FOLIA ENTOMOLOGICA HUNGARICA
ROVARTANI KÖZLEMÉNYEK
Volume 66 2005 pp. 195–206.

Light-trap surveys of the Macrolepidoptera fauna at the Aggtelek National Park

E. ÁRNYAS[1*], S. SZABÓ[1], B. TÓTHMÉRÉSZ[2] & Z. S. VARGA[1]

[1]Department of Evolutionary and Human Biology, University of Debrecen
H-4032 Debrecen, Egyetem tér 1, Hungary. E-mail: arnyaser@delfin.klte.hu
[2]Department of Ecology, University of Debrecen
H-4032 Debrecen, Egyetem tér 1, Hungary. E-mail: tothmerb@delfin.klte.hu

Abstract – The paper presents the results of a two-year (2000–2001) light-trap survey carried out in the Aggtelek karst area, north of the village Jósvafő, North Hungary. There were regular trappings by mercury-vapour bulbs throughout the entire vegetation period. Altogether, 24,352 Macrolepidoptera specimens belonging to 448 species were collected. Further 55 species were collected by personal collectings at light. In the collected material the species of the families Geometridae and Noctuidae were represented by the largest species richness and numbers of individuals, however also species of Sphingidae, Lasiocampidae and Arctiidae were frequent. There were 123 species represented by single individuals.

There was no difference in diversity between the assemblages of the two subsequent years. The similarity of the species composition was 80% by the Jaccard index, but there were considerable differences between the two years in the abundances (60% by the Bray–Curtis index). In the collected material the species living on herbaceous plants predominated, and also a considerably large proportion of species living on trees and shrubs were observed. A relatively large number of individuals of lichenophagous species were found. In the zoogeographical composition of the Macrolepidoptera fauna, the widely distributed Euro-Siberian and Holo-Mediterranean species predominate, with a significant proportion of southern continental, Ponto-Mediterranean and xeromontane species. With 1 figure and 3 tables.

Key words – Macrolepidoptera fauna, light-trap, Aggtelek National Park, faunistic composition, diversity.

* Corresponding author

INTRODUCTION

The Aggtelek National Park is located at the North Hungarian Mountain Range (Ujvárosy 1998), near to the Hungarian–Slovakian border. The National Park has a varied terrain and flora. It is basically wooded; 60% of the natural vegetation consists of forests, 20% of steppe meadow, 5% is rupicolous grassland, 5% is wetland, and 10% is cultivated (Varga *et al.* 1998, 2000). This territory lies partly under the rain-shadow effect of the higher mountains of the Slovakian karst, thus the climate of the lower karstic plateaux proved to be somewhat drier and warmer than it would result from the geographical situation. The higher plateaux and their valleys, being in direct territorial contact with the higher regions of the Slovakian karst, display the manifold effect of the fauna of the Carpathians (Varga 1999). The former arable lands and orchards were mostly abandoned, hence extended secondary grasslands and hedges have developed by oldfield succession. Extended patchy habitats have been developed which are covered by mosaic-like stands of broad-leaved trees (mostly *Quercus* spp., and *Carpinus betulus*), numerous species of scrubs, clonal forbs, tall-forbs and grasses. The semi-dry swards of the area proved to be extremely rich in species, botanically and entomologically, as well (Varga 1997, Varga-Sipos & Varga 1997, Varga *et al.* 2000).

The fauna of the Aggtelek National Park shows a characteristic composition of species and also a high species diversity, due to the transitional position of this area between the biogeographical provinces Pannonicum and Carpathicum (Varga 1995, 1997). Because the extension of nature-like and semi-natural habitats has remained considerable, several ecological corridors are functioning, which are suitable to transmit the faunal changes caused by climatic fluctuations (Varga 1997, Varga & Szabó 1997).

There are only scarce records on Lepidoptera species in the collection of the Hungarian Natural History Museum from this area before 1958. Systematic collectings of Lepidoptera were started in 1958, with the discovery of faunistically interesting species (Varga 1961, 1963). A complete list of the Lepidoptera species, collected between 1958 and 1997 in the Aggtelek karst area with discussion on the composition, habitats, frequency, population dynamics and biogeographical connections is presented in Varga (1999); an enumeration of 1079 Macrolepidoptera species is also given. Important faunistical results, based on personal collectings, were published by Gyulai *et al.* (1974, 1977, 1979). Light-trap survey started in 1970 at the local karst research station, but in some years also in other places (Szelcepuszta, Szin, Tornanádaska). Due to the systematic collectings, this region has become an intensively explored area of the country (Gyulai 1983, Varga 1999, Varga & Gyulai 1978, Varga & Szabó 1997).

The present study analyses and evaluates light-trap material and personal collectings by lamp in the Tohonya valley near Jósvafő village during the years 2000–2001. The aim of the survey was to analyse the composition of the nocturnal Macrolepidoptera fauna of the Tohonya valley and its surroundings. The number of trapped individuals was registered each month, and the quantitative ratios of the species inhabiting the area were also determined. Furthermore, the distribution of the captured species was analysed by habitat and food plant preference.

MATERIAL AND METHODS

The study area was the Tohonya valley and its surroundings, about one kilometre north from the village of Jósvafő in the northern Hungarian karst region. The valley was formed by the Tohonya creek at about 350–300 metres above sea level. The research station is situated on a gently sloping hillside of the Kis-Galya, opposite to the Tohonya ridge, lying between the Tohonya and Lófej valleys. A semi-automatic light trap was set up near to the station. Most of our material was collected with this light trap and by additional collections with lamp on the terrace of the building of the research station. The area is described in detail by VARGA *et al.* (1998). Thus, the light sources had an influence over a rather large territory with a wide spectrum of natural and semi-natural habitats.

A Jermy-type light trap was used during the research. The catching structure of the trap was on a 2 metre tall pole topped by a circular roof about 1 metre in diameter. The light source used was a 125 W mercury vapour bulb under the roof. The insects that were attracted by the light fell into a metal funnel which had at its end a container with a vial filled with chloroform (RONKAY 1997, SOUTHWOOD & HENDERSON 2000). The trap was activated by a solar light switch and it worked during the whole night. When a great number of moths were captured, the operator of the trap let them dry on a sheet of paper for a few hours, because the fluid they secreted on dying tended to cause moulding. The captured moths were stored between layers of cotton wool in cardboard boxes until being processed. To get an overall picture of the Lepidoptera fauna of the area, the material collected with light trap was supplemented by personal collectings using a 250 W mercury-vapour lamp attracting the moths, and pure chloroform for killing them. Collection lasted for about 7 hours each night, from dusk to dawn, when flying dropped sharply. The moths collected each night were carefully sorted and identified. The species, the date of capture and the number of specimens of each species captured that night were recorded. The light trap was operated from March 1st to November 15th in 2000, and from March 3rd to November 4th in 2001. It was switched on for two days in the first week of February, but the early thaw did not last long, and it was not switched on again until March.

Meteorological data (daily average temperature and rainfall) were recorded by the local station of the Hungarian Meteorological Service in Jósvafő.

The faunistic similarity of the two years of trapping was calculated by the Jaccard index of similarity for the species composition and by the Bray–Curtis index of similarity for the abundance data (SOUTHWOOD & HENDERSON 2000). Diversity comparison was based on one-parametric diversity-index families (TÓTHMÉRÉSZ 2001).

RESULTS

During the trapping periods, the trap captured a total of 24,352 specimens of Macrolepidoptera; 12,849 in 2000, and 11,503 in 2001. Owing to the competent operation of the trap, the captured material was of very good quality, and all the specimens were identified (except for some *Eupithecia* species). During the years 2000 and 2001, the trap caught 448 species; 310 of them were identical in the two years, and 138 were different between the two studied years. That material was supplemented by additional 55 species caught with lamp. The total number of species thus caught amounted to 503, which demonstrated the fact that the area was extremely rich in species.

Quantitative analysis showed that, of the 377 species caught with light trap in 2000, 22 were represented by more than 1% (129 specimens), see Table 1. Of the 377 species, 157 were represented by 10 to 100 specimens, 117 species by 1 to 10 specimens, and 71 species by a single specimen each. There was only a single species, *Orthosia cerasi*, that was represented by over 5%, but its share did not exceed 10%.

In 2001, 378 Macrolepidoptera species were captured with light trap, 23 of which were represented by more than 1% (116 specimens), see Table 1. Of the 378 species trapped in 2001, 148 species were represented by 10 to 100 specimens, 150 by 1 to 10 specimens, and 52 by a single specimen each. In 2001, it was *Tholera cespitis* that was represented by more than 5%, and like in 2000, none of the species exceeded 10%. Unlike in 2000, neither *Alsophila aescularia* [DENIS et SCHIFFERMÜLLER, 1775], nor *Lycia hirtaria* (CLERCK, 1759) reached 1% in 2001, because their most swarming period was in February due to the early thaw.

We found a 80% similarity in the composition of species between the two study years. At the same time, similarity in the abundances was smaller. The Bray–Curtis (Czekanowski) similarity was only 60%, which means that the two years differ remarkably in abundances of the trapped species.

Table 2 shows the number of specimens caught each month in 2000 and 2001 against monthly average temperatures and total precipitation. The results of collection with light trap and lamp in the Tohonya valley in 2000–2001 show that Geometridae and Noctuidae are represented by the greatest number of species and specimens in the study area, but certain species of Arctiidae, Sphingidae and Lasiocampidae also occur in large numbers, e.g. *Eilema complana* (LINNAEUS, 1758), *Deilephila porcellus* (LINNAEUS, 1758), and *Poeciliocampa populi* (LINNAEUS, 1758), see Table 3.

Woodland species (VARGA 1964) were trapped in the greatest numbers, as woodland predominates in the region and in the vicinity of the light trap, as well. In

Table 1. The species which were more frequent than 1% of the total captured individuals at least one of the studied years (2000 and 2001), and their counts. Bold figures indicate that the species was more frequent than 1%

Species	Family	Counts	
		2000	2001
Alsophila aescularia	Geometridae	**154**	76
Chlorissa viridata	Geometridae	**150**	80
Cyclophora annulata	Geometridae	**412**	41
Idaea aversata	Geometridae	123	**125**
Lycia hirtaria	Geometridae	**158**	28
Scopula immorata	Geometridae	**407**	**150**
Semiothisa chlathrata	Geometridae	**149**	84
Semiothisa glarearia	Geometridae	**204**	113
Agrochola macilenta	Noctuidae	31	**164**
Agrotis exclamationis	Noctuidae	**218**	**147**
Autographa gamma	Noctuidae	44	**362**
Cerapteryx graminis	Noctuidae	102	**149**
Conistra vaccinii	Noctuidae	**319**	**457**
Deltote deceptoria	Noctuidae	**136**	35
Eriopygodes imbecilla	Noctuidae	**184**	**159**
Mythimna conigera	Noctuidae	81	**124**
Neuronia decimalis	Noctuidae	**175**	**292**
Orthosia cerasi	Noctuidae	**884**	**194**
Orthosia cruda	Noctuidae	124	**142**
Protodeltote pygarga	Noctuidae	**308**	69
Tholera cespitis	Noctuidae	**151**	**664**
Xestia c nigrum	Noctuidae	114	**147**
Deilephila porcellus	Sphingidae	**239**	**299**
Eilema complana	Arctiidae/Lithosinae	**541**	**542**
Eilema deplane	Arctiidae/Lithosinae	**145**	**253**
Eilema lutarella	Arctiidae/Lithosinae	**190**	**127**
Eilema sororcula	Arctiidae/Lithosinae	**371**	**166**
Miltocrista miniata	Arctiidae/Lithosinae	**313**	**228**
Phragmatobia fuliginosa	Arctiidae	65	**133**
Eriogaster rimicola	Lasicampidae	35	**123**
Poecilocampa populi	Lasiocampidae	**204**	**234**

Table 2. Total number of captured individuals by the light trap in each month during the years of 2000 and 2001, and the mean temperature and total rainfall data. °C = monthly mean temperature in Celsius degrees, mm = monthly total rainfall in millimeter

	2000			2001		
Month	Counts	°C	mm	Counts	°C	mm
February	0	0.99	31.3	5	0.66	9.9
March	973	3.77	59.9	544	5.09	85.8
April	1483	12.7	52.8	543	9.51	64.2
May	2078	15.9	95.2	1399	15.9	23.2
June	2807	18.4	42.7	1551	16.2	57.4
July	2374	17.8	141	2818	19.9	104
August	1910	20.2	29	1938	20.4	65.7
September	598	13.8	15.7	1355	12.7	54.3
October	508	12.1	9.7	955	11.5	7
November	118	6.34	52.4	355	1.58	32.5

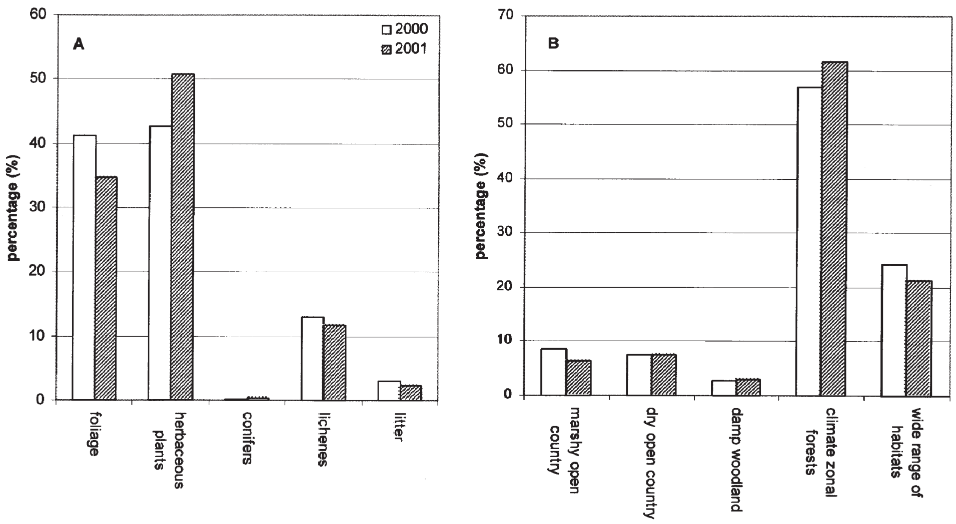

Fig. 1. Distribution of the trapped individuals according to their food plants (A), and according to their habitat preference (B). Empty bars – 2000, hatched bars –2001

Table 3. Families and their species richness, and total counts collected by the light trap during the years of 2000 and 2001. Notations: S – number of species; N – number of individuals

	2000		2001	
Family	S	N	S	N
Geometridae	117	3924	121	2217
Noctuidae	170	5651	176	6194
Sphingidae	10	288	8	353
Limacodidae	1	65	1	51
Arctiidae	13	289	11	335
Arctiidae/Lithosiinae	11	1769	8	1415
Lymantriidae	7	89	9	124
Lasiocampidae	12	364	9	471
Drepanidae	5	158	5	115
Notodontidae	15	102	17	77
Saturniidae	1	1	0	0
Zygaenidae	2	30	2	12
Psychidae	1	11	1	7
Thaumetopoeidae	1	35	1	69
Cossidae	2	11	2	11
Thyatiridae	7	53	6	38
Lemoniidae	2	9	1	14

2000 and 2001, species inhabiting climate zonal forests were represented by 56.86 and 61.69%, respectively, while species inhabiting damp woodland were represented by 2.85 and 3.06%, respectively. Euryoecious species are common and generally distributed. They were represented by 24.31 and 21.16%, respectively. Moths inhabiting open country occurred in relatively smaller percentage than the former species. The ratios of moths inhabiting dry open country and those inhabiting wet open country were nearly identical in 2000 and 2001; the former were represented by 7.41 and 7.6%, respectively in the study material, the latter by 8.54 and 6.46%, respectively. Species feeding on litter made up 3.03% of the study material in 2000, and 2.32% in 2001 (Fig. 1).

DISCUSSION

The species of families that were represented by 1% or less in the material greatly contribute to the diversity of the Lepidoptera fauna of the Tohonya valley. Quantitative analysis showed that certain species are very rare, several species being represented by a single specimen in our collection. This can probably be attributed to the fac that the light trap had an influence on a very large and heterogeneous area, and the results were affected by numerous accidental factors. Certain moths could only be captured by lamp, and there are a number of species that are only known to inhabit the area from the records of earlier collections. Thus we did not capture the following species either with light trap or lamp: *Dichonia aeruginea* (HÜBNER, 1808), *Asphalia ruficollis* ([DENIS et SCHIFFERMÜLLER], 1775), *Dioszeghyana schmidtii* (DIÓSZEGHY, 1935) and *Phalera bucephaloides* (OCHSENHEIMER, 1810). All these species are connected to xerothermic oak-scrub forests, and their typical habitats lie remote from the light-trap site. The number of specimens of the above species was below the minimum observation limit.

The material also reflects the effect of old orchards, as several moths developing on fruit trees were also collected, e.g. *Saturnia pyri* [DENIS et SCHIFFERMÜLLER, 1775], *Zeuzera pyrina* (LINNAEUS, 1758), etc. Their presence was probably due to the fact that there were remnants of abandoned orchards on the slope not far from the trap, although these species originally live also on wild *Prunus, Malus, Cerasus*, etc. species.

The number of specimens caught during the two years of study showed great differences for certain species, e.g. *Cyclophora annulata* (SCHULTZE, 1775)*, *Lycia hirtaria* (CLERCK, 1759)*, *Scopula immorata* (LINNAEUS, 1758), *Orthosia cerasi* (FABRICIUS, 1775)*, and *Protodeltote pygarga* (HUFNAGEL, 1766). The species marked with * show also considerable fluctuations according to the light traps of the forestry research stations (VARGA & UHERKOVICH 1973). Compared with the data of 2000, their number of individuals decreased considerably in 2001. The prevalence of other species, on the other hand, increased vigorously in the second year of our study, e.g. *Tholera cespitis* [DENIS et SCHIFFERMÜLLER, 1775], and *Autographa gamma* (LINNAEUS, 1758). The above trends can be attributed to the different weather conditions during the years in question and their different population cycles, etc.

The similarity of the species composition was great, measured by the Jaccard index of similarity, suggesting that the faunistic composition was stable and changed only slightly from year to year, unlike the relatively high proportion (one-fifth) of the rare species. The diversity profiles of the assemblages of the two years do not cross each other by the one-parametric diversity-index families. Therefore, 2001 was slightly more diverse both for the dominant and the rare species, but the differences are small. There are assemblages with a high number of species and count, which usually can be characterised by lognormal distribution (FISHER *et al.* 1943, WILLIAMS 1964). Consequently, diversity ordering is expected to display small differences between the two assemblages, as each can be approximated by this distribution. It is remarkable, however, that there was large variation in the abundance of the species between the two years. It was reflected by the 60% similarity of the abundance measured by the Bray–Curtis index. The differences in the abundances can be explained partly by those of the monthly precipitation and other weather conditions.

When the species collected with light trap were classified by food plants, we found that a relatively great number of lichenophagous moths inhabited the area, their ratio in the study material being 12.96% in 2000 and 11.78% in 2001. The above data show that the epiphytic vegetation of the woodland surrounding the valley was in good condition, as those plants are good indicators of the condition of forests. More than one-third of the study material was made up of species feeding on foliage; their ratio was 41.16% in 2000 and 34.69% in 2001. The species with the highest percentage, however, were moths developing on herbaceous plants. Their ratio was 42.64% in 2000 and 50.79% in 2001. Since the Tohonya valley, at 300–350 metres above sea level, was a relatively low-lying area, the ratio of moths feeding on planted conifers was low there: it was 0.19% in 2000 and 0.40% in 2001.

A light trap was operated in the study area for several years (VARGA 1999), thus our results could be compared with previous data, and changes in the population dynamics of the various species could be studied over time. Our results reveal that Mediterranean species occur in small numbers but in steady populations in the area, which was demonstrated by the number of specimens of *Eriogaster catax* (LINNAEUS, 1758) and *Catocala nymphagoga* (ESPER, 1787) taken with light trap in 2000 and 2001. *Marumba quercus* [DENIS et SHIFFERMÜLLER, 1775] was a similarly rare species, only a single specimen was taken with lamp in July 2000.

Xeromontane species inhabiting rocky grassland were typical of the karst regions. Their populations increased in the dry periods of the 1980s and 1990s. *Chersotis margaritacea* (DE VILLERS, 1789) was one of them. *Dichagyris (Albocosta) musiva* (HÜBNER, 1803), a continental xeromontane species, was regularly captured at low individual numbers. A few specimens were caught with light trap and with lamp. Steppe-inhabiting species showed a low density in the study area, the group was markedly represented by *Watsonarctia deserta* (BARTEL, 1902) and by *Chelis maculosa* (GERNING, 1780).

Euryoecious species and species inhabiting lowland deciduous forests have been represented in great numbers of specimens and species in recent years, which was proved by the distribution of *Orthosia* spp., *Agrochola* spp., *Conistra vaccinii* (LINNAEUS, 1758), and of *Eupsilia transversa* (HUFNAGEL, 1766) in the material collected with light trap (SZENTKIRÁLYI *et al.* 1996). The number of specimens of Siberian species inhabiting wetlands were decreasing since the 1980s. The above tendency could be observed in *Polia bombycina* (HUFNAGEL, 1766), *Autographa bractea* (DENIS et SCHIFFERMÜLLER, 1775), and *Diachrysia chryson* (ESPER, 1789), which were species typical of altoherbous association and in *Hydraecia micacea* (ESPER, 1789) inhabiting marshy meadows and marshy woodland. The number of specimens of the Euro-Siberian species, *Cerapteryx graminis* (LINNAEUS, 1758), on the other hand, has been increasing in recent years compared to the 1990s (VARGA 1999).

The characteristic species of the above group, and the Macrolepidoptera species inhabiting birch and alder associations adjacent to the valley occur locally and infrequently, but they have been taken both with light trap and lamp, e.g. *Leucodonta bicoloria* [DENIS et SCHIFFERMÜLLER, 1775], *Pheosia gnoma* (FABRICIUS, 1777), *Geometra papilionaria* (LINNAEUS, 1758), *Lithophane furcifera* (HUFNAGEL, 1766) and *Acronicta alni* (LINNAEUS, 1758). The Lasiocampidae sp. *Phyllodesma ilicifolium* (LINNAEUS, 1758), occurring in Hungary only in this area (and in certain areas of the Kiskunság), has been captured only by lamp at low individual numbers. The above species are generally distributed in Northern Europe and the in the northern part of Central Europe. They tend to occur at the downhills of the Alps and the Carpathians and they become more and more local and montane going to the South (UHERKOVICH 1978). The same tendency could be observed at Jósvafő, as well.

Due to the plantation of Scotch pine and Norway spruce, certain conifer-preferring species, e.g. *Hyloicus pinastri* (LINNAEUS, 1758) and *Lymantria monacha* (LINNAEUS, 1758) have recently extended their range over areas where they had previously not occurred. *Lymantria monacha* was a pest of pinewood further north, e.g. in Germany, in the Czech Republic, etc., but it has not caused significant damage in Hungary so far.

The species inhabiting continental marshy meadows constitute a separate group from the point of view of their ecological demands. They have small populations, but their abundance has been increasing in recent years. Our light trap caught e.g. *Goonallica virgo* (TREITSCHKE, 1825), *Eucarta amethystina* (HÜBNER, 1803), and *Athetis (Hydrilla) lepigone* (MOESCHLER, 1860) (VARGA 1999).

*

Acknowledgements – The authors are thankful for Ms ILDIKÓ WANTUCHNÉ-DOBI for the meteorological data and Mr. CSABA BÁRKÁNYI for the cautious handling of the light trap.

REFERENCES

FISHER, R. A., CORBET, A. R. & WILLIAMS, C. B. (1943): The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology* **12**: 42–58.

GYULAI, I. (1983): *A környezeti rendszerek rész-egész problémája egy rendszer vizsgálatának vetületében.* [The problem of "the parts vs the whole" in environmental systems: a case study.] – Manuscript. Dissert. dr. sci. nat., Miskolc, pp. 148.

GYULAI, I., GYULAI, P., UHERKOVICH, Á. & VARGA, Z. (1979): Újabb adatok a magyarországi nagylepkék elterjedéséhez II. (Lepidoptera). (New data to the knowledge of the distribution of macrolepidoptera in Hungary II.) – *Folia entomologica hungarica* **32**(2): 219–227.

GYULAI, P., UHERKOVICH, Á. & VARGA, Z. (1974): Újabb adatok a magyarországi nagylepkék elterjedéséhez (Lepidoptera). (Neuere Angaben zur Verbreitung der Gross-Schmetterlinge (Macrolepidoptera) Ungarns.) – *Folia entomologica hungarica* **27**(2): 75–83.

GYULAI, P., UHERKOVICH, Á. & VARGA, Z. (1977): A Cucullia gnaphalii Hb. (Lep.: Noctuidae) hazai előfordulása. (Das Vorkommen der Cucullia gnaphalii Hb. in Ungarn.) – *Folia entomologica hungarica* **30**(1): 187–188.

RONKAY, L. (1997): *Nemzeti biodiverzitás-monitorozó rendszer VII. Lepkék. [National biodiversity monitoring system VII. Lepidoptera.]* – Magyar Természettudományi Múzeum, Budapest, pp. 71.

SOUTHWOOD, T. R. E. & HENDERSON, P. A. (2000): *Ecological Methods*. – Blackwell, Oxford, xv + 575 pp.

SZENTKIRÁLYI, F., LESKÓ, K., KÁDÁR, F., & MOHAINÉ, MADARAS K. (1996): A hazai fénycsapda-hálózat biomonitoring rendszerként való hasznosítása. [Using the Hungarian light trap network as a biomonitoring system.] – In: *A Magyar Biológiai Társaság XXII. Vándorgyűlése, Előadások Összefoglalói. (22nd Conference of the Hungarian Biological Society, Abstracts of the papers.)* Magyar Biológiai Társaság, Budapest, 55 pp.

TÓTHMÉRÉSZ, B. (2001): Diversity and diversity measures in environmental assessment. – *Acta Pericemonologica* **1**: 151–164.

UHERKOVICH, Á. (1978): Dél-és Nyugat-Dunántúl nagylepkéinek néhány állatföldrajzi kérdése. [Some zoogeographical problems of the Macrolepidoptera of Southern and the South-Western of Transdanubia.] – *Állattani Közlemények* **65**: 153–162.

UJVÁROSY, A. (1998): Földrajzi helyzet, éghajlati viszonyok. [Geographical situation, climatic relations.] – In: BAROSS, G. (ed.): *Az Aggteleki Nemzeti Park. [The Aggtelek National Park.]* Mezőgazda Kiadó, Budapest, pp. 22–25.

VARGA, Z. (1961): Állatföldrajzi vizsgálatok az Északborsodi Karszt nagylepke-faunáján. (Zoogeographische Untersuchungen über Macrolepidopteren-Fauna des Nordungarischen Karstgebietes.) – *Folia entomologica hungarica* **14**: 345–386.

VARGA, Z. (1963): Újabb adatok az Északi-Középhegység Macrolepidoptera-faunájához. (Neuere Angaben über die Macrolepidopteren-Fauna des Nordungarischen Mittelgebirges.) – *Folia entomologica hungarica* **16:** 145–156.

VARGA, Z. (1964): Magyarország állatföldrajzi beosztása a nagylepkefauna komponensei alapján. (Zoogeographische Einteilung Ungarns auf Grund der Makrolepidopteren-Faunenkomponenten.) – *Folia entomologica hung*arica **17**: 119–167.

VARGA, Z. (1995): Geographical patterns of biodiversity in the Palaearctic and in the Carpathian Basin. – *Acta Zoologica Academiae Scientiae Hungaricae* **41**: 71–92.

VARGA, Z. (1997): Biogeographical outline of the invertebrate fauna of the Aggtelek karst and surrounding areas. – In: TÓTH, E. & HORVÁTH, R. (eds): *Research, Conservation, Management*. ANP Directorate, Aggtelek, pp. 87–95.

VARGA, Z. (1999): The Lepidoptera of the Aggtelek National Park. – In: MAHUNKA, S. (ed.): *The Fauna of the Aggtelek National Park, II*. Hungarian Natural History Museum, Budapest, pp. 443–504.

VARGA, Z. & GYULAI, I. (1978): Die Faunenelemente-Einteilung der Noctuiden Ungarns und die Verteilung der Faunenelemente in Lokalfaunen. – *Acta biologica debrecina* **15:** 257–295.

VARGA, Z. & SZABÓ, S. (1997): Changes in species composition and abundance of Lepidoptera in the Aggtelek karst. – In: TÓTH, E. & HORVÁTH, R. (eds) : *Research, Conservation, Management*. ANP Directorate, Aggtelek, pp. 137–142.

VARGA, Z. & UHERKOVICH, Á. (1973): Die Anwendung der Lichtfallen in der ökologischen Landschaftsforschung. – *Folia entomologica hungarica* **27**: 159–176.

VARGA, Z., VARGA-SIPOS. J., HORVÁTH, R. & TÓTH, E. (1998): Az Aggteleki-karszt élővilága. [The living world of the Aggtelek karst.] – In: BAROSS, G. (ed.): *Az Aggteleki Nemzeti Park. [The Aggtelek National Park.]* Mezőgazda Kiadó, Budapest, pp. 254–316.

VARGA Z., VARGA-SIPOS J., ORCI K. M. & RÁCZ I. (2000): Félszáraz gyepek az Aggteleki-karszton: fitocönológiai viszonyok, egyenesszárnyú rovar- és lepkeegyüttesek. [Semi-dry grasslands in the Aggtelek karst: Phytocenological relations, Orthoptera and Lepidoptera assemblages.] – In: VIRÁGH, K. & KUN, A. (eds): *Vegetáció és dinamizmus. [Vegetation and dynamism.]* Magyar Tudományos Akadémia Ökológiai és Botanikai Kutatóintézete [Institute of Ecology and Botany of the Hungarian Academy of Sciences], Vácrátót, pp. 196–238.

VARGA-SIPOS, J. & VARGA, Z. (1997): Phytocenology of semi-dry grasslands in the Aggtelek karst area. – In: TÓTH, E. & HORVÁTH, R. (eds): *Research, Conservation, Management*. ANP Directorate, Aggtelek, pp. 59–78.

WILLIAMS, C. B. (1964): *Patterns in the Balance of Nature and Related Problems in Quantitative Ecology*. Academic Press, London 324 pp.