UNIVERSITY OF WEST HUNGARY

DOCTORAL (PHD) THESIS

Ecological comparison of moth communities among different age Sessile oak-hornbeam forests

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1. Introduction

Forests are one of the most complex terrestrial ecosystems on the Earth. In these habitats a large mass of herbivores is represented by Lepidoptera, they have an important role in the maintenance of forest biodiversity. In Hungary, oak forests have a high species richness of insect herbivores. The forests' diversity is strongly influenced by vegetation and the forests structure. The heterogeneity of forest structure can increase the forest stability and reduce the pests' disease. In the last few decades the forest management mainly focus on the economic importance of forests instead of the maintenance of ecological stability. However, thinning even may have a positive effect on forest Lepidoptera. The method and intensity of thinning are differ in each forest type and age and may have an effect on Lepidoptera communities as well. The goal of recent examination was that get information about the change of Lepidoptera communities in Hungarian sessile oak-hornbeam forests among the time, thinning and vegetation traits. In recent study the author has investigated the following questions:

1. Similarity and difference of Lepidoptera communities between different age sessile oak-hornbeam forests.
2. How can the vegetation layers influence Lepidoptera communities in sessile oak-hornbeam forests?
3. Which processes can influence Lepidoptera communities in sessile oak-hornbeam forests?

2. Material and method

Study area and sampling sites

The investigation was conducted in in the Sopron Mountains in the Lower Austroalpides. Approximately 90% of the area is forested. After 1850, many indigenous forests were replaced by pine cultures, and the proportion of the deciduous forests continually decreased until the 1980's. Increasing of broadleaf trees' proportion has started after 1980's that partly caused by the damage of Norway spruce. The tree species composition in the Sopron Mountains still has been continuously changing.

The survey was performed in the Hungarian side of the Mountain and focused on 15 sessile oak-hornbeam forest stands. Study sites were selected in five different stand ages with three forest stands per age-class (I.: 106-115 years; II.: 81-84 years; III.: 66 years; IV.: 45-51 years; V.: 11-16 years). Sampling sites were dominated by *Quercus petraea* agg. In the tree layer further deciduous and coniferous species were also present. The main criteria for the sampling sites selection were the low proportion of pine trees; furthermore avoid any management practice in the forests during the investigation (2011-2012).

Moth sampling

Lepidoptera species were collected using portable light traps installed with UV light sources (using 3 W LED, peak wavelength 400–410 nm, operated by a 4.5 V battery). Traps were activated before sunset and switched off after sunrise. Samplings were conducted 15 times annually in 2011 and 2012 from the end of March until early November. Two traps were used in each forest stand, positioned on the ground at least 30 m apart from each other to prevent the light from interfering between them. Summarized 60 samples were collected from each site. Traps were taken onto the same plot and sampling ceased during heavy rain. The attraction radius of the 3W light source was assumed less than 20 m (based on the literatures).

Attracted moths were euthanized using ethyl acetate as a killing agent inside the traps. The collected Lepidoptera specimens were kept frozen until identification. Most of the individuals were identified by macro-morphological features. *Eupithecia* spp., *Mesapamea* spp. and damaged specimens were dissected to examine genitalia for species identification.

Data analysis

Different groups of Lepidoptera communities were used for data analysis, such as:

- The full observed Lepidoptera assemblages.
- Taxonomic groups: *Macroheterocera* and *Microheterocera*.
- Ecological groups, based on the moths' foodplants: (i) tree-feeding Lepidoptera, (ii) Lepidoptera, which develop on the under-layer vegetation, (iii) shrub-feeding Lepidoptera and (iv) herb-feeding Lepidoptera.

Data analysis was made by the following statistical methods:

a. Community and ecological characteristics:
    - Rarefaction curves with the extrapolation of data (using Michealis-Menten extrapolation model).
    - Species richness and abundance.

- Dominant species: dominance index and community dominance index.
- Rank-abundance analysis.
- Diversity indices: Shannon index, Simpson index, Pielou's equitability index.

b. Comparison of Lepidoptera communities:
- Comparison of abundance: using t-test, one-way ANOVA and Tukey's HSD-test.
- Diversity comparison: using Rényi's diversity ordering.
- Species similarity indices: using Jaccard index and Bray-Curtis index. Similarity was displayed by cluster-analysis.

c. Influence of forest traits on Lepidoptera communities:
- Principal Component Analysis (PCA): to condense forest parameters for further analysis.
- Correlation analysis: using linear correlation model (Pearson's r) to evaluate the relation between principal components and Lepidoptera communities.

3. Summary of results and thesis

Total of 71595 Lepidoptera individuals were collected, belonging to 926 species. The species richness and abundance of *Macro-* and *Microlepidoptera* significantly differed. Diversity-analysis show various results, neither the diversity indices (Shannon, Simpson, Pielou), nor the diversity ordering (Rényi's ordering) gave clear conclusion. Based on the calculated diversities, however species richness and abundance of vegetation are influence moth communities, the vegetation have no obligate role for the Lepidoptera diversity.

Lepidoptera species-similarity indices divided on two larger groups of the investigated forest age-classes. The youngest forests (V. age group: 11-16 years old) are often created a separated group from the further forest ages. Most of the comparisons showed the highest similarity between III. (66 years old) and IV. (44-51 years old) age-classes.

Community and ecological indices neither showed clear relation between the age of forests and Lepidoptera communities. Further analyses were made based on the forests' vegetation and thinning history. To avoid distortions of investigated environmental parameters, canopy-layer and site traits were condensed by principal component analysis (PCA). Four principal components (Eigenvalue>1) were used for simple linear regression to evaluate the relative impact of forest stand traits on Lepidoptera communities. The analysis showed significant correlation between PC's and moth assemblages in 12 cases. PC1 (weighted toward the thinning history parameters) was in a moderate positive correlation with the abundance of moth. However, Microlepidoptera community was in a moderate-strong negative correlation with PC1. PC4 (weighted toward the canopy cover factors) was in a moderate negative correlation with some group of Lepidoptera that can be explained by the higher closure of canopy layer.

Thesis of the dissertation

1. The author has found Lepidoptera species that new for the Sopron Mountains.

The Lepidoptera fauna around Sopron is well-known, presence of 794 Macrolepidoptera species have been published. In spite of the intensively studied fauna in the region, the author found 13 moth species that previously have not published from the Sopron Mountains: *Jodis putata*, *Idaea inquinata*, *Cyclophora pendularia*, *Eulithis populata*, *Nudaria mundana*, *Catocala nymphagoga*, *Catocala promissa*, *Catocala sponsa*, *Diachrysia stenochrysis*, *Callopistria juventina*, *Auchmis detersa*, *Hada plebeja*, *Dichagyris flammatra*. The occurrence of *Jodis putata* and *Dichagyris flammatra* has a high importance in the Sopron Mountains.

2. The species richness and abundance of Macrolepidoptera were significantly higher compare to Microlepidoptera.

A larger part of the Hungarian Lepidoptera fauna is presented by micromoths and they cover a wide range scale of ecological parameters. However, both the species richness and abundance of detected micromoth were significantly lower compare to the macromoth.

3. The complex vegetation is an important factor for moth assemblages in the investigated sessile oak-hornbeam forests, but vegetation layers per se have not determined significantly the Lepidoptera communities.

The relation between vegetation layers and moth communities was induced by the species richness and cover of plants. However, this relation was not clear in every case. The highest species richness of Lepidoptera often was detected in the IV. age class. In these sites a high species richness of herb-feeding Lepidoptera was detected among the high species richness of herb species. However, the shrub layer’s cover has not influence the species richness of shrub-feeding Lepidoptera. The species richness of tree-feeding Lepidoptera was the highest in IV/A site, but canopy closure was higher in IV/B site, so it neither showed a clear relation between moth and vegetation layers. The lowest species richness of herbs and herb-feeding Lepidoptera were in the V. age class that also support the relation between vegetation and Lepidoptera communities.

4. The vegetation's cover has an effect on moth diversity in the investigated sessile oak-hornbeam forests, but vegetation layers per se have not determined significantly the Lepidoptera diversities.

Based on the diversity ordering, the I. and IV. forest age-groups often have the highest Lepidoptera diversities. In the I. age-class the canopy closure was lower, while the cover of herb-layer was higher, that related with the Lepidoptera diversities: tree-feeding Lepidoptera have lower, herb-feeding Lepidoptera have higher diversities. In the IV. age-class the canopy cover was higher that related with the higher diversities of tree-feeding Lepidoptera. However the diversities of herb-feeding Lepidoptera related with the herb species richness.

Nevertheless, the diversity ordering did not always show clear relation between the vegetation (species richness and abundance) and the Lepidoptera communities. The ranking of young forests (V. age-class) diversity to the further forest ages was not possible.

5. The investigated forest age classes were divided on two groups, based on the Lepidoptera species similarity indices, but it was not fully explain the relation between the forests' age and moth communities.

Lepidoptera species similarity between forest age-classes (Jaccard and Bray-Curtis indices) were displayed on cluster diagrams. The youngest forest group (V.) often separated from the older forests, except the species similarity of micromoths and dominant species. The highest similarity usually was between III. and IV. forest age-classes. However, these results were not shown by every cluster diagrams, so the relation between forest age and Lepidoptera species similarity was not clear.

6. The forest stand age per se is not influence significantly the investigated forests' Lepidoptera communities.

Lepidoptera communities between the investigated forest age-classes were compared by community and ecological characteristics: species richness, abundance, Shannon- and Simpson diversity indices, Pielou's equitability index and species similarity indices (Jaccard and Bray-Curtis). The goal of these analyses was to establish a rank between forest age-classes, but it was not possible. Some community and ecological characteristic of Lepidoptera show significant difference, but it was not always clear to the ranking. Some results rather support the relation between vegetation and moth assemblages.

7. The author has found a positive correlation between PC1 (weighted toward the thinning history parameters in each forest) and Lepidoptera communities in the investigated sessile oak-hornbeam forests.

The PC1 (weighted toward the thinning history parameters in each forest) and Lepidoptera communities were in a moderately positive correlation. It supports that number and intensity of thinning (in short time scale) can increase the abundance of Lepidoptera. After thinning the occurring microhabitats will be populated by species, which have good vagility that can support the increasing abundance of Lepidoptera.

8. The PC1 (weighted toward the thinning history parameters in each forest) has different effect on the abundance of Macro- and Microlepidoptera.

The abundance of macromoths – similar to the full Lepidoptera communities – was in a moderately positive correlation with PC1. However, the abundance of micromoths was in a moderately or strongly negative correlation with PC1. It can be explained by the different vagility of Macro- and Microlepidoptera. After thinning the occurring microhabitats will be populated by species, which have better vagility, like most of the macromoths. Most of the micromoths have worst vagility and the thinning can cause the decrease of theirs abundance (in short time scale).

9. The canopy-layer's and shrub-layer's cover influence the species richness and diversity of Lepidoptera in the investigated sessile oak-hornbeam forests.

The species richness of micromoths and tree feeding Lepidoptera, the Shannon and Simpson diversity of shrub-feeding Lepidoptera and the abundance of herb-feeding Lepidoptera were in a moderately negative correlation with PC4 (weighted toward the vegetation cover factors). The high closure of canopy-layer causes a lower cover and structural diversity of underlayer vegetation; due to this the species richness and diversity of shrub- and herb-feeding Lepidoptera decrease.

4. Relevant publications

Papers

1. Horváth B. & Lakatos F. (2014): Éjszakai nagylepkék diverzitásának vizsgálata különböző korú gyertyános-kocsánytalantölgyes erdőállományokban. Erdészettudományi Közlemények 4 (1): 185–196.
2. Horváth, B., Tóth, V. & Kovács, Gy. (2013): The Effect of Herb Layer on Nocturnal Macrolepidoptera (Lepidoptera: Macroheterocera) Communities. Acta Silvatica et Lignaria Hungarica 9: 43–56.
3. Horváth, B. (2013): Különböző erdőállományok diverzitásának összehasonlítása az éjszakai nagylepke közösségek alapján (Lepidoptera: Macroheterocera) fénycsapdák alkalmazásával. Erdészettudományi Közlemények 3: 229–237.

4. Horváth B. (2013): Diversity comparison of nocturnal macrolepidoptera communities (Lepidoptera: Macroheterocera) in different forest stands. Natura Somogyiensis 23: 229–238.
5. Szalóki D., Horváth B., Merkl O. (2012): First record of *Ripidius quadriceps* and data of the other wedge-shaped beetles in Hungary (Coleoptera: Ripiphoridae). Folia Entomologica Hungarica 73: 35–43.
6. Sáfián Sz., Ambrus A., Horváth B. (2009): Új fajok Sopron környékének éjjeli nagylepkefaunájában (Lepidoptera: Macroheterocera). Praenorica Folia historico-naturalia XI: 189-201.

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2. Horváth B. (2011): Védett lepkék vizsgálata (Védett és/vagy veszélyeztetett állat- és növényfajok populációgenetikai vizsgálata, védett rovarok és védett erdők (erdőrezervátum és Natura 2000 területek) részprojekt). Támop 4.2.1.b-09/1/KONV Szellemi, szervezeti és K+F infrastruktúra fejlesztése a Nyugat-magyarországi Egyetemen projekt, Természeti örökségünk megőrzése és fenntartható hasznosítása alprojekt műhelytalálkozója, Sopron.
3. Horváth B. (2011): Különböző korú erdőállományok ökológiai szempontú összehasonlító vizsgálata az éjszakai lepkék alapján (Módszertani alapok, valamint biotikus és abiotikus tényezők hatása a lepkékre). Doktoranduszok Tudományos Konferenciája az Erdőmérnöki Karon, Sopron.

Conference posters

1. Horváth, B., Tóth, V., Kovács, Gy. (2013): The effectt of herb-layer on nucturnal macrolepidoptera (Lepidoptera: Macroheterocera) communities. Poster, 18th European Congress of Lepidopterology, 2013. 07. 29-08. 03., Blageovgrad, Bulgaria.
2. Horváth B., Sáfián Sz., Winkler D. (2009): Éjjeli nagylepkék, mint a biológiai diverzitás indikátorai a hazai erdőállományokban. 8. Magyar Ökológus Kongresszus, természetvédelmi ökológia alszekció, Szeged, 2009. augusztus 27.

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1. Horváth, B., Tóth, V., Kovács, Gy. (2013): The effectt of herb-layer on nucturnal macrolepidoptera (Lepidoptera: Macroheterocera)

communities. In: XVIII European Congress of Lepidopterology Programme and Abstracts, p. 42.

2. Horváth B. (2011): Különböző korú erdőállományok ökológiai szempontú összehasonlító vizsgálata az éjszakai lepkék alapján (Módszertani alapok, valamint biotikus és abiotikus tényezők hatása a lepkékre). In: Lakatos F., Polgár A., Kerényi-Nagy V. (szerk.) (2011): Tudományos Doktorandusz Konferencia, Konferencia-kötet, Nyugat-magyarországi Egyetem, Erdőmérnöki Kar, 141-143 p.

5. Non-relevant publications

Papers

1. Sáfián Sz, Ambrus A., Horváth B. & Horváth Á. (2012): A sárga gyapjasszövő – *Eriogaster catax* (LINNAEUS, 1758) – Sopron környéki élő-helyei és állományainak természetvédelmi helyzete (Lepidoptera: Lasiocampidae). Szélkiáltó 15: 54−56.
2. Horváth B., Szentirmai I. & Sáfián Sz. (2012): Segítik-e az agrár-környezetgazdálkodási programok a nappali lepkék védelmét? Esettanulmány az Őrségi Nemzeti Parkból. Szélkiáltó 15: 57−59.
3. Sáfián Sz., Szentirmai I., Horváth B. & Davey, P. (2012): A lápi tarkalepke – *Euphydryas aurinia* (ROTTEMBURG, 1775) – állomány-térképezésének eredményei az Őrségi Nemzeti Park területén. Szélkiáltó 15: 51−53.
4. Horváth B., Sáfián Sz., Kovács Gy. (2012): A Koppányvölgyi lepkefauna (Lepidoptera) vizsgálatának első eredményei. Natura Somogyiensis 20.
5. Sáfián Sz., Horváth B. (2011): A selyemfényű puszpángmoly – *Cydalima perspectalis* (Walker, 1859) (Lepidoptera: Crambidae), egy potenciális kertészeti kártevő megjelenése Magyarországon. Növényvédelem 47 (10): 437-438.
6. Sáfián Sz., Horváth B. (2011): *Cydalima perspectalis* (Walker, 1859), new member in the Lepidoptera fauna of Hungary (Lepidoptera: Crambidae). Natura Somogyiensis 19: 245-246.
7. Ambrus A., Kiss Sz., Sáfián Sz., Horváth B., Horváth Á. (2010): A Sárga gyapjasszövő – *Eriogaster catax* (Linnaeus, 1758) európai jelentőségű populációja Váton (Lepidoptera: Lasiocampidae). Natura Somogyiensis 17:293-298

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(2012): Nappali lepke atlasz / Atlas dnevnih metuljev / Butterfly atlas Őrség-Goricko (Ábrahám L szerk.). Őriszentpéter, 248 pp.

2. Tuba K., Horváth B., Lakatos F. (2012): Inváziós rovarok fás növényeken. Nyugat-magyarországi Egyetem Kiadó, Sopron, 120 pp.

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1. Horváth B., Lakatos F. & Szentirmai I. (2013): Hagyományos művelésű őrségi kaszálógyümölcsösök szerepe a nappali lepke védelemben. Előadás, Nyugat-magyarországi Egyetem, Kari Tudományos Konferencia, Sopron, 2013. december 10

Conference posters

1. Pintérné Nagy E. & Horváth B. (2013): Különböző megvilágítottságú mintaterületeken fénycsapdával befogott lepkék összehasonlító értékelése. Poszter, Nyugat-magyarországi Egyetem, Kari Tudományos Konferencia, Sopron, 2013. december 10.
2. Horváth, B., Szentirmai, I. (2013): Do agri-environmental measures efficiently protect Maculinea butterflies in Őrség, western Hungary? Poster, 18th European Congress of Lepidopterology, 2013. 07. 29-08. 03., Blageovgrad, Bulgaria.
3. Sáfián, Sz., Horváth, B., Winkler, D. Scherer, Z., Strausz, M., László, M. Gy. (2013): Utilization of organic and intensively managed vineyards by butterflies in Western Hungary. Poster, 18th European Congress of Lepidopterology, 2013. 07. 29-08. 03., Blageovgrad, Bulgaria.
4. Sáfián, Sz., Szentirmai, I., Horváth, B., Scherer, Z., Strausz, M., Csontos, G. (2012): Results of the landscape-scale butterfly mapping in the Őrség Special Protection Area (HUON10001) in west Hungary 2010-2011. Poster. International Symposium: Future of Butterflies in Europe III., Wageningen, Netherland.
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6. Horváth B., Szentirmai I. (2011): Agrár-környezetgazdálkodási programok szerepe a nappali lepke védelemben. Poszter. VII. Magyar Természetvédelmi Biológia Konferencia. Debrecen, Hungary.
7. Sáfián Sz., Horváth B., Scherer Z., Strausz M., Csontos G., Szentirmai I. (2011): Természetvédelmi célú nappali lepke térképezés az Őrség

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9. Sáfián, Sz.; Szentirmai, I.; Mesterházy, A. , Horváth, B. (2010): The extiction of Danube Clouded Yellow – *Colias myrmidone* (Esper, 1781) from the Őrség National Park and Hungary. Poster. VIII. Butterfly Conservation Symposium, Reading.
10. Horváth B., Szentirmai I., Sáfián Sz. (2010): Segítik-e az agrár-környezetgazdálkodási programok a nappali lepke védelmet? Esettanulmány az Őrségi Nemzeti Parkból. Poszter. III. Madártani Kongresszus, Bősárkány.
11. Sáfián Sz., Ambrus A., Horváth B. , Horváth Á. (2010): A sárga gyapjasszövő – *Eriogaster catax* (Linneaus, 1758) Sopron környéki élőhelyei és állományainak természetvédelmi helyzete (Lepidoptera: Lasiocampidae). Poszter. III. Madártani Kongresszus, Bősárkány.
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Conference abstracts and extended abstracts

1. Horváth B., Lakatos F. & Szentirmai I. (2014): Hagyományos művelésű őrségi kaszálógyümölcsösök szerepe a nappali lepke védelemben. In: IV. Kari Tudományos Konferencia, Konferencia Kiadvány. Nyugat-magyarországi Egyetem, Erdőmérnöki Kar, Sopron, p. 316–319.
2. Pintérné Nagy E. & Horváth B. (2014): Különböző megvilágítottságú mintaterületeken fénycsapdával befogott lepkék összehasonlító értékelése. In: IV. Kari Tudományos Konferencia, Konferencia Kiadvány. Nyugat-magyarországi Egyetem, Erdőmérnöki Kar, Sopron, p. 330–332.
3. Horváth, B., Szentirmai, I. 2013): Do agri-environmental measures efficiently protect Maculinea butterflies in Őrség, western Hungary In: XVIII. European Congress of Lepidopterology Programme and Abstracts, p. 41–42.
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7. Horváth B., Szentirmai I. (2011): Agrár-környezetvédelmi programok szerepe a nappalilepke-védelemben. In: Lengyel Sz., Varga K., Kosztyi B. (szerk.): VII. Magyar Természetvédelmi Biológia Konferencia Absztrakt-Kötet. Magyar Biológiai Társaság, Budapest, 118 p.
8. Sáfián Sz., Horváth B., Scherer Z., Strausz M., Csontos G., Szentirmai I. (2011): Természetvédelmi célú nappali lepke térképezés az Őrség SpA területén (2010-2011). In: Lengyel Sz., Varga K., Kosztyi B. (szerk.): VII. Magyar Természetvédelmi Biológia Konferencia Absztrakt-Kötet. Magyar Biológiai Társaság, Budapest, 156 p.
9. Sáfián Sz., Horváth, B., Scherer, Z., Strausz, M., Szentirmai, I. (2011): Preliminary results of the butterfly mapping in the Őrség Special Protection Area (Western Hungary)(Papilioniodea and Hesperioidea). In: XVIIth European Congress of Lepidopterology, Book of Abstracts, 68 p.
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11. Horváth B., Sáfián Sz., Kovács Gy. (2010): A Koppányvölgyi Élőhely-rehabilitációs Kísérleti Terület lepkefauna vizsgálatának előzetes eredményei. In: Kovács Gy., Gelencsér G.: Az élhető Vidékért 2010 Környezetgazdálkodási Konferencia Absztrakt Kötet, 42 p.