

Trophic relationships and mining seasons of the Nepticulidae of Lithuania: an updated survey

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This study provides updated summarised data on host-plant preferences and mining seasons of the Nepticulidae of the Lithuanian fauna. It revealed that the Lithuanian Nepticulidae are trophically associated with 34 genera and 14 families of host plants. Four of these host-plant families stand out in a number of mining Nepticulidae species and all together host about 80% of the Lithuanian Nepticulidae. As regards feeding specialisation, the fauna of the Lithuanian Nepticulidae consists of three constituents: monophagous species (about 44%), narrow oligophagous species (about 48%), and true oligophagous species (about 8%). There are two distinctive peaks of mining: the summer peak from mid-June until mid-July and the autumn peak from early September until mid-October, when most species mine simultaneously.

Keywords: leaf mines, Lepidoptera, Lithuanian fauna, pygmy moths

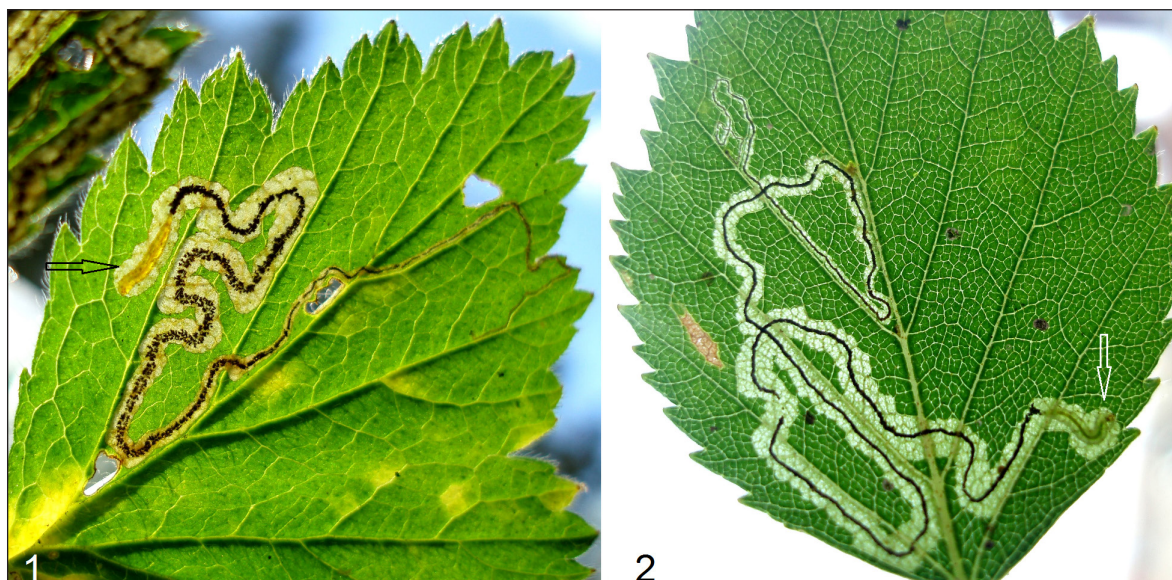
INTRODUCTION

Ecologically specialised Nepticulidae are probably among the most interesting families of the order Lepidoptera (Diškus, Stonis, 2012; Navickaitė, 2014; Navickaitė et al., 2014). The larvae of Nepticulidae are characterised by a mining mode of life in photosynthetic plant tissues: they produce leaf mines (Figs 1, 2) and rarely mine in other parts of plants. A great deal of useful information on morphological and ecological characteristics of the family can be found in monographs by Johansson et al. (1990), Puplesis (1994), Puplesis, Diškus (2003), and particularly Diškus, Stonis (2012).

The data on the ecology of the Lithuanian Nepticulidae were obtained by field collecting by Povilas Ivinskis, Saulius Pakalniškis (the former Institute of Zoology and Parasitology, Vilnius), Rimantas Puplesis, and later especially actively collected by Arūnas Diškus (the former Lithuanian University of Educational Sciences, currently Vytautas Magnus University).

One of the most prominent works on the ecology of the Lithuanian Nepticulidae published up to date is a monograph analysing the Lithuanian fauna of pygmy moths (Diškus, Stonis, 2012). Shortly after that the investigation of the Lithuanian Nepticulidae and their ecology was continued by a number of biology students and researchers: Asta Navickaitė (Navickaitė et al., 2014;

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Figs 1, 2. Leaf mines of Nepticulidae with feeding larvae. 1 – *Stigmella pretiosa* (Heinemann), a leaf mine on *Geum rivale*; 2 – *S. confusella* (Wood & Walsingham), a leaf mine on *Betula pubescens*

Navickaitė et al., 2014), Jolanta Rimšaitė, Povilas Ivinskis (Ivinskis et al., 2012; Ivinskis, Rimšaitė, 2013), Vilija Zeleniūtė (Zeleniūtė, 2015), Agata Skorb (Skorb et al., 2018), Brigita Paulavičiūtė (Paulavičiūtė, Inokaitis, 2018; Paulavičiūtė, 2020), and Inga Banytė (Banytė et al., 2020). Early this year, Stonis et al. (2022) published a review on the history of research into the Lithuanian Nepticulidae within the guide to leaf mines of these pygmy moths in Lithuanian.

Thus, some new data on the ecology and mining seasons of Nepticulidae were collected during the recent period of the investigation, and this updated survey is a brief review of the data on all currently known species of pygmy moths of the Lithuanian fauna.

MATERIALS AND METHODS

This study is based solely on the Nepticulidae fauna of Lithuania, which is part of the Baltic region and lies at the edge of the North European Plain, between latitudes 53° and 57°N and mostly between longitudes 21° and 27°E. Therefore, the studied Nepticulidae belong to the fauna of the temperate forest biome (Stonis et al., 2022). The review encompasses all 77

species of Nepticulidae currently known in Lithuania. For a full species checklist, see Stonis et al. (2022). The species known only from adjacent countries, including *Stigmella stettinensis* (Heinemann) (see Ivinskis, 2004; Sobczyk, van Nieukerken, 2021), are not included in the current count. *S. vimineticola*, a species previously recorded in Lithuania (Diškus, Stonis, 2016), is also excluded from the current biological survey until more evidence on the occurrence of this species in the country is received (Stonis et al., 2022).

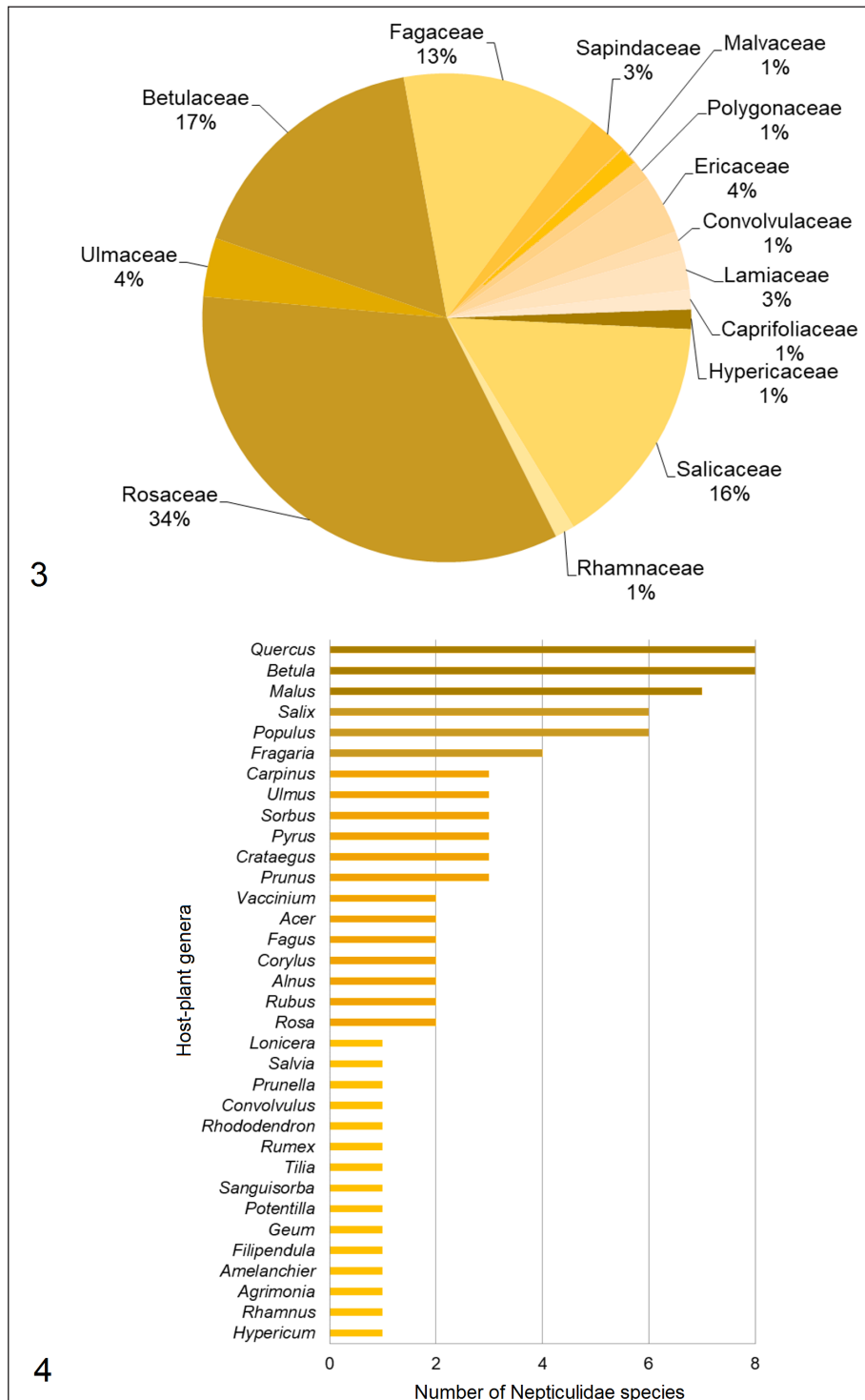
Because of some recent additions to the Lithuanian fauna and new ecological data (including new host plants) discovered by the authors, trophic relationships and the data on seasonal activity needed to be revised and updated. Having combined our data with the data published earlier (Diškus, Stonis, 2012), we produced a simple count illustrated with graphs and a data table.

As regards the methods of collecting ecological data on Nepticulidae, they were described in detail by Puplesis, Diškus (2003) and Diškus, Stonis (2012). All leaf mines of the studied sample of the Lithuanian Nepticulidae were illustrated in Stonis et al. (2022).

Tropical relationships of Nepticulidae recorded in Lithuania

According to the summarised data from the research conducted in Lithuania, the Lithuanian Nepticulidae are tropically associated with 14 host-plant families (Fig. 3) and

34 host-plant genera (Fig. 4). One third of all Lithuanian pygmy moths (34%) are tropically associated solely with the Rosaceae family. Many species of Nepticulidae also feed on Betulaceae, Salicaceae, and Fagaceae. These four plant families alone host 80% of all Nepticulidae species in Lithuania, whereas such plant



Figs 3, 4. Trophic relationships of the Lithuanian Nepticulidae. 3 – host-plant families; 4 – host-plant genera recorded for the fauna of the Lithuanian Nepticulidae

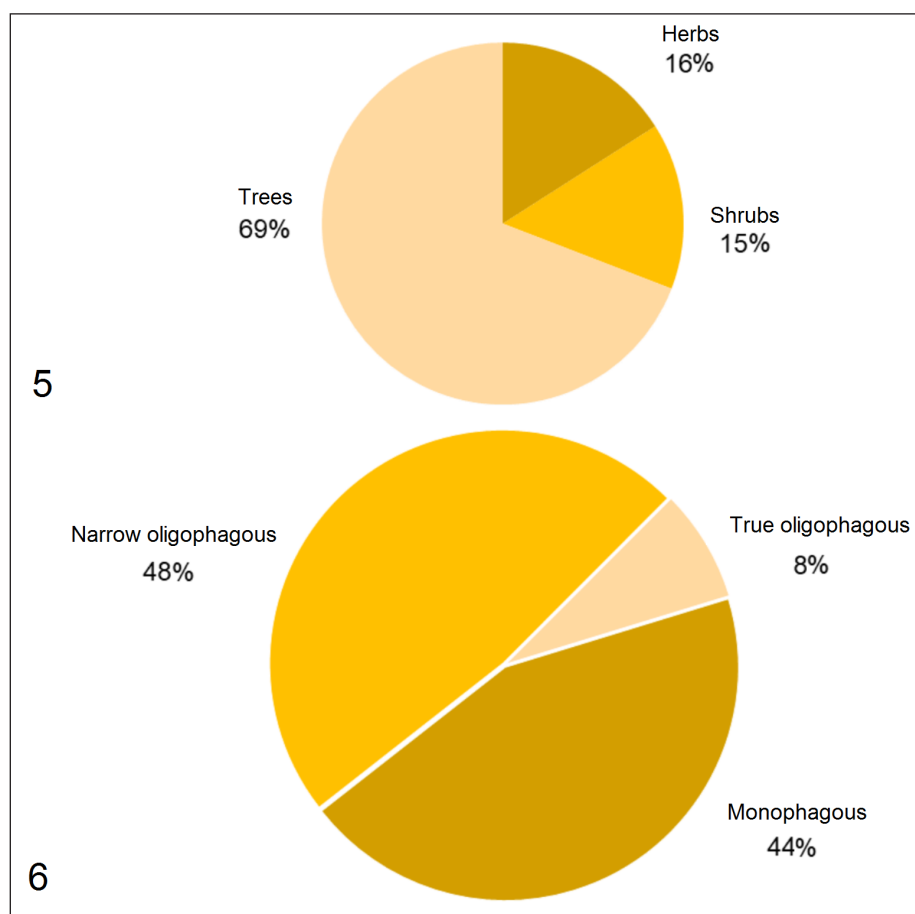
families as Malvaceae, Polygonaceae, Convolvulaceae, Caprifoliaceae, Hypericaceae, and Rhamnaceae host a single Nepticulidae species each. Although some of these plant families are not very common in Lithuania, it is not the only reason why Nepticulidae are uncommon on these families in this country.

A review of the data on the generic diversity of host plants showed that two plant genera were distinctly predominant, namely *Quercus* and *Betula*, each hosting eight Nepticulidae species in Lithuania. The analysis showed that at least four groups could be distinguished among the host-plant genera: (1) genera of host plants with 6–8 species of trophically associated Nepticulidae each; (2) genera of host plants with 3–4 species of trophically associated Nepticulidae each; (3) genera hosting 2 Nepticulidae species

each, and (4) genera hosting a single Nepticulidae species each (Fig. 4).

Most of the Nepticulidae in Lithuania are trophically associated with trees. Studies have shown that about 69% of Nepticulidae in this country are miners on trees, 15% on shrubs, and about 16% of species are trophically associated with herbs (Fig. 5).

Adults of pygmy moths do not feed, but their larvae feed and are 'typical' stenophagous species. The majority of them are monophagous or narrow oligophagous, and some are true oligophagous. The summarised data showed that monophagous species made up about 44% and various oligophagous species slightly more than half (56%) of the Lithuanian Nepticulidae fauna (Fig. 6). However, only a small proportion of them (about 8%) belong to the so-called



Figs 5, 6. Particularities of the biology of the Lithuanian Nepticulidae. 5 – predominance of Nepticulidae feeding on trees; 6 – predominance of monophagous and narrow oligophagous species

true oligophagous, and the remaining part, to the narrow oligophagous. The difference between narrow oligophagous and true oligophagous is small but still significant. While the narrow oligophagous feed on two or more species of plants closely related to each other, i.e., belong to one plant genus, true oligophagous feed on two or more species belonging to two or more plant genera of the same plant family (i.e., they feed on related genera). The data show that the latter are almost exclusively Rosaceae miners in Lithuania.

Narrow oligophagous are sometimes treated as part of monophagous species (Bernays, Chapman, 1994; Schoonhoven et al., 2005; Xu et al., 2021). Were this conception applied, then monophagous Nepticulidae species would comprise about 92% of the Lithuanian Nepticulidae fauna and oligophagous species about 8%. It should be emphasised here that since the authors of the article do not rely on the above conception of monophagous-oligophagous species, according to our data, the Lithuanian Nepticulidae fauna consists of three constituents in terms of feeding specialisation: monophagous, narrow oligophagous, and true oligophagous.

The data analysis did not show disjunct oligophagous and broad oligophagous within the Lithuanian Nepticulidae. The broad oligophagous feed on plants from two or more related families, while disjunct oligophagous feed on plants of two or more unrelated (distant) families. However, according to the currently available research data, such species are not characteristic of the Lithuanian Nepticulidae (i.e., no such species have been found).

Because Nepticulidae species are trophically related only to certain plants, the host-plant species, genus, or plant family are among the most important diagnostic characters for the identification of Nepticulidae species (Stonis et al., 2022).

Mining seasons of the Nepticulidae of Lithuania

As regards the development strategy, two-generation (bivoltine) species predominate among the

European pygmy moths (Johansson et al., 1990). Field observations show that, under favourable conditions, bivoltine species can become polyvoltine (Diškus, Stonis, 2012). Monovoltine species make up about a third of the country's Nepticulidae fauna, but their relative abundance varies across genera. There are quite many monovoltine species in the genus *Stigmella* Schrank, but within the Lithuanian fauna, monovoltine species are very characteristic of *Ectoedemia* Busck, *Glaucolepis* Braun, and *Bohemannia* Stainton (Diškus, Stonis, 2012).

The analysis of the summarised data showed that the larvae of Nepticulidae in Lithuania could be found from April until the end of October. However, both spring mining and late autumn mining is scarce (i.e., only very few species are mining) (Table). For example, the early, spring, species are *Ectoedemia atrifrontella* (Stainton), *Fomoria weaveri* (Stainton), and *Etainia sericopeza* (Zeller) (larvae of these species hibernate and continue mining in spring). The late, autumn, species include *Stigmella anomalella* (Goeze), *S. aeneofasciella* (Herrich-Schäffer), *S. atricapitella* (Haworth), *S. ruficapitella* (Haworth), *S. basiguttella* (Heinemann), *S. roborella* (Johansson), *Ectoedemia atrifrontella* (Stainton), *E. argyropeza* (Zeller), *E. turbidella* (Zeller), *E. intimella* (Zeller), *E. hannoverella* (Glitz), *E. klimeshi* (Skala), *Fomoria weaveri* (Stainton), and *Etainia sericopeza* (Zeller). It should be noted that a large proportion of these species are miners on oak and poplar.

Nevertheless, active mining, when many species of Nepticulidae mine simultaneously, begins in mid-June and lasts until mid-September in Lithuania (Table). The summarised data of our current and previous studies (Diškus, Stonis, 2012) allow identifying not only various seasonal cycles of the Lithuanian pygmy moths but also two distinct peaks in larval mining (Fig. 7). The first period of mining activity lasts from mid-June until mid-July, when more than half of all known species of Nepticulidae mine simultaneously; the second period of mining activity lasts from early September until mid-October, when even more species mine simultaneously. This autumn peak is not only higher

Table. Updated data on the mining seasons of the species of Nepticulidae in Lithuania

Species	Mining period (1, first half of the month, 2, second half of the month)														
	IV		V		VI		VII		VIII		IX		X		XI
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
1. <i>Johansoniella acetosae</i>					•	•	•	•	•	•	•	•	•		
2. <i>Stigmella lapponica</i>						•	•								
3. <i>S. confusella</i>					•	•	•	•							
4. <i>S. freyella</i>					•	•				•					
5. <i>S. tiliae</i>					•	•	•				•	•	•		
6. <i>S. microtheriella</i>					•	•	•	•	•		•	•	•	•	•
7. <i>S. betulicola</i>					•	•			•	•	•	•	•		
8. <i>S. alnetella</i>							•	•				•	•		
9. <i>S. luteella</i>								•	•	•	•	•	•		
10. <i>S. glutinosae</i>							•	•				•	•		
11. <i>S. nivenburgensis</i>						•	•				•	•	•		
12. <i>S. sakhalinella</i>						•	•				•	•			
13. <i>S. prunetorum</i>						•	•				•	•	•		
14. <i>S. aceris</i>					•	•	•	•	•	•					
15. <i>S. nylandriella</i>						•	•	•	•						
16. <i>S. oxyacanthella</i>										•		•	•	•	
17. <i>S. minusculella</i>						•	•		•						
18. <i>S. desperatella</i>										•	•	•	•	•	
19. <i>S. pyri</i>						•				•	•	•	•	•	
20. <i>S. crataegella</i>						•	•								
21. <i>S. magdalenae</i>						•	•	•	•						
22. <i>S. hybnerella</i>				•	•	•	•		•	•	•	•			
23. <i>S. anomalella</i>						•	•	•	•					•	•
24. <i>S. centifoliella</i>						•					•	•	•		
25. <i>S. catharticella</i>						•	•			•	•	•	•	•	
26. <i>S. malella</i>					•	•		•	•	•	•	•			
27. <i>S. viscerella</i>												•	•		
28. <i>S. ulmivora</i>									•	•					
29. <i>S. sanguisorbae</i>										•	•				
30. <i>S. trimaculella</i>						•	•					•	•	•	
31. <i>S. assimilella</i>								•	•	•	•	•			
32. <i>S. salicis</i>						•	•	•			•	•	•		
33. <i>S. myrtillella</i>						•	•				•	•	•		
34. <i>S. obliquella</i>						•	•				•	•	•		
35. <i>S. zelleriella</i>						•	•					•	•		
36. <i>S. benanderella</i>					•	•	•	•	•	•					
37. <i>S. floslactella</i>					•	•	•	•	•			•	•		
38. <i>S. tityrella</i>						•	•					•	•		

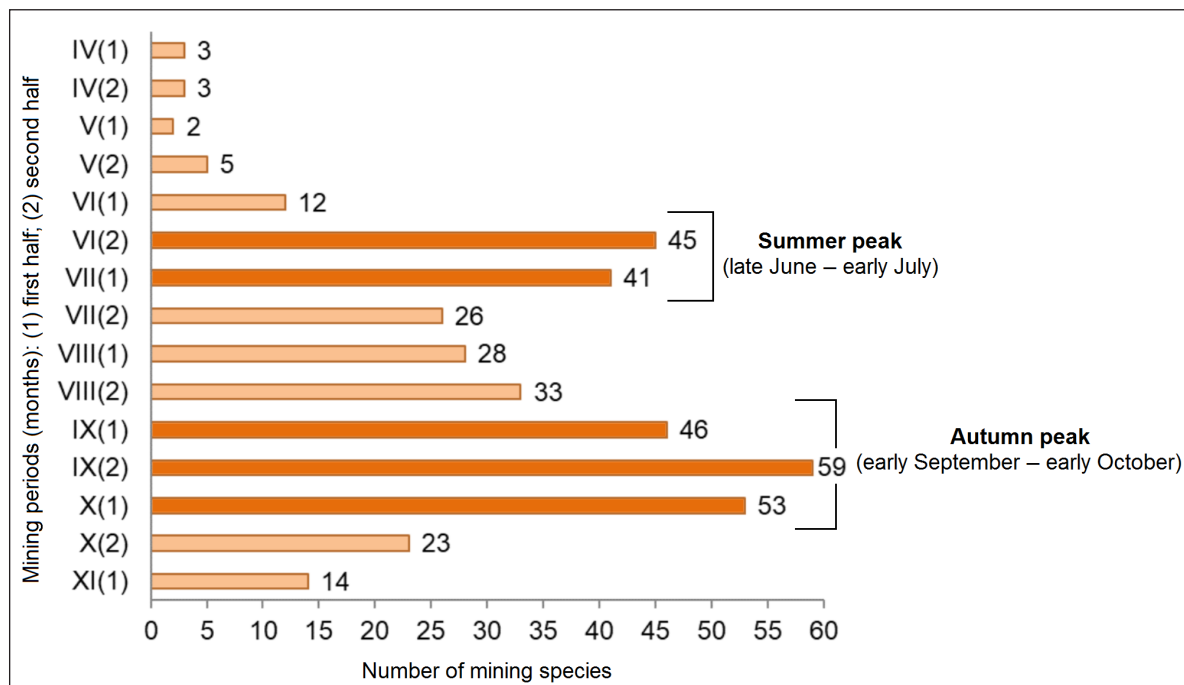


Fig. 7. Two seasonal mining peaks of the Lithuanian Nepticulidae

in the number of mining species but also in a significantly larger abundance of larvae (the highest peak of mining during the year).

CONCLUSIONS

1. The Lithuanian Nepticulidae are trophically associated with 34 genera and 14 families of host plants; four of these host-plant families, Betulaceae, Salicaceae, Fagaceae, and especially Rosaceae, clearly stand out in a number of mining Nepticulidae species and all together associate about 80% of the Lithuanian Nepticulidae. The majority (about 69%) of pygmy moths of Lithuania are trophically associated with trees, 15% with shrubs, and about 16%, with herbs (Fig. 5).

2. Regarding specialisation, the fauna of the Lithuanian Nepticulidae consists of three constituents: monophagous species (about 44%), narrow oligophagous species (about 48%), and true oligophagous species (about 8%).

3. Although the larvae of the Lithuanian Nepticulidae mine from April until the end of October, active mining, when numerous species of Nepticulidae mine simultaneously, lasts

from mid-June until mid-September in Lithuania and has two distinctive peaks: the summer peak from mid-June until mid-July and the autumn peak from early September until mid-October, when most species mine simultaneously.

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LIETUVOS NEPTICULIDAE MITYBINIŲ RYŠIŲ IR MINAVIMO SEZONIŠKUMO APŽVALGA

Santrauka

Remiantis apibendrintais tyrimų duomenimis, Lietuvos mažieji gaubtagalviai (Nepticulidae) yra trofiškai susiję su 34 mitybinių augalų gentimis, priklausančiomis 14 augalų šeimų, iš kurių gausiausios minuotojais (apie 80 % Nepticulidae rūšių) yra Betulaceae, Salicaceae, Fagaceae ir ypač Rosaceae šeima. Tarp mitybinių augalų genčių pagal minuojančių Nepticulidae rūšių skaičių išskirtos keturios grupės; dvi augalų gentys (*Quercus* ir

Betula) yra daugiausiai minuojamos (su kiekviena šių augalų genčių yra mitybiškai susiję po aštuonias mažųjų gaubtagalvių rūšis). Dauguma mūsų šalies Nepticulidae yra trofiškai susiję su sumedėjusiais augalais (apie 69 % Nepticulidae faunos). Trofinės specializacijos požiūriu Lietuvos Nepticulidae fauną sudaro trys komponentai: monofagai (apie 44 % Lietuvos Nepticulidae faunos), vienalyčiai oligofagai (apie 48 %) ir tikrieji oligofagai (apie 8 %). Nors Lietuvoje minuojančių Nepticulidae vikšrų gali būti aptinkama nuo balandžio iki spalio mėnesio pabaišos, tačiau aktyvus minavimas, kai vienu metu minuoja daug Nepticulidae rūšių, Lietuvoje prasideda nuo birželio vidurio ir tęsiasi iki rugsėjo vidurio. Nustatyti du gausiausio vikšrų minavimo periodai: nuo birželio vidurio iki liepos vidurio ir nuo rugsėjo pradžios iki spalio vidurio, jų metu minuoja daugiausiai Lietuvos Nepticulidae rūšių.

Raktažodžiai: lapų minos, Lepidoptera, Lietuvos fauna, mažieji gaubtagalviai