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Use of the Malaise trap to assess the biodiversity of parasitoids (Hymenoptera: Eulophidae) in Israel

YEFREMOVA[1, 2] Z., KRAVCHENKO[1] V., STRAKHOVA[2] I., YEGORENKOVA[3] E.
[1]*Department of Zoology, The George S. Wise Faculty of Life Sciences, Tel-Aviv University, 69978 Tel-Aviv, Israel*
Email: vasiliy1953@yandex.ru
[2]*Department of Zoology, Ulyanovsk State Pedagogical University, Ulyanovsk, 432700, Russia*
Email:eulophids@mail.ru
[3]*Department of Geography, Ulyanovsk State Pedagogical University, Ulyanovsk, 432700, Russia*
Email:egorenkova80@mail.ru
Corresponding author: Zoya Yefremova (eulophids@mail.ru)

ABSTRACT

This article presents data on the species diversity of eulophids of Israel (63 species from 25 genera), *following* a one-year study using a Malaise trap. These data are compared with the existing material in Israel, identified over the course of 50 years (44 species from 27 genera). The use of the Malaise trap is a promising method, especially in areas with high aridity. The bimodal seasonal dynamics in the number of specimens was determined. The Shannon index of diversity (H) varies as does the number of specimens and species, diminishing in summer and increasing from October to January. The seasonal fluctuations in Eulophidae parasitoids were recorded in Israel for the first time. The reasons are discussed for these fluctuations, which are associated with a high level of biodiversity (H) and inhomogeneity (low J) in the Eulophidae.

KEYWORDS: Parasitic wasps, new records, fauna, Israel

INTRODUCTION

The Eulophidae is a large family of ecto and endoparasitoid wasps (0.5-2.0 mm in size). This group is represented in all zoogeographical regions, in all land ecosystems. The Eulophidae currently encompass 332 genera and more than 4500 species placed in 4 subfamilies as follows: Entiinae 17 genera and 148 species, Eulophinae 97 and 1316, Entedoninae 87 and 1307 and Tetrastichinae 91 and 1644 (Noyes, 2013). Eulophinae adults are free-living individuals. They are almost always sexually dimorphic, and females are considerably larger than the males. The larvae of most of

species are primary parasitoids on a huge range of insects at all stages of development. They are larval ectoparasitoids (Eulophinae, Euderinae), or endoparasitoids (Entedoninae and many Tetrastichinae) of concealed larvae, especially in leaf mines of Lepidoptera (Gracillariidae, Nepticulidae, Leucopteridae, Tischeriidae) (Bouček and Askew, 1968). Most of them are polyphagous, feeding on several species of leaf miners (Askew, 1971). Some are ectoparasitoids of leaf-mining flies: *Agromyza* sp., *Liriomyza* sp., *Phytomyza* sp., *Napomyza* sp., *Phytoagromyza* sp., *Cerodontha* sp. and *Chromatomyza* sp. (Diptera: Agromyzidae) (Bouček and Askew, 1968). Other eulophids attack gall-forming species of Cecidomyiidae (Diptera). Some are also hyperparasitoids of *Apanteles* sp., *Microgaster* sp. (Hymenoptera, Braconidae), *Diadegma trochanterata* (Thomson), *Ephialtes rufatus* Gm., *Phytodietus polyzonias* (Förster), *Scambus calobatus* (Gravenhorst) (Hymenoptera, Ichneumonidae) (Bouček and Askew, 1968). Fully-grown the larvae of these parasitoids pupate on leaves around their dead host (Gradwell, 1957; Yefremova and Michshenko, 2012, Yegorenkova and Yefremova, 2013). Overwintering is normally as a prepupa or pupa. Several species of eulophid are important in biocontrol programmes. The European species *Dahlbominus fuscipennis* (Zetterstedt) partially is responsible for the control of diprionid sawfly pests of pines in Europe (Yefremova, 2007). The species composition of the Eulophidae in Israel and their seasonal activity have not been particularly studied, though at least 44 species have been mentioned as entomophagous, with potential application for biological control (Avidov *et al*., 1963; Gerling and Limon, 1976; Avidov, 1970; Mendel *et al*., 1984; Mendel, 1986; Rubin and Kuslitzky, 1992; Mendel *et al*., 2004). Seasonal variation in the species composition and in the occurrence of the different species has never being investigated in Israel. Some of the material from this Malaise trap contained species of the genus *Elasmus* was published (Yefremova and Strakhova, 2012). Here, all the data on the species composition collected during a year are discussed together.

The main purpose of the current project was to collect eulophids using a Malaise trap, to identify them and to investigate the seasonal dynamics of parasitoids in Tel Aviv (the Mediterranean region) of Israel.

The accumulated data will serve for further systematic research on the eulophids of Israel.

MATERIALS AND METHODS

Location. The Malaise trap was installed in the Botanical Gardens of Tel Aviv University (32°06′13″N, 34°48′16″E), 2 km from the shore of the Mediterranean Sea.

Habitat. Seasonally dry with the sparse low grasses typical for the Mediterranean. The trap was oriented north-south, its head toward the west, and situated on a small hill surrounded by nectariferous bushes that bloom and attract insects almost year around: *Rhus tripartita* (Anacardiaceae) flowering from September to January; *Thymelea hirsuta* (L.) Endl. (Thymeleaceae) flowering from March to July; *Gymnocarpos decander* Forssk. (Caryophyllaceae) flowering from January to April; and

Fig.1. Malaise trap in the Botanical Gardens of Tel Aviv University, 27 July 2011.

Atriplex halimus (L.) (Chenopodiaceae) flowering from March to October.

Collection period. Malaise traps are easy to install and can capture insects over a long period. They are well suited for collecting small hymenopterans (Darling and Packer, 1988; Noyes, 1989) and in some habitats may be more efficient than net sweeping (Lookwood *et al*., 1996) as shown by Noyes (1989) in a tropical rainforest.

The Malaise traps used were modifications of Townes (1972) design and were placed on the ground in the herb-shrub layer (Fig. 1). The collecting jar with 75% alcohol was emptied twice to three times per month. Insect specimens were sorted under a Leica M80. All Eulophidae were labeled and identified by the authors.

Seasonal changes in species diversity were measured by Shannon index (H); the more diverse the community – the higher the index (Magurran, 2004). The evenness of the species community is represented by Pielou's evenness index (J), which quantifies how uniform the community is numerically (Magurran, 2004).

RESULTS

A total of 333 specimens belonging to 63 species from 25 genera of Eulophidae from 4 subfamilies were collected: Eulophinae – 22 species from 11 genera, 130 specimens (39.0% of total), Tetrastichinae – 23 species from 8 genera, 78 specimens (23.4%), Entedoninae – 16 species from 5 genera, 114 specimens (34.2%) and Entiinae – 2 species from one genus, 10 specimens (3.0%) (Table 1).

Table 1
Checklist and number of specimens (nn) of the Eulophidae collected by Malaise trap.

Species	nn	Species	nn
Subfamily Entedoninae		**Hemiptarsenus zilahisebessi* Erdös	1
**Chrysocharis submutica* Graham	8	**Hemiptarsenus ornatus* (Nees)	1
**Chrysocharis viridis* (Nees)	2	**Hemiptarsenus Hemiptarsenus unguicellus* (Zetterstedt)	5
Chrysocharis sp.	5	**Hyssopus nigritulus* Zetterstedt	1
**Closterocerus trifasciatus* Westwood	3	**Miotropis unipuncta* Thomson	1
**Chrysocharis gemma* (Walker)	18	**Platyplectrus desertus* Yefremova	24
Entedon costalis Dalman	1	**Pnigalio mediterraneus* Ferrière & Delucchi	1
Neochrysocharis formosa (Westwood)	19	**Sympiesis gordius* Walker	1
Neochrysocahris sp.1	3	**Zagrammosoma talitzki* (Bouček)	1
**Pediobius flaviscapus* (Thomson)	2	**Subfamily Tetrastichinae**	
**Pediobius lysis* (Walker)	1	**Aprostocetus caudatus* Westwood	5
**Pediobius metallicus* (Nees)	8	**Aprostocetus forsteri* (Walker)	2
**Pediobius nigritarsis* (Thompson)	2	*Aprostocetus hagenowii* (Ratzeburg)	5
**Pediobius pyrgo* (Walker)	29	**Aprostocetus lycidas* (Walker)	3
Pediobius saulius (Walker)	6	**Aprostocetus pausiris* (Walker)	4
**Pediobius crassicornis* (Thomson)	1	**Aprostocetus pygmaeus* (Zetterstedt)	4
Pediobius sp.1	7	*Aprostocetus* sp. 1	6
Subfamily Entiinae		*Aprostocetus* sp. 2	4
Euderus albitarsis (Zettersted)	10	*Aprostocetus* sp. 3	5
Subfamily Eulophinae		*Aprostocetus* sp. 4	7
**Cirrospilus staryi* Bouček	1	*Baryscapus crassicornis* (Erdös)	2
**Cirrospilus vitcola* (Rondani)	1	**Baryscapus daira* (Walker)	7
**Elachertus* sp.1	21	**Baryscapus evonymellae* (Bouché)	1
Elasmus aternalis Strakhova &Yefremova	34	**Baryscapus impeditus* (Nees)	5
**Elachertus charondas* (Walker)	4	*Baryscapus* sp. 1	2
**Elachertus fenestratus* (Nees)	2	*Baryscapus* sp. 2	3
Elasmus flabellatus (Fonscolombe)	14	*Baryscapus adalia* (Walker)	2
Elasmus nudus (Nees)	6	**Neotrichoporoides szelenyii* (Erdös)	1
Elasmus platyedrae Ferrière	2	**Oomyzus sempronius* (Erdös)	2
Elasmus steffani Viggiani	1	**Ootetrastichus crino* (Walker)	2
Elasmus viridiceps Thomson	4	**Sigmophora brevicornis* (Panzer)	1
Elasmus westwoodi Giraud	3	**Tamarixia* sp.1	2
**Euplectrus liparidis* Ferrière	1	**Tetrastichus* sp.1	3
		Total:	333

* – New record for Israel.

Most species were represented by fewer than 10 specimens. Only 8 species: *Elasmus aternalis* Strakhova & Yefremova, *Pediobius pyrgo* (Walker), *Platyplectrus desertus* Yefremova, *Elachertus* sp.1, *Neochrysocharis formosa* (Westwood), *E. flabelatus* (Fonscolombe), *Chrysocharis gemma* (Walker) and *Euderus albitarsis* (Zetterstedt) numbered between 10-34 individuals, and these comprised almost half (49.2%) of the total number of specimens collected.

The number of collected specimens and species varied similarly (Fig. 2). The number of specimens per two months varied from 9 to 152, reaching the highest values in winter (October to January), and dropping during summer (April to September). The number of species ranged from 6 to 28, in summer and winter respectively.

The Eulophidae community demonstrates seasonal variability at the species level (Fig.3). The Shannon index of diversity (H) varied similarly to the number of specimens and species. It is dropping in summer and rose in autumn and winter. Index of

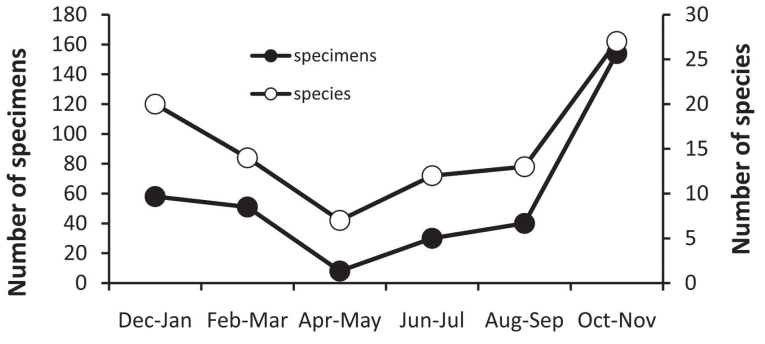

Fig. 2. Number of collected specimens and species along the season.

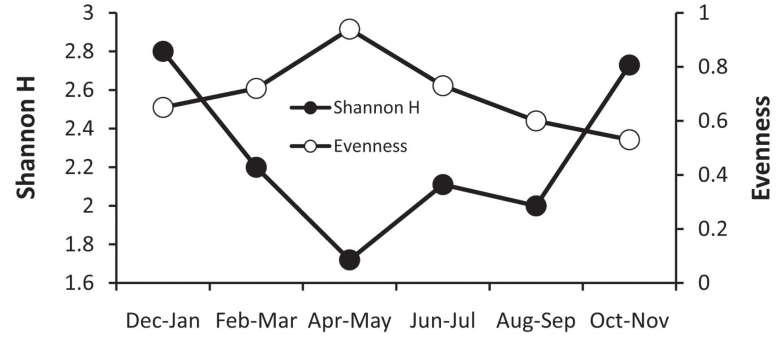

Fig. 3. Seasonal dynamics of species diversity (Shannon H) and evenness (e^H/S).

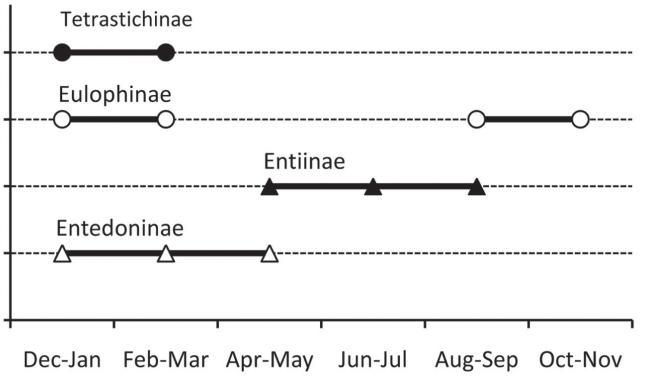

Fig. 4. The highest rate of occurence of species of the different subfamilies.

evenness (J) contrasted the Shannon index, ranging from 0.54 in winter to 0.94 in summer.

They also demonstrated seasonal variability at the subfamily level (Fig. 4). Tetrastichinae and Entedoninae appeared only in winter, species of Eulophinae mostly in autumn and winter, and Entiinae in the summer (April to September).

The rate of similarity between species assemblages for the different months was estimated using Spearman's non-parametric coefficient of correlation (Table 2).

The highest similarities (r = +0.96, +0.88; $p<0.01$) were detected between species communities during the summer months (April to September). During the period of the highest species diversity (October to March), the coefficient between months ranged from +0.55 to +0.58, still significant ($p<0.05$) but much lower than in summer.

Table 2
Spearman's coefficient of correlation between species assemblages for the different months.

	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov
Dec-Jan						
Feb-Mar	0.27					
Apr-May	0.41	**0.57**				
Jun-Jul	0.01	0.64	**0.96**			
Aug-Sep	**0.58**	0.17	**0.88**	0.45		
Oct-Nov	**0.55**	0	0.02	0.21	0.03	

Bold – coefficient is 0.5-0.8; bold and gray – coefficient is > 0.8.

DISCUSSION

Our one-year period of research of the eulophid fauna of Israel revealed 63 species from 25 genera of Eulophidae: Eulophinae (22 species from 11 genera, 15 species and 5 genera are new records), Tetrastichinae (23 species from 8 genera, 15 species and 5 genera are new records), Entedoninae (16 species from 5 genera, 10 species are new records), and Entiinae (2 species from one genus). So 40 species and 10 genera are new records for Israel (Table 1).

The number of species obtained using the single Malaise trap was shown to be even higher than the total number of species previously known in Israel (44 species from 27 genera) and derived from 50 years of collection by different methods, predominantly rearing and net sweeping. This indicates the efficacy of applying the Malaise trap to collect Eulophidae in arid areas, and the possibility of future detection of many new records of eulophids in Israel.

The total list of species of the eulophid fauna of Israel acquired by the use of other methods of research will be published in subsequent works. Along with the study of species composition, the present research allowed us to identify the best seasons for the study of species diversity in an area not previously investigated in regard to the seasonal dynamics of the abundance, not only for eulophids but also for chalcidoids as a whole.

Analysis of seasonal variation among Eulophidae, enabled by the Malaise trap, revealed that the highest number of species and specimens occurs in winter, while in summer it drops considerably. In the East Mediterranean winter (November-January) is characterized by the highest monthly precipitation (100.3-226.9 mm) and moderate temperatures (9°C to 17°C), while from April to September the temperature rises (24°C to 30°C) and precipitation is low (0.0-4.1 mm) (Israel Meteorological Service, 2011).

Consequently, early spring (February-March) in the Mediterranean region constitutes the period of highest rate of plant growth (Ne'eman and Goubitz, 2000), while also being the period of mass development of larvae of the phytophagous insects that host the Eulophidae parasitoids. This period is associated with a high level of biodiversity ("H") and inhomogeneity (low "J") among the Eulophidae. The summer drought suppresses plant growth, leading to impoverishment and homogeneity among species communities of phytophagous insects and the Eulophidae. Only one genus of the Entiinae was found in the summer, due to the presence their host (Coleoptera, Buprestidae). In late autumn (October-November) the number of Eulophidae rose again. These findings make it possible to accurately plan future research for those seasons when particular species of Eulophidae are numerous. This research, applying Malaise traps, offers a first step towards further study of species composition, in order to determine host-parasitoid relationships and in the study of tritrophic links.

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