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Pteromalid Fauna (Chalcidoidea: Pteromalidae) in the Grasslands of Vitosha Mountain, Bulgaria: Generic Composition, Diversity, Abundance and Phenology

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Abstract: This work presents a two-year study on the Pteromalidae (Hymenoptera) in the grasslands of Vitosha Mountain. Totally, 45 genera were found. Their diversity and phenology during May-September were described and analysed. The analysis of the relative abundance revealed that the pteromalids were dominated by six genera: *Mesopolobus* (23.1%), *Spintherus* (14.3%), *Chlorocytus* (14.2%), *Pteromalus* (12%), *Trichomalus* (6.6%) and *Gastrancistrus* (5.2%). The diversity was assessed using Fisher's Alpha Index, ranging between 2.8 and 28.1; the highest values were recorded in May and July, while the lowest index was found in the autumn (September). We recorded two peaks in both abundance and number of species.

Key words: Pteromalidae, grasslands, abundance, diversity, phenology, fauna, Vitosha Mountain, Bulgaria

Introduction

The family Pteromalidae Dalman, 1820 is one of the most taxonomically and biologically diverse groups in the superfamily Chalcidoidea, with more than 3500 species and 618 genera described worldwide (Noyes 2015). Works on pteromalids focus mainly on taxonomy, host ranges and, more rarely, on some behavioural features. Studies concerning ecology or phenology are relatively rare (László 2001; László & Tóthmérész 2006; László & Tóthmérész 2011; Todorov *et al*. 2012). Furthermore, previous studies are mostly confined to a few species and rarely concern the pteromalid fauna as a whole (Hall *et al.* 2014). Until now, phenological data for some species from Bulgaria were reported by Pelov (1975), Thuróczy (1990), Georgiev & Stojanova (2006), Todorov (2011, 2013) and Todorov *et al*. (2014) but never for the entire pteromalid fauna in a certain area. The aim of the present study was to examine the composition of the pteromalid fauna at the generic level during the warm seasons in Vitosha Mountain by comparing the abundance of the major sampled genera and by analysing their diversity and phenology. This mountain was chosen as an appropriate area because it has vigorous grass habitats and gradually increasing elevation, thus providing habitats for a diverse insect fauna. The mountain is situated in the western part of Bulgaria within the European continental climatic region (Subev & Stanev 1959; Tishkov 1982). Three climatic zones are defined based upon the altitudinal changes in the mountain climate: low zone (up to 1450 m a.s.l.), middle zone (1450-1850 m a.s.l.) and high-mountain zone (above 1850 m a.s.l.) (Hristov 1959). The annual rainfall is between 771 mm (low zone) and 1252 mm (high-mountain zone). The mean temperatures in May range from 4°C to 10.7°C in the high-mountain zone and the low zone, respectively. In the warmest months, July and August, they range between 9°C (high-mountain zone) and 17°C (low zone; Hubenov 1990).

Materials and Methods

Sampling of insects

A minimum of three samples per month during the first, second and third decades were collected at every sampling site in May-September. We sampled 13 sites in the mountain, using cross sweeping along two perpendicular lines. Every line was 10 meters long and each sample was made by 10 plus 10 sweeping movements. Upon collection, the insects were preserved in 95% ethanol and dried using HMDS-method (Heraty & Hawks 1998). Taxa were identified following Graham (1969), Dzhanokmen (1978), Askew (1980), Doganlar (1985), Boućek & Rasplus (1991), Askew & Kennaugh (1992), Graham (1992), Heydon (1995), Dzhanokmen (1996), Bouček & Heydon(1997), Dzhanokmen (1999), Gibson (2009), Mitroiu (2010) and Rizzo & Mitroiu (2010). Most of the specimens have been deposited in the collection of the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences; a small number of mounted pteromalids will be deposited in the National Museums of Scotland (Edinburgh). All sample sites, habitats and zonal locations are included in Table 1. Habitat abbreviations are as follows: mdf - meadow in deciduous forest; mcf - meadow in coniferous forest; mmf - meadow in mixed forest; om - open meadow; sam - subalpine meadow.

Data analysis

All identified genera were analysed using their total abundance, i.e. the number of collected specimens of all species. The phenology of the pteromalid fauna was analysed in two ways: using the number of species per decade and the number of specimens per decade. In the first approach (number of species per decade), we included all identified species plus all taxa identified to generic level and considered as unidentified morphospecies. In the second approach (number of specimens per decade), all specimens of all genera were used to present the temporal dynamics in abundance of the pteromalid fauna. Thus, phenology was depicted by six simple curves, formed by data from 2010 and 2011 and from combined data from these years (Figs. 3 and 4).

Species diversity was determined using Fisher's alpha index of diversity $S=\alpha*\ln(1+n/\alpha)$, where S is the number of species, n is the number of individuals and α is Fisher's alpha. It was chosen because of its good discriminant ability and low sensitivity to sample size (Magurran 1988). All calculations of diversity were made to species level. Charts were prepared in Microsoft Excel 2010 and SigmaPlot 12 and were edited in Adobe Photoshop CS5.1.

Results

Generic composition and abundance

During 2010 and 2011 a total of 390 samples were collected comprising 4033 chalcidoid specimens. Among collected wasps, Pteromalidae amounted to726 specimens (18%). Of these pteromalids 511 were identified as 97 previously known species belonging to 42 genera (Todorov 2011, 2013; Todorov *et al*. 2014). In addition to these taxa, 31 remained unidentified: 17 species of *Chlorocytus*, seven of *Pteromalus* and one each of *Collentis*, *Colotrechnus*, *Gastrancistrus*, *Homoporus*, *Pseudocatolaccus*, *Stenomalina* and *Stinoplus* (total 69 specimens). Approximately 20% of the material (142 specimens) was identified to genus but their specific identity was uncertain. In summary, 45 genera were determined. The most abundant genus was *Mesopolobus* (168 specimens), followed by *Spintherus* (104 specimens) and *Chlorocytus* (103 specimens: Fig. 1). The most speciose genus in Europe, *Pteromalus* with 372

Table 1. List of the sample sites, with their habitat and zonal location

Locality	Coordinates	Elevation	Habitat	Zonal location
Mechkata area	42°38'16"N/23°13'24"E	1100	mdf	lower mountain
Belite Brezi hut area	42°37'17"N/23°13'41"E	1280	mdf	lower mountain
Zlatni Mostove	42°36'56"N/23°14'13"E	1429	mcf	lower mountain
W Malinka hut	42°36'02"N/23°13'45"E	1532	mcf	middle mountain
SW Ostritsa hut	42°35'14"N/23°12'24"E	1556	mmf	middle mountain
NW Selimitsa hut	42°34'30"N/23°12'07"E	1325	mmf	lower mountain
Shevovitsa area	42°32'25"N/23°20'54"E;	1224	om	lower mountain
Shevovitsa area	42°32'34"N/23°20'15"E	1432	mmf	lower mountain
Plachkovitsa area	42°32'43"N/23°19'45"E	1595	om	middle mountain
Karachair area	42°32'49"N/23°17'32"E	2160	sam	higher mountain
Marochki koshari area	42°30'59"N/23°15'35"E	1492	om	middle mountain
Shupni kamak area	42°30'08"N/23°15'12"E	1389	om	lower mountain
Elovitsa area	42°29'25"N/23°15'52"E	1227	om	lower mountain

described species (Noyes 2015), was represented by 87 specimens in our samples. Some taxonomically diverse genera, such as *Trichomalus*, *Gastrancistrus* and especially *Halticoptera*, were clearly underrepresented in the grassland habitats we studied with respectively only 48, 38 and 5 specimens. Only six genera were represented by more than 20 specimens whilst fourteen genera (*Miscogaster*, *Anogmus*, *Euneura*, *Holcaeus*, *Notoglyptus*, *Panstenon*, *Peridesmia*, *Psilonotus*, *Sphegigaster*, *Stinoplus*, *Synedrus*, *Tomicobia*, *Toxeuma* and *Spalangia*) were represented by singles specimens.

Diversity

Seasonal changes in the species diversity of the Pteromalidae are shown by Fisher's alpha diversity index. Values ranged between 2.8 and 28.1, the higher values occurring in May and July and the lower values in autumn (September).

Phenology

Analyses of both species richness and abundance had similar dynamics during the period May-September in the two years of study. It is clearly visible (Fig. 3) that the total number of species ("Total" curve) reached two peaks in the first decades of July and August, respectively. These peaks were almost equal in height and were separated from each other by a period of one month. The "2011" curve, depicting results for 2011 only, was very similar, but its second peak was observed one decade later. The "2010" curve differed significantly in having only one well-defined peak during the summer. Curves based on the number of specimens (Fig. 4) were similar and had two well-marked peaks at the same times in both 2010 and 2011.

Discussion

Generic composition and abundance

It is not surprising that the combined abundance of *Mesopolobus* was higher than that of any other genus because *Mesopolobus* includes a large group of species living in grassland habitats in the Northern hemisphere, associated especially with the phytophagous Eurytomidae. The other three dominant taxa, *Chlorocytus*, *Pteromalus* and *Trichomalus*, are also amongst the richest genera in northern Europe, containing tens or hundreds of species which attack principally phytophagous hosts in grasses and in stems and flower heads of herbaceous plants (especially Poaceae, Asteraceae and Fabaceae) of grasslands. *Chlorocytus* spp. are often parasitoids of *Tetramesa* (Eurytomidae), *Pteromalus* of Tephritidae and *Trichomalus* of Apionidae and Curculionidae. In a broad sense, their high abundance in the studied mountain areas was expected to some extent, but not clearly corresponds for *Pteromalus* and *Trichomalus*, which includes enormous number of European species. Other Pteromalidae with great European species diversity, such as *Halticoptera* (42 species), *Seladerma* (36 spp.), *Gastrancistrus* (69 spp.) and

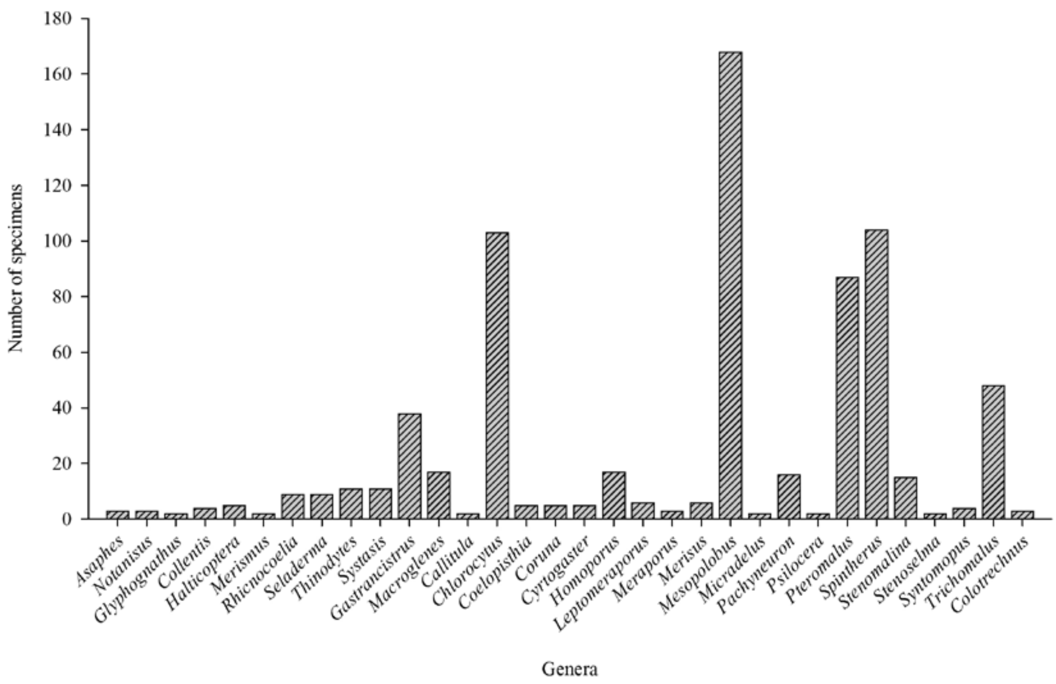

Fig. 1. Generic composition of the pteromalid fauna in the grasslands of Vitosha Mountain and comparison between taxa based on the number of collected specimens. Genera represented by one specimen only are not included.

Homoporus (35 spp.), were not numerous in our samples (Fig. 2), the former three probably because they are mostly associated with hosts in woodlands, shrubs and weeds in disturbed habitats. The relative under-representation of *Homoporus*, however, is rather surprising, as many species are known as parasitoids of *Tetramesa* and of other grass-associated hosts, such as Cecidomyiidae and Cephidae and of their primary hymenopteran parasitoids. Among genera represented by only one specimen, *Sphegigaster* (18 European species) and *Spalangia* (16 spp.) are clearly less abundant compared to the others. On the other hand, some small genera, such as *Rhicnocoelia*, *Thinodytes* and *Systasis*, are relatively numerous compared to other more diverse taxa. This is obviously demonstrated by monotypic *Spintherus*, represented by *Spintherus dubius* (Nees, 1834), which comprises slightly more than 14 % of all pteromalid material.

Results of the faunistic studies are related to the sampling method used. Sweeping in meadows is always very productive for insects, which develop in grasses or use them for shelter. Having in mind data for the biology of species from established genera and their relation to grasslands, we consider that most of the taxa compared in Fig. 2, have species that are at least partly associated with grassland habitats. Although some species-rich genera, such as *Mesopolobus* and *Pteromalus*, include species with various biological relations to hosts in trees (Askew 1995; Askew et al. 2001, 2013; Gómez et al. 2006; Yao & Yang 2008), there are also a number of species, which attack mining or gall-making hosts in grasses (Garrido Torres & Nieves-Aldrey 1999; Askew et al. 2001; Baur et al. 2007). However, sweeping in meadows is not likely to catch some pteromalids. Amongst the taxa in the studied material, such genera are certainly *Anogmus*, *Psilonotus* and *Spalangia*, the hosts of which live in a range of different habitats, respectively in coniferous trees (Picea), birch trees (Betula) and livestock manure. *Tomicobia* also is not typical of grassland due to its association with bark beetles (Noyes 2015). Nevertheless, we could conclude that Fig. 2 represents correctly the generic composition and the abundance of the specific pteromalid fauna in the grasslands of Vitosha Mountain and shows the dominating groups of the Pteromalidae in these mountain habitats.

Diversity

Species diversity, as measured by Fisher's Alpha Index (Fig. 2), was high at the commencement of sampling in May but then declined to the termination of sampling in September, with two peaks, the first peak in the third decade of June and the second in the first decade of August. In May the numbers of species and individuals were both low, no species being represented by a high number of individuals, so that species diversity was high. In June, up to the second decade, species numbers increased steadily but the number of individuals increased relatively rapidly so that diversity declined. The diversity peak in the third decade of June indicated a reduction of the difference between the number of species and of individuals with species numbers continuing to rise but numbers of individuals not increasing at the same rate. The peak in species numbers in the first decade of July corresponded with a fall in diversity as there was no matching increase in the numbers of individuals. In the first decade of August, species diversity reached a second peak with species numbers also increasing but with a proportionally smaller increase in individual numbers. Thereafter, till September, the curves for species diversity and species numbers mirrored each other as the numbers of individuals dropped away more rapidly than the numbers of species.

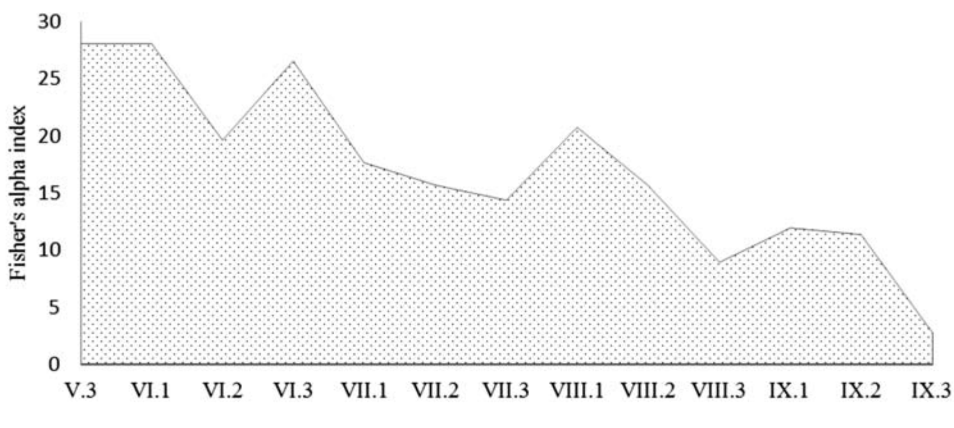

Fig. 2. Species diversity of Pteromalidae (Fisher's Alpha Diversity Index) from May to September.

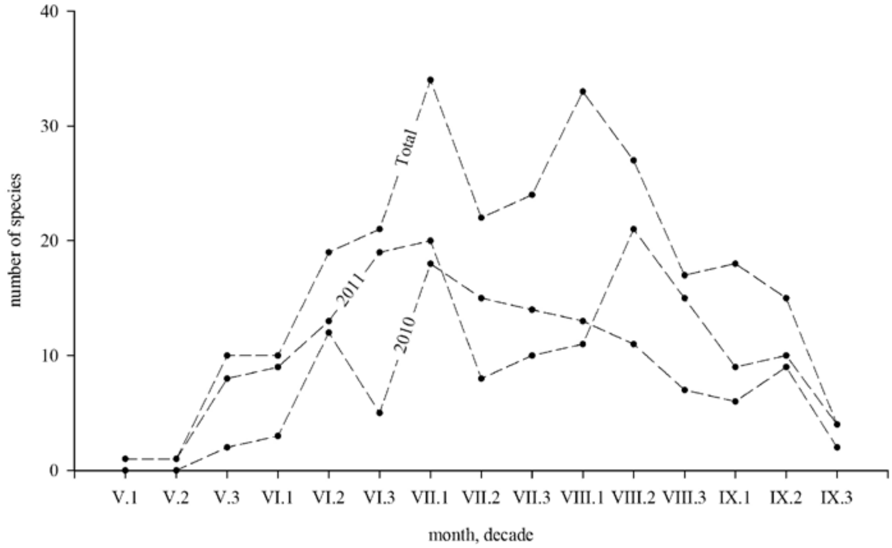

Fig. 3. Dynamics of the Pteromalidae species richness in Vitosha Mountain during the sampling period.

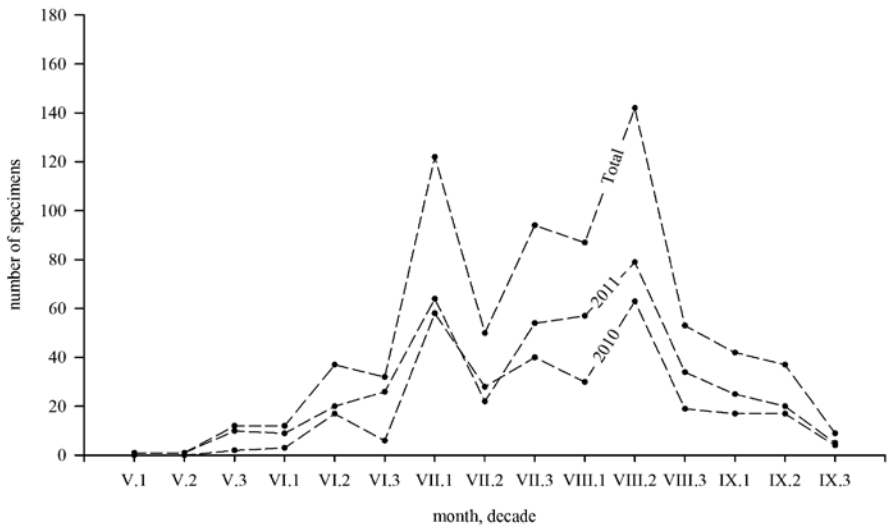

Fig. 4. Dynamics of the abundance of the Pteromalidae species in Vitosha Mountain during the sampling period.

Phenology

We found similar tendencies in species richness and abundance. The species richness increased more gradually before its first peak and later decreased more gradually after the second peak as compared to the abundance in the same periods. Moreover, established increases of the studied variables towards the second peak showed different dynamics: species richness had no an intermediate decrease at the first decade of August, whereas abundance showed such a decrease in 2010 and for averaged 2010 and 2011 data (Fig. 4, red and green curves). On the other hand, changes in the numbers of species during 2010 (Fig. 3, red curve) did not have a second peak in August but this minor variation had minimal effect on the averaged data (green curve). Although observed differences were apparent, they could not be explained without detailed studies of all species, including study of their biology, population density and adaptation to abiotic factors in their environment. However, the phenological dynamics presented here showed that the populations of most of the species developed more successfully during the period July-August, when the grasses were growing well. In this period habitats sustain diverse insect fauna and probably provide more hosts for parasitation.

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