

Ecological Patterns of European Lepidoptera: A Multifaceted Analysis of Non-Adult Stages and Parasitoid Communities

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Abstract

We examined 638 Lepidoptera specimens on the territories of 13 European countries in our search for parasitoids. We collected eggs, larvae and pupae. In total, 251 Lepidoptera species were identified, belonging to 169 genera from 30 families. Of the total sample, approximately one-third (32.23%) were parasitized. In 168 samples (26.42%), we identified only one parasitoid species per host. In addition to these data, 224 plant species from 114 genera were identified, of which the vast majority were feeding plants.

KEY WORDS: diversity, Lepidoptera, eggs, caterpillars, pupae, feeding plants, parasitoids

Introduction

There are approximately 157,761 lepidopteran species described in world fauna and they are classified into 131 families (Goldstein, 2017). According to the online data base Lepiforum (<http://www.lepiforum.de>), 10,543 species from 27 families are found in Europe. Although there are some studies regarding the diversity and spatial distribution of certain Lepidoptera species that are recorded as being present in a particular territory, there are errors. Some species were only occasionally found in the studied fauna although they do not actually develop in the specified area, regardless of the presence of host plants for their larvae or limiting climatic conditions. Such cases usually suggest that the species have been wrongly identified but could also be a result of the introduction of insects carried by the wind or through various human activities, such as transportation. One such example is the pine processionary moth, *Thaumetopoea pityocampa* (Denis & Schiffermüller) (Notodontidae), which was reported in central Serbia after the collection of several adults in light traps (Glavendekić, 2010; Glavendekić & Mihajlović, 2012). After that, the pine processionary moth was not recorded either by checking typically made caterpillar nests or by setting pheromone traps during 2016-2018 (personal work). Previous incidental findings leave the possibility that adults may have been transferred by wind to another territory. The second case was a single adult specimen of *Utetheisa pulchella* (L.) (Erebidae), collected with a light trap in the north of Serbia (Vajgand, 2012). Another good example is *Polyommatus escheri* Hübner, which was recorded in Serbia in various places far from its host plant (Popović & Verovnik, 2018).

The intention of the authors was to present an assemblage of numerous data on caterpillar samples collected on feeding plants. Originally, caterpillars were collected for rearing in laboratories in order to obtain parasitoids for trophic-chain investigations. We believe that the material is worth sharing with the scientific community, as it was collected over a period

of 30 years and contains a vast amount of data on caterpillars, their feeding plants, as well as their parasitoids. Such a massive exploration of non-adult diversity in the field has never been published before, especially for the eastern European region.

Materials and Methods

Different stages of Lepidoptera, mainly larvae, were sampled together with their feeding plants. Some of the plants were herbarized and identified by a botanist, while the remainder was used to feed the caterpillars. Sampling was carried out in 13 European countries, predominantly in eastern Europe (Fig. 1). The material was collected over a period of 30 years, from 1989 to 2019. For most of the individuals, photographs were taken and sent to experts for identification. A large number of caterpillars, as well as eggs and chrysalides, were grown in laboratory conditions, anticipating parasitoids in the case they were previously parasitized, or until death of the caterpillars or the emergence of lepidopteran imagoes. In these cases, we provided data on whether the individuals were parasitized, and the number of parasitoid species that emerged from them. Abbreviations of legators: AN = A. Nahirnić, AP = A. Petrović, BH = B. Hric, DD = D. Djordjević, DM = D. Marczak, H-PT = H-P. Tschorsnig, KK = K. Kos, ML = M. Lazarević, MIM = M. Ilić Milošević, MR = M. Ristić, NK = N. Kavallieratos, NKD = N. Kisić Dedić, NV = N. Veljković, OMI = Óscar Moreno Iriondo, PJ = P. Jakšić, SS = S. Stanković, SST = S. Stevčić, ŠM = Š. Modić, VŽ = V. Žikić, YML = Y. M. León, ŽT = Ž. Tomanović, [only initials: JF, ŽP, LV, LM, MK, AH, GU, JR, ST, TB, MV].

Results

The largest number of specimens is from Serbia (467), followed by samples from Greece (47), Slovenia (47), Montenegro (37), Poland (14), Spain (9), Austria (5), Croatia (4), Bulgaria (4), with one specimen each from Bosnia and Herzegovina, Italy, Sweden and UK (Table A1, Fig. 1). Summarizing all the findings, the total number of examined samples was 638. The number of registered lepidopterans was 251 species belonging to 169 genera from 30 families. We identified 224 plant species from 114 genera, of which the vast majority were feeding plants. Cases where caterpillars were found on plants that are not recorded in their diet menu are marked with an asterisk (*) in Table A1. The number of plant families was 47. Most of the samples were collected from plants of the Rosaceae family (134) with 14 genera and 33 species, followed by the Asteraceae family with 8 genera and 13 species and the Fabaceae family with 12 genera and 20 species.



Figure 1. Number of samples collected per country.

Eighty-six lepidopteran species were not found on feeding plants but on the ground or on bark, such as *Agrotis segetum* (Denis & Schiffermüller, 1775), *Thalpophila matura* (Hufnagel, 1766), in beehives – *Galleria mellonella* (Linnaeus, 1758), as well as in stored products and grains – *Plodia interpunctella* (Hübner, 1813). The vast majority of caterpillars were found as mature larvae in their final (L5) instar. In some cases, for the same species, all larval instars (L1-L5) and even pupae, were found, e.g., *Lymantria dispar* (Linnaeus, 1758), *Malacosoma neustria* (Linnaeus, 1758), *Saturnia pavoniella* (Scopoli, 1763), *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775), or all four species from the genus *Yponomeuta*.

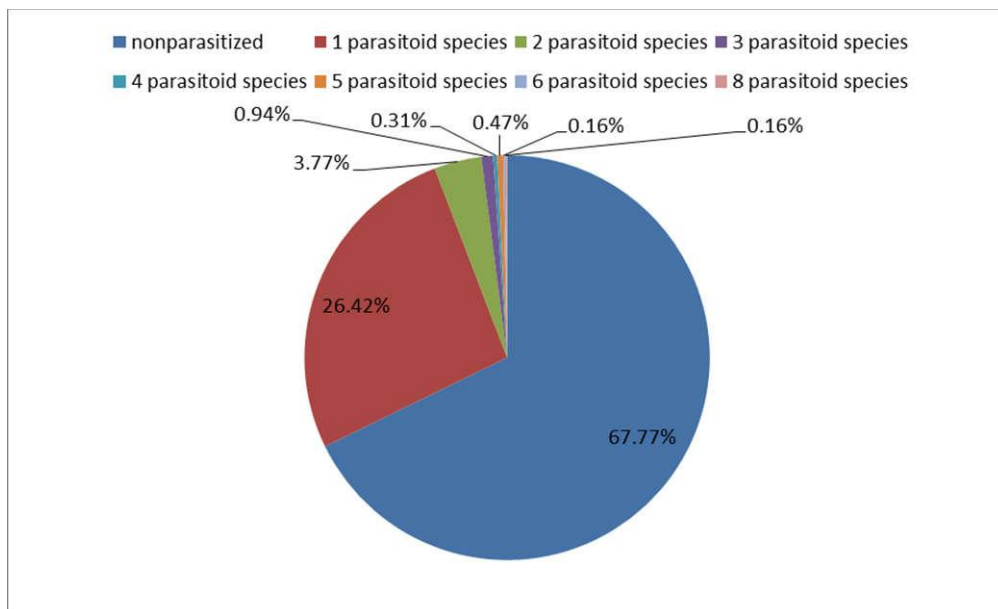


Figure 2. Number of parasitoid species collected per host displayed in percentage.

About two-thirds of the analyzed samples (67.77%) were either not parasitized or the hosts died before the parasitoids could leave their bodies (Fig. 2). In 205 cases, the larval or other stages were parasitized. The number in the last column in Table A1 shows the exact number of parasitoid species recorded, including primary and secondary parasitoids. This information refers to both hymenopteran (various superfamilies and families) and dipteran (fam. Tachinidae) species. For the vast majority of hosts (26.42%; 168 samples) we registered only one parasitoid species per host, or 2 parasitoids per host (3.77%; 24 samples). In 6 cases we found 3 different parasitoid species, such as in *Pleuroptya ruralis* (Scopoli, 1763), a species frequently found on common nettle. In the case of *Yponomeuta cagnagella* (Hübner, 1813), we identified 4 parasitoid species and 5 per the following lepidopterans: *Heterogynis zikici* de Freina 2018; *Y. malinellus* (Zeller, 1838) and *Y. padella* (Linnaeus 1758). The olive moth, *Prays oleae* (Bernard, 1788) was found to be parasitized with 6 parasitoid species. The most parasitoid species (8) were found in *Zygaena filipendulae* (Linnaeus 1758).

Discussion

Although most of the Lepidoptera samples were collected primarily in the search for their parasitoids, we used the opportunity to contribute to the knowledge about butterfly and moth fauna for the investigated territories. There is a strong need to collect precise data on lepidopterans in their immature stages, since this contributes to an understanding of their ecology and can help in removing these species from the checklist of a region in

which they do not breed, i.e., they are not native on the investigated territory. Following new trends in systematics and phylogeny, we tried to present as accurately as possible the systematics of Lepidoptera we analyzed and commented on. Nowadays the availability of molecular analyses, and in particular the use of the barcoding sequence of cytochrome oxidase 1 (COI), sheds new light on taxonomy, resulting in changes in the taxonomic status and/or names of many taxa. These changes elucidate trophic associations, the number of host plants per lepidopteran species and also the parasitoid spectrum.

In analyzing Table A1, it is noticeable that the gypsy moth *Lymantria dispar* and the lackey moth *Malacosoma neustria* occur in outbreaks. In Serbia, an outbreak of the gypsy moth occurred in 2013 and in Greece in 2016. An outbreak of the lackey moth was registered in the territory of Greece in 2016, where it was in direct competition with the gypsy moth (Žikić *et al.*, 2017).

We wish to point out that in addition to the 638 samples and 251 lepidopteran species presented here, we also collected and photographed more than 400 individuals that are as yet unidentified (currently identified to the family level). A large number of unidentified caterpillars belong to the group of "Microlepidoptera", in particular, twirler moths (Gelechiidae), blotch leaf miner moths (Gracillariidae), diamond-back moths (Plutellidae) and many more. We hope that once they are identified by experts, data will be published in forthcoming papers. For future studies, it may also be important to resolve whether unknown host plants recorded for some lepidopterans are new in their diet, and if not, provide definitive confirmation of accidental finding.

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