977, KHEIRALLAH 1979, BANO & KRISHNAMOORTHY 1981).

Table 1: Main physicochemical parameters of litter in the forest of Sophiko (December 1985, from KARAmaouna 1987).

Litter type	DW ± SE kg m^{-2}	Th ± SE cm	WC ± SE % WW	Ca % DW	pH
Ph	2,1 ± 1,4	1,0 ± 0,2	41 ± 3	1,65	6,4
Q	2,8 ± 1,6	2,5 ± 0,3	46 ± 2	1,75	6,5
Pm	3,2 ± 3,0	2,0 ± 0,3	45 ± 2	2,05	6,8
A	3,4 ± 2,7	3,1 ± 0,4	52 ± 1	1,90	5,8

DW: mean dry weight; **Th:** mean thickness; **WC:** water content; **WW: Wet weight.**
Abbreviations of litter types: Ph *Pinus halepensis;* **Q** *Quercus coccifera;* **Pm** *Phillyrea media;* **A** *Arbutus unedo.*

3.3. Statistical Treatments:

Spearman correlation (SIEGEL 1956) was used to clarify the relations between the monthly variations of millipede density and the pattern of both rainfall and temperature during the annual cycle. Kruskal-Wallis ANOVA and non-parametric multiple comparisons (ZAR 1984) were used to define the microhabitat preference of the species in the field.

4. Results:

4.1. General Characteristics:

S. impartitus is one of the dominant species of the millipede community of the pine forest in Sophiko, representing 20 % of the total mean annual density and 90 % of the respective biomass.

The mean annual density and biomass (dry weight) per m^2 of litter were 8 ind. and 100 mg respectively.

4.2. Phenology: Monthly Variations of Density and Biomass:

These variations are illustrated in Fig. 1. Evidently, the appearance of the species in litter samples is strictly confined to the rainy season, from October or November to March. Peak densities were observed in December and January, 40 and 28 ind. m^{-2} of litter. During the same months peaks of biomass (dry weight) were also observed, 570 and 384 mg m^{-2}.

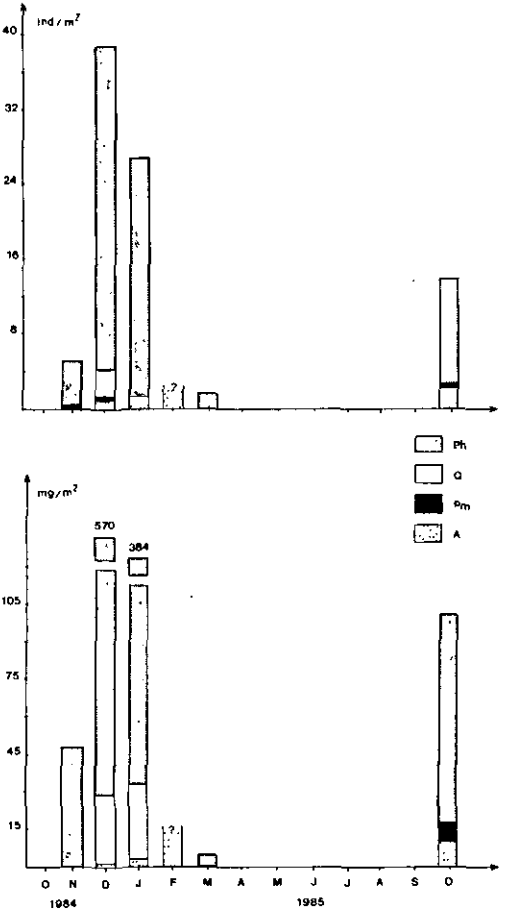

Fig. 1: Variations of density and biomass (dry weight) of *S. impartitus* per m^2 of litter in the pine forest of Sophiko during the study period (October 1984 to October 1985). Abbreviations as in Table 1.

In order to clarify the relations between the phenology of the species and both rainfall and temperature, statistical treatment was used. Positive correlation ($p < 0.01$) between monthly variations of millipede density and the pattern of rainfall, and negative correlation with temperature variations ($p < 0.01$) during an annual cycle was found. A hygrothermograph was constructed according to BARLOW (1957). Fig. 2 shows that peaks of density are associated with monthly rainfall ranging

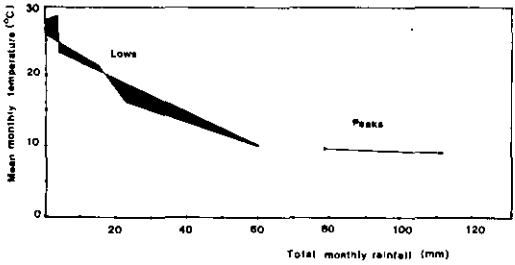

Fig. 2: Hygrothermograph of peaks and lows of density of *S. impartitus* in the pine forest of Sophiko during the study period (October 1984 to October 1985).

from 80 to 110 mm and temperature ranging from 9 to 10° C, while low millipede densities are associated with rainfall ranging from 0 to 60 mm and temperature 11 to 28° C.

4.3. Horizontal Distribution:

Quantitative data concerning the density of *S. impartitus* in the four different microhabitats were analysed statistically using the Kruskal-Wallis ANOVA and non-parametric multiple comparisons (ZAR 1984). The results of this treatment (Table 2) show a clear preference for *P. halepensis* litter.

Table 2: Microhabitat preference of *S. impartitus*: Results of the statistical treatment of field data concerning density in the four different litter types of the forest of Sophiko. (Kruskal-Wallis ANOVA and non-parametric multiple comparisons; H_0: there is no microhabitat preference among the four litter types). Abbreviations of litter Types as in Table 1.

Kruskal-Wallis ANOVA	Non-parametric multiple comparisons
H = 13,69	Ph > Q = Pm = A
p < 0,005	p < 0,05

4.4. Laboratory Experiments of Behavioural Preference of Microhabitat:

The results of these experiments are presented in Table 3. According to these results 37 % of the individuals were found in *P. halepensis* litter, while 31 % were found in *Ph. media,* 18 % in *A. unedo* and 14 % in *Q. coccifera* litter.

Table 3: Behavioural microhabitat preference of *S. impartitus* regarding the four litter types of the forest of Sophiko. Percentage of individuals in each litter type. N (number of replicates) = 6 (15 individuals per replicate).
Conditions: RH = 100 %, Mean temperature = 15° C, Natural photoperiod. Date: 2nd week of December). Abbreviations as in Table 1.

Ph	Q	Pm	A
37 %	14 %	31 %	18 %

5. Discussion:

Most literature data on the ecology of iulid millipedes concern species living in temperate forests of Europe (e.g. VAN DER DRIFT 1951, BLOWER & GABBUTT 1964, BLOWER 1970, GEOFFROY 1981, DAVID 1982, PHILLIPSON & MEYER 1984). Compared with these data, the ecology of *S. impartitus* presents sharp contrast to the species of temperate forests. *S. impartitus* has a unimodal pattern with peaks in winter and appearance restricted to the rainy season, whereas the other species exhibit a bimodal pattern of phenology with peaks of density and biomass in spring and autumn, and appearance throughout the year.

According to my field observations, the species is aestivating during the whole dry period (April to September/October), enclosed in chambers made of "terra-rossa" soil. This phenology pattern is related to the "escape" or "avoidance" mechanism (DI CASTRI 1973 b) towards climatic conditions, as described by WALLWORK (1976). This phenology is common in hygrophilous soil arthropods of mediterranean ecosystems ((DI CASTRI 1973 a, DI CASTRI & VITALI-DI CASTRI 1981, KARAMAOUNA 1987, 1990).

In addition, whereas most iulids avoid the pine forest (CHOTKO & STRIGANOVA 1975, ARPIN et al. 1986, DAVID 1986), *S. impartitus* prefers *P. halepensis* litter in the pine forest where other shrubs are also present (*Q. coccifera, Ph. media, A. unedo*). An important question arising from this horizontal distribution or microhabitat preference concerns the factors which determine it. The organization of an animal community may be determined by competitive interactions within the community (for millipedes, e.g.: O'NEILL 1967, MILLER 1974, GEOFFROY 1981). However, some scientists (e.g. SIMBERLOFF 1982, STRONG et al. 1984) do not accept the existence of competition as based on evidence in the field, unless this was proven by laboratory experiments. These authors point out the importance of autecological processes in the organization of animal communities.

In the case of *S. impartitus,* laboratory experiments on behavioural microhabitat preference are in accordance with field data: The species exhibits a preference for *P. halepensis* litter. These results, corroborated by observations made by the author in recent researches in *P. halepensis* forests of Attika and Skopelos island, might suggest that the above preference reflects mainly the autecological status of the species.

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