

SEASONAL DYNAMICS OF CAMPODEIDAE (DIPLURA) IN AN OAK FOREST IN KRAGUJEVAC (SERBIA)

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Over a period of one year, members of the family Campodeidae were collected in an oak forest (Šumarice) in the vicinity of Kragujevac (Serbia). The abundance and diversity of the members of this family were monitored, as were factors that may exert influence on their dynamics (soil temperature and moisture at different depths). From the collected material, the following members of the family Campodeidae were separated: *Campodea (Campodea) colladoi* (Silvestri, 1932), *Campodea (Campodea) wallacei* (Bagnall, 1918), *Campodea (Dicampa) campestre* (Ionescu, 1955), *Campodea (Dicampa) frenata* (Silvestri, 1931), *Campodea (Paurocampa) suensoni* (Tuxen, 1930), and *Podocampa serbica* (Karaman & Blesić, 1983). The most abundant species among them was *Campodea (Dicampa) campestre* (84.14%), which had significant influence on the dynamics of abundance of this family by virtue of its dominance and frequency. Other species of the family were less numerous, but they contributed by their presence to increased density and diversity of this group of soil insects.

KEY WORDS: Diplura, Campodeidae, oak forest, ecology

INTRODUCTION

The Apterygota represent a major component of terrestrial ecosystems. This group is important at most trophic levels in food webs, as well as in decomposition of organic matter as fungivores and detritovores (CROSSLEY & COLEMAN, 1999; NEHER, 1999). Among them, members of the order Diplura (especially of the

family Campodeidae) constitute a significant part of the hemiedaphon and contribute to the better functioning of terrestrial ecosystems by their presence in soil. Also, other representatives of the Apterygota (members of the orders Collembola and Protura) have a significant role in the same process (SILVESTRI, 1932; IONESCU, 1955; CONDE, 1956; PALISSA, 1964).

BLESIC (1983a) performed a taxonomic–ecological study of the family Campodeidae (Apterygota, Diplura) in the vicinity of Kragujevac. In addition to members of the meadow fauna, he also analyzed members of the forest fauna. This work represents an attempt to gain a better understanding of relations of the researched group with abiotic and biotic factors and establish variations resulting from influence of the complex of ecological parameters.

MATERIAL AND METHODS

The investigation was conducted in an oak forest (Šumarice) in the vicinity of Kragujevac during the period of September 2004 – September 2005. Once monthly, three soil samples were collected from different layers (a–layer depth: 0–10 cm; b–layer depth: 10–20 cm) at each of five different points. Soil temperature and soil moisture were measured at these depths to establish the influence of ecological factors on Campodeidae distribution. Tullgren–Berlesse apparatuses were used for separation of individuals in the laboratory. Material was preserved in 70% ethanol, and individuals were determined to the species level after preparation.

The investigated period of one year was divided into four seasons for easier review of the results: season I (September, October and November 2004), season II (December 2004, February and March 2005), season III (April, May, and June 2005) and season IV (July, August, and September 2005).

RESULTS

During the research period, the total number of collected individuals of the order Diplura was 609. The total number of individuals of the family Campodeidae was 498 (81.78%), and 111 individuals (18.22%) belonged to the family Japygidae. On the basis of the obtained results, it can be concluded that members of the first family were dominant in soil samples.

Within the family Campodeidae, six species were identified. A list of them and variability of their total numbers are given in Tab. I.

Table I

Abundance of species of the family Campodeidae during all months of investigation.

Species	Sep	Oct	Nov	Dec	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
<i>Campodea</i> (<i>Dicampa</i>) <i>campestre</i>	86	56	43	36	32	14	1	25	22	55	30	19
<i>Campodea</i> (<i>Dicampa</i>) <i>frenata</i>	4	0	2	3	0	3	0	0	2	3	0	0
<i>Campodea</i> (<i>Campodea</i>) <i>wallacei</i>	3	2	0	0	0	0	0	0	0	0	0	0
<i>Campodea</i> (<i>Campodea</i>) <i>colladoi</i>	0	3	0	0	0	0	0	1	0	0	0	3
<i>Campodea</i> (<i>Paurocampa</i>) <i>suensoni</i>	8	16	0	0	0	0	0	0	2	1	0	0
<i>Podocampa</i> <i>serbica</i>	7	5	1	3	0	0	2	4	0	0	0	1

Seasonal dynamics of members of the family Campodeidae is presented on Figs. 1 and 2.

During September 2004, this family achieved the first maximum of abundance. The presence of six species was found in this period. During the first and second seasons a gradual decrease of their abundance occurred. Also, we noticed that their fauna became less diverse during the second season. After minimal abundance of Campodeidae during the third season (because of increased soil moisture), their numbers gradually increased and reached new maximum in July 2005. During the fourth season, the abundance of this family's members decreased.

Throughout the period of investigation, members of family the Campodeidae reached their maximum of abundance in the upper soil layer. We noticed their migration into lower soil layers during the second and fourth seasons (winter and summer months) in order to avoid direct influence of adverse environmental factors. On the basis of the obtained results, it can be concluded that most of members of this family were sensitive to soil desiccation, as well as to increased soil moisture. Gradual changes of their abundance can indicate their tolerance to variation of the investigated parameters.

The most abundant species was *Campodea (Dicampa) campestre*. During September 2004, this species achieved the first maximum of abundance, with a total number of 86 individuals (Tab. I). During the next months of the same year,

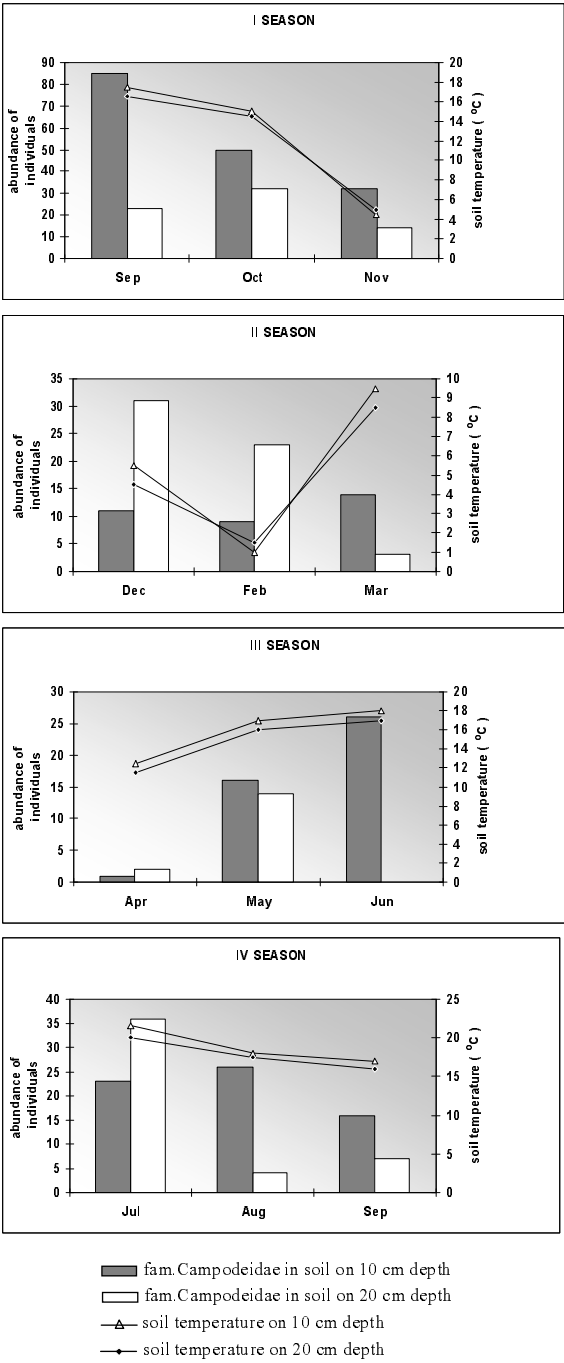


Figure 1. Total abundance of members of the family Campodeidae in relation to soil temperature at different depths.

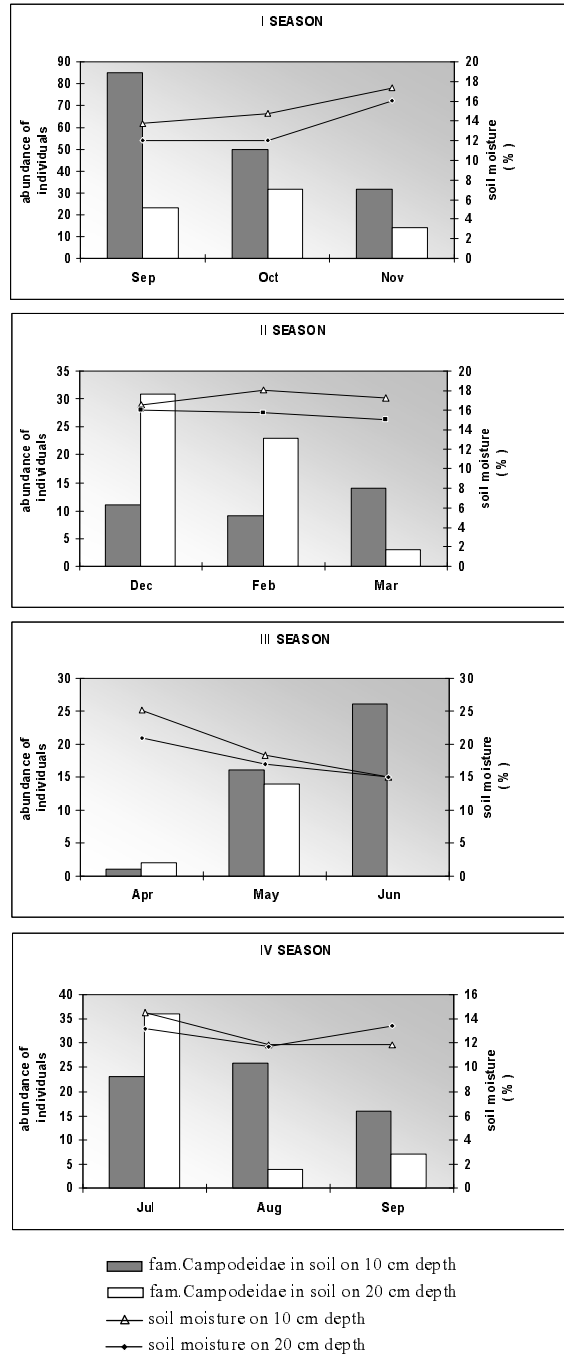


Figure 2. Total abundance of members of the family Campodeidae in relation to soil moisture at different depths.

abundance gradually decreased and reached a minimum with one individual in April 2005. Density of the population subsequently increased to reach the second maximum of abundance with a total number of 55 individuals in July 2005, after which the number of specimens of *Campodea (Dicampa) campestre* decreased again. Increased soil moisture in April 2005 is only one of the factors causing decreased abundance. Minimal abundance of this species during the second and fourth seasons (winter and summer periods) could be a result of its migrations into layers below a depth of 20 cm, its horizontal migrations in search of optimal environmental factors, and increased mortality.

The species *Campodea (Dicampa) frenata* was less abundant, but was nevertheless frequently recorded. It was present with a smaller number of individuals, and no significant variations of its abundance were noticed. During October 2004 and February, April, May, August, and September 2005, it was not present in soil samples. This could be a result of horizontal and vertical migrations of members of the given species.

Campodea (Campodea) wallacei was present in samples only at the beginning of the first season. This is a rare species that was not registered in soil during the other months. At the moment of sampling, it was more numerous in the upper soil layer.

Campodea (Campodea) colladoi was one of the less abundant species. It was noticed in the upper soil layer in October 2004, and in May and September 2005.

Campodea (Paurocampa) suenisoni was most numerous in October 2004, with a total number of 16 individuals (Tab. I). A second period when it was noticed with a greater number of individuals was in June 2005, after which its abundance declined. Reduced abundance of this species during the second and fourth seasons (winter and summer periods) could be a result of its migration into layers below a depth of 20 cm.

Podocampa serbica had increased abundance during the first season. This species was not present in soil samples in February, March, June, July, and August 2005, which could be a result of avoiding conditions inadequate for its survival and increased mortality with alteration of environmental factors.

On the basis of the obtained results, it can be concluded that the species *Campodea (Dicampa) campestre* was the main representative of the family Campodeidae, with about 70% of its abundance. The other species were less numerous.

Calculations showed that the most frequent species was *Campodea (Dicampa) campestre* throughout the whole investigated period, while the other species were frequent only during the first season.

DISCUSSION

On the basis of the obtained results, it can be concluded that the species *Campodea (Dicampa) campestre* was dominant during investigated period and exerted significant influence on the dynamics of abundance of the family Campodeidae. This species is more tolerant of variability of the followed parameters and showed gradual changes of its activity. According to the obtained results, optimal soil temperature for development of the fauna of Campodeidae was in the interval from 17.5 to 21.5°C, while optimal soil moisture was in the interval from 13.5 to 14.5%. However, almost identical values of the followed parameters do not always lead to appearance of a maximum of abundance, owing to the complexity of ecological factors. That is demonstrated in this study. Members of the family Campodeidae migrate into deeper soil layers during the winter and summer periods in order to avoid direct influence of adverse environmental factors (inadequate soil temperature and moisture, increased numbers of their predators and competitors, etc.).

The species *Campodea (Paurocampa) suenisoni* achieved maximal abundance in October 2004, when soil temperature was in the interval from 14 to 15°C and soil moisture was in the interval from 12 to 14.5%. Its non-appearance in soil samples during the other seasons, can be attributed to more intensive migration in search of optimal environmental factors, and increased mortality of its individuals.

The species *Podocampa serbica* was present in soil samples during the first and third seasons, while during the other seasons it migrated deeper in order to avoid conditions inadequate for its survival. Other members of the family Campodeidae showed more sensitivity to variations of soil temperature and soil moisture.

Also, primary controllers of the abundance of Diplura are their predators – Chilopoda, Pseudoscorpiones, Aranea, Nematoda, etc. (PACLT, 1957), which cause significant changes in the abundance of their fauna.

BLESIC (1983a) performed a taxonomic–ecological study of Campodeidae (Apterygota, Diplura) in the vicinity of Kragujevac. In addition to members of the meadow fauna, he also analyzed members of the forest fauna. His results showed lower diversity of the family Campodeidae. He registered the presence of three species: *Campodea (Dicampa) frenata*, *Podocampa serbica*, and *Campodea (Campodea) colladoi*. BLESIC (1983a) reported that populations of Campodeidae achieved maximal abundance in July, when soil temperature was in the interval from 16 to 16.5°C. The most significant species was *Campodea (Dicampa) frenata*.

The present study shows that the family Campodeidae had two peaks of abundance, the first maximum occurring in September 2004 (when soil temperature was in the interval from 16 to 16.5°C), the second maximum in July 2005 (when soil temperature was in the interval from 20 to 21.5°C). It also shows

that the dominant species was *Campodea (Dicampa) campestre* (defined by BLESIĆ as a meadow species).

BLESIĆ (1983a) deduced that the optimal temperature for development of the species *Campodea (Dicampa) frenata* is in the interval from 12 to 16°C, whereas for the species *Podocampa serbica* it is in the interval from 9.5 to 12.5°C. The present study indicates that both species achieved maximal abundance at higher soil temperatures. Optimal temperature for development of the species *Campodea (Dicampa) frenata* was in the interval from 17.5 to 21.5°C, whereas for the species *Podocampa serbica* it was in the interval from 16.5 to 17.5°C.

In both investigations, the species *Campodea (Campodea) colladoi* was less present in soil samples. The obtained results showed this species to be more sensitive to soil dessication. They also showed that the pattern of development of this species was the main reason of its appearance in October and April.

BLESIĆ (2000) established that members of the family Campodeidae can have increased feeding activity during the autumn and winter periods. During these periods, individuals usually prepared for reproduction and accumulated the organic matter needed for development of their eggs. That activity begins in March and can be continued until late autumn, depending on ecological parameters.

A great deal of information about the fauna of Diplura is presented in other studies of BLESIĆ (1981, 1983b, 1984, 1991, 2002, 2004). *Podocampa serbica* is a species new to science that was first detected on the territory of Kragujevac (BLESIĆ, 1983b). The greatest diversity of the Diplura fauna, on the territory of Serbia, was detected in oak forests which could be a result of the greater frequency of occurrence and wider dispersion of these forests (BLESIĆ, 2006).

On the basis of all the mentioned results, it can be concluded that soil temperature and moisture are not the only parameters that exert significant influence on the dynamics of abundance of the Campodeidae fauna. Its seasonal dynamics is a result of the influence of a complex of ecological factors. It is therefore necessary to study other factors serving as regulators of this fauna's abundance: environmental chemistry, humus structure, availability of food, abundance of predators and parasites, the presence of competitors, and characteristics of reproduction and development of individuals.

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СЕЗОНСКА ДИНАМИКА CAMPODEIDAE (DIPLURA) ХРАСТОВЕ ШУМЕ У КРАГУЈЕВЦУ (СРБИЈА)

АНА МИТРОВСКИ-БОГДАНОВИЋ И БЕЛА БЛЕСИЋ

ИЗВОД

У овом раду дат је приказ сезонске динамике појединих врста фамилије Campodeidae (Apterygota, Insecta). Истраживање је спроведено током периода септембар 2004 – септембар 2005. године у храстовој шуми у околини Крагујевца. Прегледом сакупљеног материјала установљено је присуство 6 врста Campodeidae: *Campodea* (*Campodea*) *colladoi* (Silvestri, 1932), *Campodea* (*Campodea*) *wallacei* (Bagnall, 1918), *Campodea* (*Dicampa*) *campestre* (Ionescu, 1955), *Campodea* (*Dicampa*) *frenata* (Silvestri, 1931), *Campodea* (*Paurocampa*) *suensoni* (Tuxen, 1930) и *Podocampa serbica* (Karaman & Blesić, 1983). Најзаступљенија врста фамилије Campodeidae била је *Campodea* (*Dicampa*) *campestre* (84.14%).

За врсте *Campodea* (*Dicampa*) *frenata* и *Podocampa serbica* показано је да своје максимуме бројности могу остварити и при вишим температурама у поређењу са резултатима истраживања која су спроведена пре 24 године. Такође је показано и да је врста *Campodea* (*Dicampa*) *campestre* остварила доминантност у земљишту храстове шуме, а која је иначе у досадашњим истраживањима окарактерисана као ливадска врста.

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