SELECTED STUDIES OF HUNGARIAN RESEARCHERS' PROJECT OF LIGHT TRAPPING OF INSECTS

L. Nowinszky and J. Puskás (editors)

Jermy type light-trap with 200W normal bulb

Photo: Dr. Zsuzsanna Kúti PhD

SAVARIA UNIVERSITY PRESS

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SAVARIA UNIVERSITY PRESS

Szombathely

2018

ISBN 978-615-5753-16-9

Printed in

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Sonderdruck aus Bd. 95 (1983), H. 1, S. 83–92

Zeitschrift für angewandte Entomologie

VERLAG PAUL PAREY · SPITALERSTRASSE 12 · D-2000 HAMBURG 1

Influence of solar activity on the outbreaks and daily light-trap catches of *Scotia segetum* Schiff. (Lep., Noctuidae)

By G. Tóth and L. Nowinszky

Abstract

The authors tried to find a connection between the solar activity and the outbreaks and daily light-trap catches of *Scotia segetum* Schiff. It has been established by means of autocorrelation and cross-correlation functions that, the outbreaks are connected with the solar cycle. A moderate increase of solar radio flux measured at 2800 MHz in preceeding day coincided with an increase however, a slight decrease or marked increase of the radio flux with a decrease in the light-trap catches. On nights following the solar H-alpha flares of importance (class) 2 and 3, the yield of light-trap catches also decreased. The results of this paper may find an application in the plant-protecting forecasting.

1 Introduction and survey of literature

The electromagnetic and corpuscular radiations of the Sun are regarding as general factors, which have a general modifying effect for weather and climate. The weather influences the symptom of life of the insects and, of course, their multiplication and flying activity too. The influences are of common character for large area at a given time therefore, have an effect on first of all no in space but in time variable processes. It is justified however to investigate the change of catches by light-trap of insects as a function of solar activity.

The boundary of solar physics and meteorology is investigated by numerous researchers. After one day of the contact of solar wind and the atmosphere appeared a strong correlation between the solar wind and cyclones in northern hemisphere as was pointed out by Wilcox (1975). Roberts and Olson (1973) as well as Hines and Halevy (1977) demonstrated that the electric conditions in the magnetosphere of the Earth are strongly influenced by the variation of solar activity, the latter nevertheless operate on the formation of weather.

Cohen and Sweester (1975) found a negative correlation between the sunspot numbers and tropical cyclones in Atlantic and their duration respec-

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Z. ang. Ent. 95 (1983), 83–92

ISSN 0044-2240 / InterCode: ZANEAE

tively. By opinion of POLGÁR (1966) the maxima and minima of sunspots coincide with drought and years of internal waters respectively. Similar results were found by VIBERT (1976) with the help of modern mathematical methods. His results verify that the solar periodicity more intensively influences the amount of precipitation than the weather phenomena. DYER (1975) made a comparison between the solar activity and the precipitation measured at 157 meteorological stations in South Africa in the interval of 1810–1912. He showed that the amount of precipitation may be connected with the periodicity of sunspots. FILEWICZ (1962) as well as KING et al. (1974) proved the connection between the solar activity and severe winters and, the mean temperature in Great Britain, respectively. BLACK and THOMSON (1978) emphasised the importance of two maxima of solar activity for the agriculture because, the second greater one often causes droughts from the end of first maximum to the second one.

Many investigators searched for some connections between the solar activity and mass reproduction of insects. Their data for outbreaks were originated from no uniform observations therefore, fundamental conclusions from these could not be verified by mathematical methods. HAŠEK (1971) reported on the connection between the sunspot maxima and the amount of coppices in Czech forests. The coppices are helping to form of outbreaks of *Lymantria dispar* L. MARTINEK (1972) established that the occurrence of *Neodiprion sertifer* Geoffr. coincides with the solar maxima, e. g. by each eleven years can be observed in large numbers.

A number of damaging insects was searched by KLIMECZEK (1976) for their outbreaks in the time interval beginning with 1810 up to 1970. According to his opinion one must be taken into account their damage at time of sunspot maxima but, the presented values of the coefficient of correlation are low. In the paper of MANNINGER (1975) one can read on many investigations, which were made through several decades. He suggested a relation between the outbreaks of damaging insects and the years of droughts or internal waters, the latters are connected with solar activity. He was able to document that, in the second half of arid period those species have made the outbreaks preferring the drought, and in second half of period of internal waters the humidity preferring ones. The authors of this paper in one of their early works (TÓTH et al., 1978) stated by means of data processing of light-trap catches using methods of mathematical statistics, that the outbreaks of four damaging species (*Colotois pennaria* L., *Erannis aurantiaria* Hbn., *Erannis defoliaria* Cl. and *Operophthera brumata* L.) follow the sunspot maxima by 2–3 years.

In the literature known by us, we could not find such papers, which analyse the daily catches of insects by light-trap as a function of solar activity and other common factors of environment modifying the catches.

2 Light-trap data

Our calculations to search for a connection between the periodical solar activity and the hypercyclic moving, have been made from observations of 7 stations of the Hungarian light-trap network from 1961 to 1979. During the data processing we have been worked with yearly catches of *Scotia segetum* as a sum of the first and second generations. The separation of both generations has not been justified because, the whole number of first generation is usually very low, the two generations have not been appeared from time to time separately, finally we do not know the most sensitive phenological state of the species towards the solar activity, in such a way it seems to be used the yearly catches.

We used to investigate the solar activity versus catches the data obtained by uniform light-trap network of Jermy type being worked in Hungary from two decades, belonging to agricultural and forestrial organizations. The data processed are originating from 44 stations of the country from the years 1960–1976 and contain 238 swarmings of *Scotia segetum*. Each swarming has been taken into account, which number of individuals were overreached 20 pieces. Altogether 9722 data have been processed, observed during 1751 nights. In the given period 27942 pieces were collected by light-traps from imagos of the species.

3 Short description of solar activity

The solar activity called as sum total of informations, taken by various methods, observable from the Sun at surface or environment of the Earth. The most remarkable phenomenon are the periodic occurrence of sunspots on the observable surface of the Sun's disc, these were registered daily beginning with the middle of 18th century. The periodicity of their occurrence by amount is at moment about 11.2 years. The conventionally accepted measure of their number is the so called Wolf's relative number (RW), which is an arbitrary quantity being deduced from the number of sunspots observed (f) and their number of groups (g) by the following way:

$$RW = k \cdot [10\,g + f]$$

where k is a constant, depending on the behaviour of telescope used to observe them.

The Wolf's relative numbers are determined by Zürich Observatory as a world's center and, nowadays are edited by Tokyo Observatory named as Quarterly Bulletin of Solar Activity. The yearly tabulated relative numbers are shown in table 1.

The radio flux of the Sun measured at the frequency of 2800 MHz (10.7 cm expressed in wave length), and observed daily at Ottawa beginning with 1948. The radio flux measured at this frequency contains as well the thermal radiation of quiet Sun as the disturbed one in time of solar flares for example, and integrated through a day in units of 10^{-22}w/m^{-2}/Hz^{-1}. The radio flux correlates very closely with RW at a coefficient of correlation of 0.98.

The flares can be observed through 10–20 min on the Sun's surface in monochromatic light (conventionally at the H-alpha line of 656.3 μm wavelength), and the observer sees them as lightning up in the chromosphere, usually at the vicinity of sunspots. Their importance (class) can be numered as the area of whole Sun's disc from units of 1 – (smallest rea) to 3 + (largest area). When we take into account of their cosmic influence, the flares of

Table 1. The mean relative numbers of sunspots 1951–1979

Year	RW	Year	RW	Year	RW	Year	RW
1951	69.4	1952	31.4	1953	13.9	1954	4.4
1955	38.0	1956	141.7	1957	189.9	1958	184.8
1959	159.0	1960	112.3	1961	53.9	1962	37.5
1963	27.9	1964	10.2	1965	15.1	1966	47.0
1967	93.8	1968	105.9	1969	105.5	1970	104.5
1971	66.6	1972	68.9	1973	38.0	1974	34.5
1975	15.5	1976	12.6	1977	27.5	1978	92.5
1979	155.4						

importance 2 and 3 have in general of high energy outputs. In time of appearence of intensive solar flare one can measure thousand times of emitted corpuscular energy compared with the case of quiet Sun. These corpuscular particles consist of electrons, protons and others. They propagate around the space with about 1500 km/s, such a way towards the Earth. These electrically charged particles form the so called solar wind, which in contrast with electromagnetic radiation, after 26–28 h reach the Earth's environment. This time delay is offering to use between the occurrence of flare and the phenomenon of biosphere, after one day to be found. The flare particles in their way to the Earth must penetrate through the interplanetary space but, the latter necessarily modulate them by the general magnetic field of galactic cosmic raditation. The penetrated particles reach the Earth's magnetosphere therefore, everything flare do not cause the change of physical state of magnetosphere. The change of behaviour of the upper atmosphere induces the temporary modification of weather, and through this the variation of phenomena in biosphere. The daily trend of quiet magnetic field of the Earth, as a matter of fact, is also changed by charged particles originated from the Sun. For a reference of modern solar research and data on solar-terrestrial relationship see for example the following monographies: KUNDU (1965), ŠVESTKÁ (1976) and WHITE (1977).

4 Evaluation of data

If wanted to search for the connection between solar activity and the outbreaks, the measured data collected at various stations, we are obliged to have them in a comparable form. For that very reason, we introduced the so called coefficient of population (NOWINSZKY et al. 1978; EKK et al. 1980). The coefficient of population (P) is defined as a quotient of the number of individuals of a generation to be caught (N), and of the geometrical mean of the catch observed during a number of years at the same observing station ($\overline{X}_g$):

$$P = N / \overline{X}_g$$

From the number of individuals of *Scotia segetum* to be caught we have calculated yearly the P-values (table 2), which are forming a time series. We consider these values as realizations of stationary ergodic stochastic process, therefore we have computed from these the values of autocorrelation function: $R\tau$. By the same consideration, the autocorrelation function of yearly Wolf's relative number has been calculated.

The autocorrelation function is related to the correlation of a given quantity itself. Knowing the function value at time t, we can predict the value for time $t + \tau$. The autocorrelation function in our case can be considered as two realizations of P with τ time delay. Because, the sampling interval is accurately 1 year therefore, the time delay will be also one year.

Furthermore, we have calculated the cross-correlation function of RW and P values. The latter function can be considered as an extension of correlation methods between two quantities. The cross-correlation function naturally is an even function because, for the first, establishes contact with undelayed RW and delayed P; for the second, inversely, that is with delayed RW and undelayed P. Because the relative numbers of sunspots must be consider as undependent variable, there is enough for our purpose to compute only the first function, the second one has no meaning.

Table 2. The values of the coefficient of population yearly for various observing stations of *Scotia segetum* Schiff.

Year	Felsötárkány	Gerla	Répáshuta	Sopron	Tolna	Tompa	Várgesztes	Average
1961	×	×	×	×	1.618	×	×	1.618
1962	22.267	1.308	29.62	8.693	5.014	11.134	40.536	15.345
1963	0.783	0.506	0.878	0.572	2.286	1.144	0.145	0.954
1964	0.609	1.153	1.207	0.858	0.855	2.157	0.984	1.014
1965	1.74	1.167	1.755	0.4	2.074	1.679	0.203	1.188
1966	0.696	0.818	0.11	1.087	1.994	1.51	1.013	0.921
1967	3.218	0.83	7.24	1.887	1.413	0.9	0.723	2.984
1968	6.523	5.134	19.747	0.972	7.771	4.399	26.444	9.321
1969	1.131	1.28	0.11	0.172	0.991	0.947	0.318	0.739
1970	0.783	1.055	4.287	0.172	1.721	2.336	3.038	1.914
1971	0.087	2.039	1.316	0.343	1.835	0.375	1.591	1.232
1972	0	0	0	0	0	0	0	0
1973	0.87	3.587	3.511	11.61	0.798	0.582	1.881	3.054
1974	1.218	×	6.911	2.288	1.288	0.366	2.691	2.251
1975	1.827	1.069	1.097	1.315	0.251	0.619	0.463	0.993
1976	1.218	3.263	2.743	4.575	1.456	2.955	3.559	2.999
1977	0.174	0.549	0.549	0.686	0.342	0.835	0.868	0.673
1978	0.957	2.321	0	1.887	0.433	1.013	0.463	1.218
1979	0.087	0.422	0	0.572	0.456	1.201	0.116	0.4

Note: × = the light-trap did not work.

It has been calculated the percentage (increasing or decreasing) daily values of ΔS from the solar radio flux (S), measured at 2800 MHz. We have used the integer values only, the fractions have been rounded off.

The daily catches observed at various stations and time, might not compare with one another by direct way. For this reason it has been computed the so called relative catch (RC) for each night of a given swarming. The RC values can be obtained as a quotient of the number of individuals caught during a night and of the daily mean number of catches of a given swarming. We give the change of relative catches in percent (ΔRC). We have pair-values formed from percentage change of relative catches and from the previous daily changes of solar radio fluxes. Then the ΔRC values, belonging to equivalent quantities of ΔS, have been summed and averaged. After this handling, at least partially to eliminate the disturbing effects being modified the catches, we have the ΔRC values filtered using the five-points moving average method of URMANTSEV (1967) by the following equation:

$$\tilde{x}_i = \frac{1}{10}\left[x_{i-2} + 2x_{i-1} + 4x_i + 2_{i+1} + x_{i+2}\right]$$

where $x_i = (\Delta RC)_i$.

Applying the method of least-squares, one can obtain a cubic function as a best fitting, resulting:

$$\widetilde{\Delta RC} = a_0 + a_1(\Delta S) + a_2(\Delta S)^2 + a_3(\Delta S)^3$$

The regression constants are:

$a_0 = 1.640570015$ $\quad a_1 = 1.895445879$

$a_2 = -0.1244346072$ $\quad a_3 = -0.0181098711$

The solar H-alpha flares of importance 2 and 3 occurrence sporadically and relative rarely. The change of relative catches are naturally larger at the environment of the middle of swarming, than at beginning and the end of the latter. Therefore the flares occurred at time of middle of swarming are connected with relative greater variations than with flares at beginning or end of swarming. To investigate the influence of solar flares we must elaborate other method.

As before, we have calculated the 5-points moving averages for each swarmings and days. The calculated values we have considered as expected ones for various portion of swarming phenology. After this, the relative catches expressed in percent and counted by method of Urmantsev, belonging to first and second days after the flare's phenomenon, have been daily summed and averaged.

At the end, we have computed power spectra from the mean daily relative catches of 86 swarmings, longer than 45 days, to search for finding periodic phenomena of the swarming phenology. The power spectrum is a Fourier transform of the autocorrelation function (the cross-Spectrum is of the cross-correlation function) and, at its maximum value appears the primary period of the process.

5 Results

The readable times of periods from autocorrelation functions and cross-correlation ones are shown in table 3 and fig. 1. For the sake of spare in place, we present the function only that is computed from the mean data of all stations.

The effect on the changes of catches of *Scotia segetum* by light-trap are shown in table 4 and fig. 2.

The influence on the behaviour of the catches developed by solar flares of importance 2 and 3; table 5 gives some informations.

In the computed power spectrum appeared a significant maximum at 27.15 days.

Table 3. The time of period for *Scotia segetum* Schiff. calculated by auto- and cross-correlation functions at various observing stations

Observing station	Time of period in years	
	autocorrelation	cross-correlation
Felsötárkány	6	6
Gerla	5	11
Répáshuta	6	11 and 5
Sopron	11	6
Tolna	6	11
Tompa	6	doubtful
Várgesztes	6	11 and 6
The mean of all stations	6	11 and 6

6 Discussion

The computed autocorrelation functions in all show a periodicity about 6 years, which are (owning in mind the resolving power of our method applied) correspond with the half-period of solar activity. The cross-correlation function gives to anyone better results because of its higher resolving power (it

Table 4. The change of relative catch of *Scotia segetum* Schiff. as a function of the change of solar radio flux measured in previous day at 2800 MHz

ΔS %	Data number	ΔRC %	$\widetilde{\Delta RC}$ % by 5-points moving average
−11.7	46	−13.04	
− 9.8	98	7.08	
− 8	35	−23.63	−12.38
− 7	87	− 7.61	−10.78
− 6	238	−15.19	−11.59
− 5	353	− 6.83	− 8.13
− 4	483	− 2.63	− 5.97
− 3	823	−10.7	− 5.1
− 2	819	1.11	− 1.6
− 1	1348	1.71	− 0.11
0	1536	0.13	0.83
1	1213	0.29	1.34
2	463	2.63	2.66
3	579	4.98	5.41
4	402	5.37	8.29
5	322	17.84	10.23
6	292	13.14	7.33
7	112	−11.08	− 0.56
8	110	1.85	− 1.8
9	131	− 9.12	− 7.96
10	53	1.89	− 9.23
11	100	−39.55	−14.97
12	39	− 4.33	
14.2	40	22.55	

Table 5. The influence of H-alpha flares on residuals of relative catches of *Scotia segetum* Schiff.

H-alpha flares of importance 2 and 3	Number of flares of importance 2	3	Data number	ΔRC %
the same day	114	16	787	−0.848
after one day	–	–	795	−5.033
after two days	–	–	793	0.295

includes two variables). In accordance with this fact, in many cases, the cross-correlation functions show the periodicity of solar activity, e. g. about 11 years. It is noted that in the power spectrum computed from the mean P values of all stations, a half-period of solar activity can be seen but, with less maximum. Based on results reported, we suppose the hypothesis to be justified that the solar activity strongly influences the hypercycle of the given species. This result can be used especially to elaborate plant-protection prognoses of long duration.

The effect of the change of solar radio flux measured at 2800 MHz on *Scotia segetum* by light-trap is contrasted in two fields. When ΔS decreases or increases within intervals from − 8 % to + 5 %, results the decrease or increase of catch respectively. In opposition of the latter, within the change of ΔS from + 5 % to + 11 %, increasing solar flux decreases the catches. The calculated index of correlation (CI = 0.964) signalizes the strong connection. This relations are connected with 99.999 % of level of the significance. We do not know yet the mechanism, how acts the solar activity, particularly the radio flux on the insects, especially the species investigated. It is suggested, that the

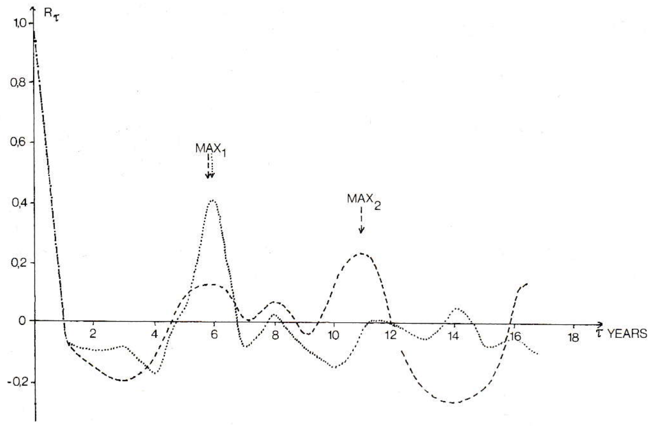

Fig. 1. The autocorrelation function of *Scotia segetum* Schiff. calculated from the mean of all observing stations (dotted line), and the same function deduced from relative number of sunspots (dashed line)

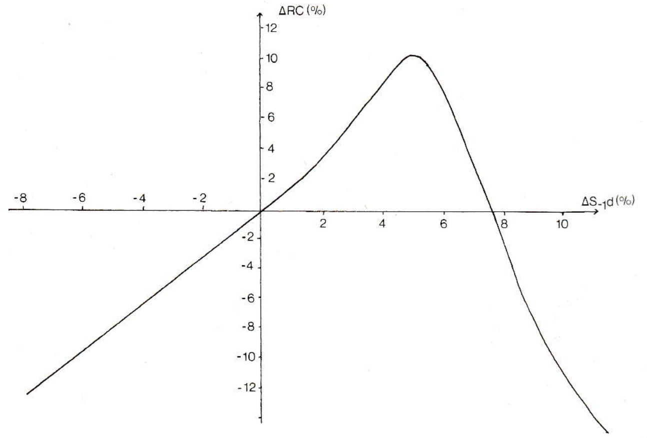

Fig. 2. The change of relative catch (ΔRC) of *Scotia segetum* Schiff. plotted against the change of solar radio flux of previous day (ΔS_{-1}), both expressed in percent

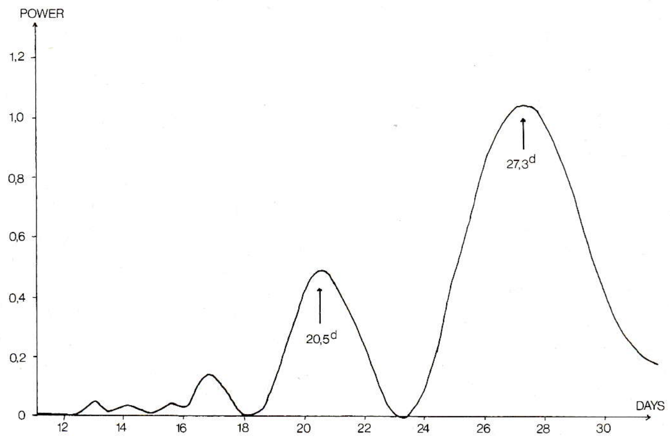

Fig. 3. The power spectrum of *Scotia segetum* Schiff.

weak increase of solar activity creates such meteorological situations, which are increasing the flying activity. Its decrease or strong increase makes unfavourable conditions for flying. In this field further investigations are needed.

The role of forming the catch of H-alpha flares of importance 2 and 3 are relatively smaller. In a day after the outburst the catch shows a decrease of 5 percent. In the same and two days after the appearence of solar flares, one can observe such a catch by light-trap, which is situated around the mean values. As was pointed out in section 2.2, not all flares cause variations in weather. Knowing this, it is supposed that influence of flares on changing weather is being larger observed by light-trap catches. Sorry, but we have had no possibilities to select such flares, which are affecting the weather on the Earth's surface.

The calculations of power spectra have resulted a peak-period of 27.15 days, which is associated with the average rotational period of the Sun. This period of time is needed for sunspots to reappearence ones more in solar disc, if after one rotation they existed. The results obtained by power spectrum computations verify the influence of solar activity on daily light-trap catches. Therefore it is indispensable to take into account the solar activity in data processing of daily catches as we have done and explained.

Zusammenfassung

Einfluß der Sonnenaktivität auf die Gradation und Lichtfallenfänge von Scotia segetum Schiff. (Lep., Noctuidae)

Die Autoren untersuchten, ob ein Zusammenhang zwischen der Sonnentätigkeit und der Gradation bzw. den täglichen Ergebnissen der Lichtfallenfänge von *Scotia segetum* besteht. Es wurde mit Hilfe von Auto- und Kreuzkorrelationsrechnungen gefunden, daß die Gradationen mit dem Sonnenzyklus im Zusammenhang stehen. Eine mäßige Zunahme des Sonnenfluxus, gemessen im Frequenzbereich von 2800 MHz am vorangehenden Tag, erhöhte –, eine stärkere Zu- oder Abnahme dagegen verminderte die Lichtfallenfänge. Die H-alfa chromosphärischen Eruptionen (Flare) der Intensitätsklasse 2 und 3 verminderten die Lichtfallenfänge am folgenden Tag. Die Ergebnisse dieser Arbeit können für die Pflanzenschutzprognose Verwendung finden.

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Modern Applications of Bioequivalence & Bioavailability
ISSN: 2577-2856

Juniper Publishers
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Mini Review
Volume 3 Issue 4 - March 2018

Mod Appl Bioequiv Availab

Light Trapping of Microlepidoptera Spec. Indet. Depending on Sunspot Numbers

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Submission: March 09, 2018; **Published:** March 28, 2018

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Abstract

The study examined the light trapping of Microlepidoptera spec. indet. in connection with the sunspot numbers. The catching data of moths (Microlepidoptera spec. indet.) were taken from the light-trap registers of the Hungarian Light-trap Network. During these years (1962, 1963, 1964, 1966, 1967, 1968 and 1969), 590,139 moths were caught during 1,479 nights by the 49 light-traps. Number of observing data are 21,761. Three divisions were formed from the years in accordance to the average sunspot numbers were in swarming period of less than 30, between 30-100, and was there more than 100. Our results show that in different years, the result of light trapping is different, according to the intensity of solar activity.

Keywords: Light-trap; Moths; Sunspots

Introduction

The activity of the Sun is the common name of the larger local disturbances of the sun's radiation. Electromagnetic and corpuscular radiation from the Sun changes the geophysical parameters on Earth. The coincidence or delay of the appearance of a terrestrial phenomenon depends on whether electromagnetic or corpuscular radiation is caused. Such events may be changes in the ionosphere and the upper atmosphere's magnetosphere, the formation of weather fronts, and sudden changes in the characteristics of ground magnetism. These can be followed by changes in the biosphere's phenomena. The solar activity, such as solar flares, may cause irregular departures from typical climatic conditions.

Blunck & Wilbert [1] assumes that insect gradations may be related to solar activity.

Polgár [2] found that the dry and the inland water years coincide with the sunspot with maxima or minima. Manninger [3] made observations on the gradation of harmful insects during a long period. There was a connection between gradations and dry and rainy periods that are related to the activity of the Sun. It has been shown that in the second half of the dry season there was gradation for drought-loving species, while at other times the gradation occurred in wet habitats for moisture-loving species. Richmond [4] suggests the sunspots affect the weather, which in turn affects the abundance of insects. There is not any study with relationship between sunspot numbers and light trapping of insects in the literature.

Material

Lepidoptera (Macro- and Microlepidoptera) is the best-processed group. Until now, however, no studies were published on the most injured moths. The reason for this is understandable that the unidentified specimens were recorded as "Microlepidoptera spec. indet." name. Because they were not known according to by species, it was not possible for further investigations. However, if we consider that there is a huge amount of collection data, we could see possibility for this research.

The catching data of Microlepidoptera spec. indet. were taken from the light-trap registers of the Hungarian Light-trap Network. During seven years (1962, 1963, 1964, 1966, 1967, 1968 and 1969) 590,139 moths were caught by the 49 light-traps. Of course, not all light-traps operated full years, but some of them were ceased, others sited later. This many moths were trapping in 1,479 nights. However, because more light-trap worked during one night, we could work up 21,761 observation data. The sunspot data were taken from the World Data Center SILSO, Royal Observatory of Belgium, Brussels.

Methods

The daily values of the sunspot numbers showed significant differences in the various years therefore we looked into the question of whether sunspot numbers that show significant differences from one year to the other modifies the number of the caught of examined moths collected in the different years. Three classes were formed from the years in accordance to the average sunspot numbers were in swarming period of less than 30 (1962, 1963, 1964), between 30-100 (1966), or was there more than 100 (1967, 1968, 1969).

The individual number is not the same in the different years and regions concerning to the same species. Because of this, relative catching (RC) values were calculated from number quotient of individuals caught during the sampling time unit (generally it is one night) and the average individual number in unit time of sampling [5]. Within the three groups, we made divisions using Sturges' method [6]. Finally, we averaged within groups the sunspot and relative catch data pairs. In the figures are plotted the results and in them were shown the confidence intervals.

Result and Discussion

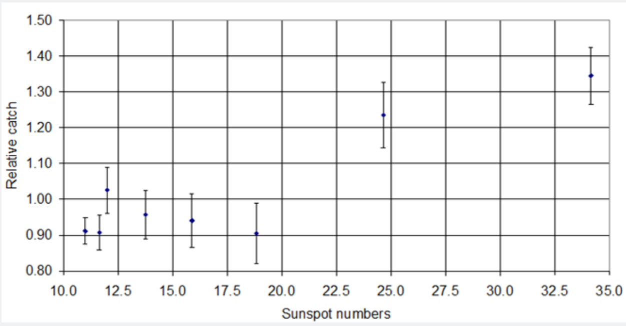

Figure 1: Light-trap catch of Microlepidoptera spec. Indet. In connection with the sunspot numbers (1962, 1963, 1964) (Average number of sunspot is between 0 and 30).

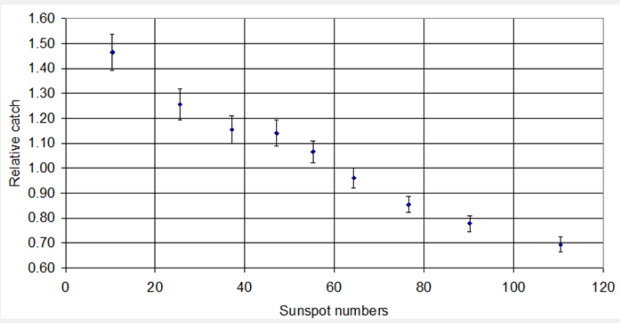

Figure 2: Light-trap catch of Microlepidoptera spec. Indet. In connection with the sunspot numbers (1966) (Average number of sunspot is between 30and 100).

Our results are shown in Figures 1-3. The flight activity and light-trap catches of Microlepidoptera species increased in those years when the average of sunspot numbers less than 30. By contrast, they are decrease in the year, when the averages of sunspots are between 30 and 100. The catch first increases in those years when the sunspot average higher than 100 and then deceases.

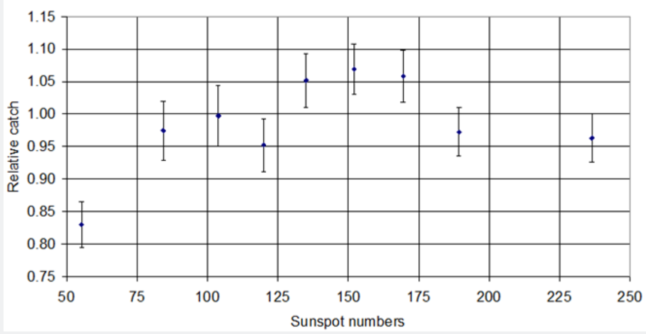

Figure 3: Light-trap catch of Microlepidoptera spec. Indet. In connection with the sunspot numbers (1967, 1968, 1969) (Average number of sunspot numbers are higherthan100).

It seems in this last groups, therefore, that during the swarming periods it is favourable for these moths if the number of sunspots is the same as the average. Both the smaller and the higher number of sunspots reduce the flying activity. We do not know exactly why. However, we assume that the influence of solar activity is related to a change in terrestrial weather conditions and geomagnetic disturbances or other environmental factors. These all affect the life phenomena of insects, including their flying activity.

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How to cite this article: László N, János P, Miklós K. Light Trapping of Microlepidoptera Spec. Indet. Depending on Sunspot Numbers. Mod Appl Bioequiv Availab. 2018; 3(4): 555619.

International Journal of Theoretical & Applied Sciences **6**(2): 23-30(2014)

ISSN No. (Print): 0975-1718
ISSN No. (Online): 2249-3247

Light Trapping of the Caddisflies (Trichoptera) in Hungary (Central Europe) at Different Values of the Q-index Expressing the Different Intensities of Solar Flares

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(Received 06 July, 2014, Accepted 24 July, 2014)

ABSTRACT: The Q-index is the index-number of the solar activity. The study deals with the connection Jermy-type light-traps operated in Hungary. Part of the species was collected in connection with the increasing the high values of the Q-index, but decrease were observed in part of other species. It can be experienced in some cases the increase of the catch after the decrease of it if the values of the Q-index is high. The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the Q-index, expressing the different lengths and intensities of the solar flares. The different form of behaviour, however, is not linked to the taxonomic position. Further testing will be required to fuller explanation of the results.

Key words: caddisflies, light-trap, Q-index

I. INTRODUCTION

There are solar flares surrounding of the active parts solar surface as part of global solar activity. They are followed by intensive radiation (X-ray, gamma and corpuscular), which after obtaining Earth there is a reciprocal effect between radiation and upper part of atmosphere and the electromagnetic circumstances are changed [1].

The flares are classified according to the size of their area as compared to the total solar surface. The flares of primary importance (1) do not reach 250 times the half of on millionth part of the total solar surface. If the flare takes 250-600 times this size, it receives an index number of 2; if greater 600 times than that, it has a significance of 3. Because of their significant energy emissions, the cosmic influence of the flares No. 2 and 3 is the most considerable. [2] was the first researcher, who introduced the concept of Q-index Q = (i x t), to use the daily flare activity through quantification of the 24 hours of the day. He assumed that this relationship gives roughly the total energy emitted by the flares. In this relation, "i" represents the intensity scale of importance and "t" the duration (in minutes) of the flare. Some researchers of flare activity using Kleczek's method are given for each day by [2], [3], [4], [5] and [6]. [7] calculated and published the flare activity numbers based on similar theoretical principles ("Flare Activity Numbers") for the period of 1957-1965.

The solar activity also exerts influence on life phenomena. In the literature accessible to the authors, however, no publication can be found that would have dealt with the influence of flares on the collection of insects by light-traps. Earlier we have published our studies and demonstrated the influence of hydrogen alpha flares 2 and 3 [8] on light-trap catches.

Most daily flare activities are characterised by Turkish astronomers [6] by index Q that expresses the significance of flares also by their duration. Its calculation is made by the following formula:

$$Q = (i \times t)$$

where i = flare intensity, t = the time length of its existence.

The solar activity also exerts influence on life phenomena. In the literature accessible to the authors, however, no publication can be found that would have dealt with the influence of flares on the collection of insects by light-traps. Earlier we have published our studies and demonstrated the influence of Hα flares No. 2. and 3. and the Q-index on light-trap catches [8], [9], [10], [11] and [12]. Other authors did not publish studies on theme of solar activity and light trapping of insects.

II. MATERIALS AND METHODS

Our catching data were collected from registers (between 1980 and 2000) and studies of Kiss [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23]. Jermy-type light traps were used to collect of caddisflies. The light source of the applied Jermy-type light-traps was a 100W normal white light electric bulb hanged under a metal cover (Ø: 1m) at 200 cm height above the ground. The traps were operated through every night during the season from April until October [24].

The collecting stations, years, and geographical coordinates and the catching data of caddisflies species are presented in Table 1.

Table 1: The name of the species caught the trapping sites and years, number of individuals and nights.

Species and light-trap stations	Geographic coordinates	Number of individuals	Number of nights
Hydropsychidae			
Hydropsyche instabilis Curtis 1834			
Szilvásvárad Szalajka stream, 1980	48°64'N; 20°23'E	1761	89
Bükk Vöröskő-Valley, 1981	48°34'N; 20°27'E	2656	86
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	8135	79
Bükk Vöröskő-Valley, 1983	48°34'N; 20°27'E	11483	95
Szarvaskő, Eger brook, 1989	47°59'N, 20°51'E	3561	104
Polycentropodidae			
Neureclipsis bimaculata Linnaeus 1758			
Bükk Vöröskő-Valley, 1981	48°34'N; 20°27'E	366	85
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	15704	96
Bükk Vöröskő-Valley, 1983	48°34'N; 20°27'E	13282	90
Limnephilidae			
Potamophylax nigricornis Pictet 1834			
Bükk Vöröskő-Valley 1982	48°34'N; 20°27'E	3661	83
Bükk Vöröskő-Valley 1983	48°34'N; 20°27'E	5858	91
Halesus digitatus Schrank 1781			
Szilvásvárad Szalajka stream, 1980	48°64'N; 20°23'E	837	64
Bükk Vöröskő-Valley, 1981	48°34'N; 20°27'E	112	29
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	1287	86
Bükk Vöröskő-Valley, 1983	48°34'N; 20°27'E	1049	99
Szarvaskő, Eger brook, 1989	47°59'N, 20°51'E	714	99
Szolnok Tisza River, 2000	47°10'N, 20°11'E	1030	57
Sericostomatidae			
Sericostoma personatum Kirby & Spence 1862			
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	988	119
Bükk Vöröskő-Valley, 1983	48°34'N; 20°27'E	1279	119
Odontoceridae			
Odontocerum albicorne Scopoli 1763			
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	653	117
Bükk Vöröskő-Valley, 1983	48°34'N; 20°27'E	839	119

The Q-index daily data for the period 1980-2000 were provided by Dr. T. Ataç (Bogazici University Kandilli Observatory, Istanbul, Turkey).

The number of individuals of a given species in different light-trap stations and different years are not the same. The catching efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all stations and at the time of catching, so it is easy to see that the same number of items captured at two different observing place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used [24]. From the collection data of the caddisflies (Trichoptera) species relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 night or 1 hour) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different points [24].

The Q-index values in the swarming periods of different years were quite different. Therefore we rendered them into two groups. The first includes the years in which the average value of the Q-index of the years were between 5 and 10 were added to group 1 (1983, 1984, 1988, 1992 and 1998). The second group includes the years in which the average values of the Q-index of the years were above 10 (1980, 1981, 1982 and 1989). The catching data in all two groups were processed the same way. We paired the data of the relative catch to the Q-index on every day during the collection period.

We arranged the values of the Q-index into classes using the method of Sturges [25] [26] and then calculated the average relative catch data related to them within both class. We demonstrated our results and communicated the equations of the curves and significance levels too.

III. RESULTS AND DISCUSSION

Our results are shown in Figs. 1-12. The characteristic curves associated parameters are indicated in the figures and significance levels are also given.

Figure 1 The light-trap catches of the *Hydropsyche insteblis* Curtis depending on the Q-index as a function of strong solar activity years (1980, 1981, 1982 and 1989)

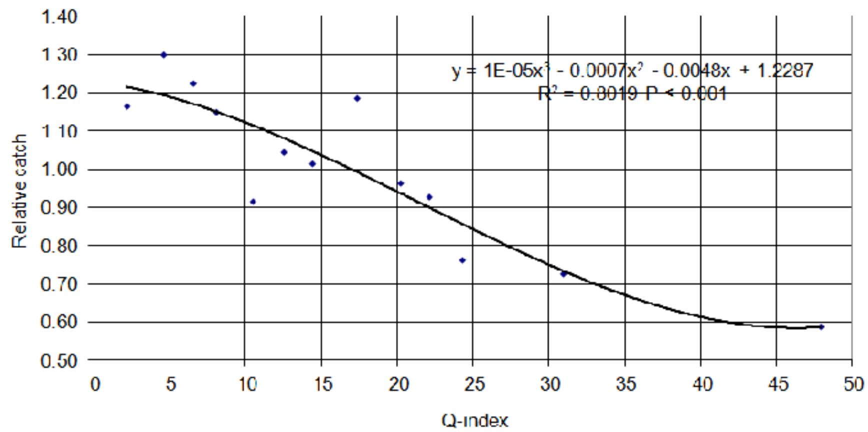


Figure 2 The light-trap catches of the *Hydropsyche instabiis* Curtis depending on the Q-index as a function of moderate solar activity year (1983)

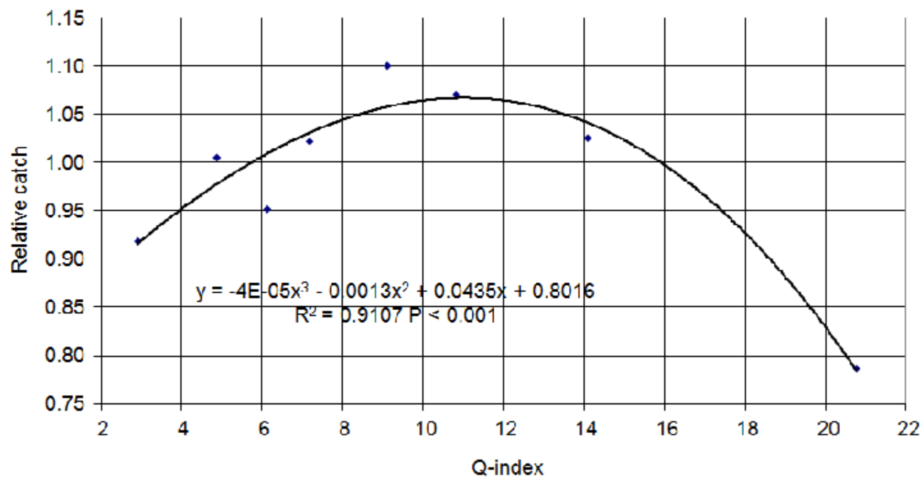


Figure 3 The light-trap catches of the *Neureclipsis bimaculata* L. depending on the Q-index as a function of strong solar activity years(1981 és 1982)

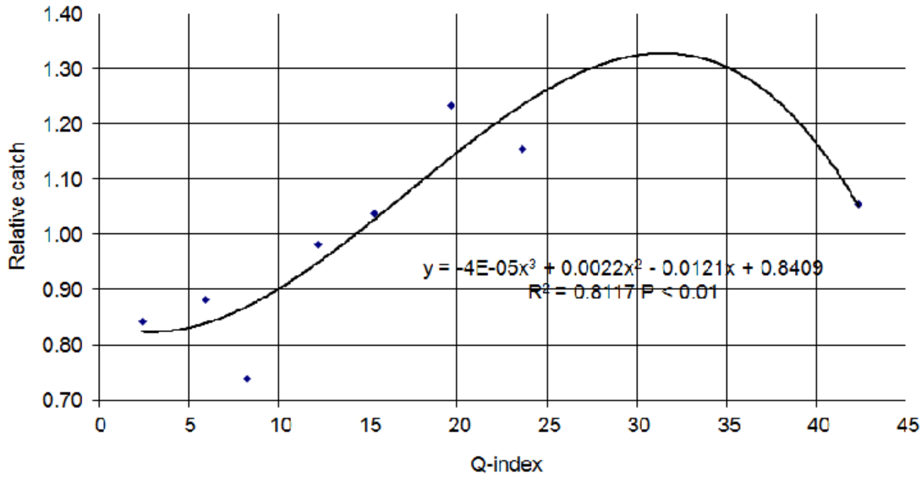


Figure 4 The light-trap catches of the *Neureclipsis bimaculata* L. depending on the Q-index as a function of moderate solar activity year (1983)

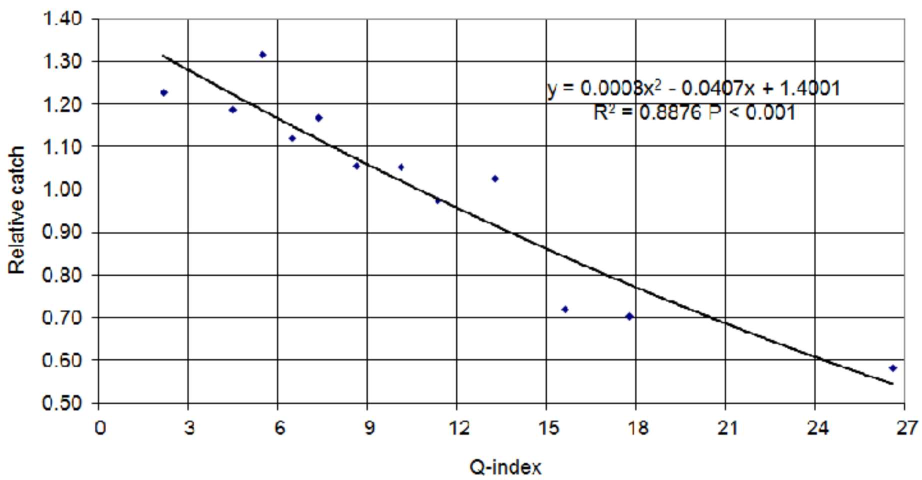


Figure 5 The light-trap catches of the *Potamophylax nigricornis* Pictet depending on the Q-index as a function of strong solar activity year (1982)

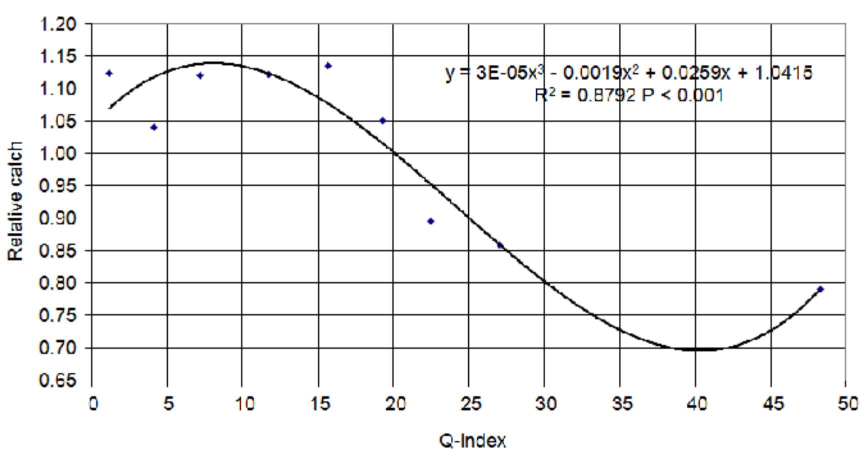


Figure 6 The light-trap catches of the *Potamophylax nigricornis* Pictet depending on the Q-index as a function of moderate solar activity year (1983)

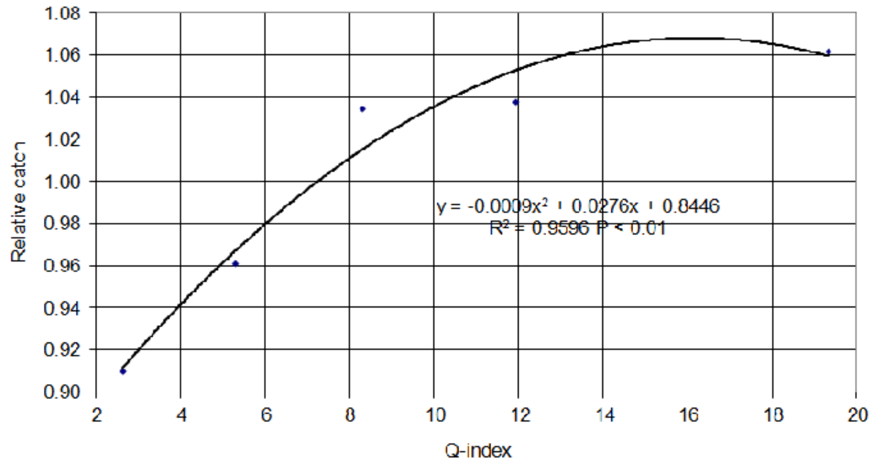


Figure 7 The light trap catches of the *Halesus digitatus* Schrank depending on the Q index as a function of strong solar activity years (1980 1982 and 1989)

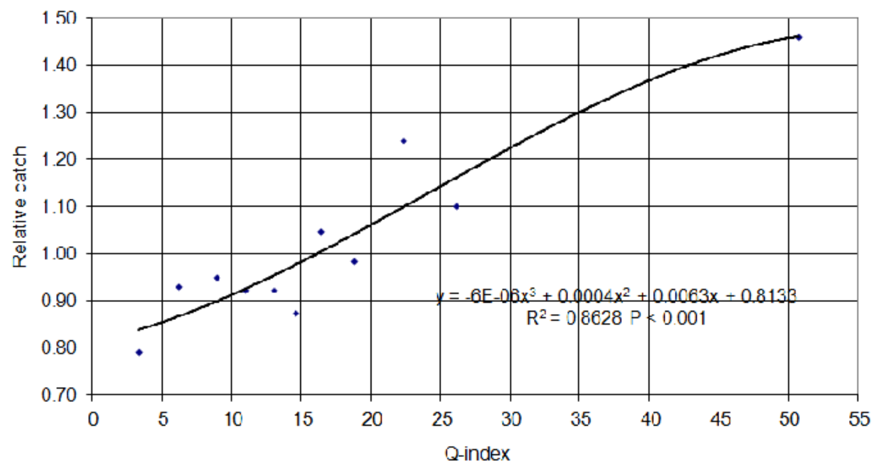


Figure 8 The light-trap catches of the *Halesus digitatus* Schrank depending on the Q-index as a function of moderate solar activity years (1983 and 2000)

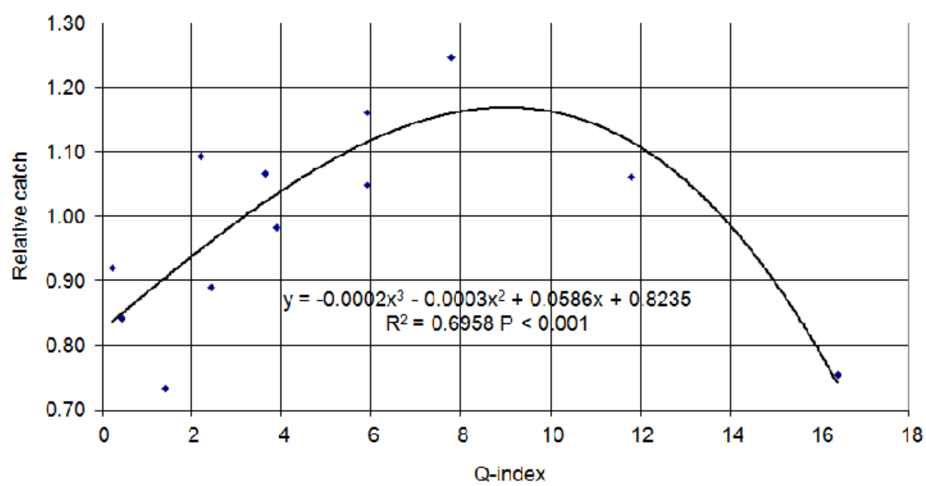


Figure 9 The light-trap catches of the *Sericostoma personatum* Spence depending on the Q-index as a function of strong solar activity year (1982)

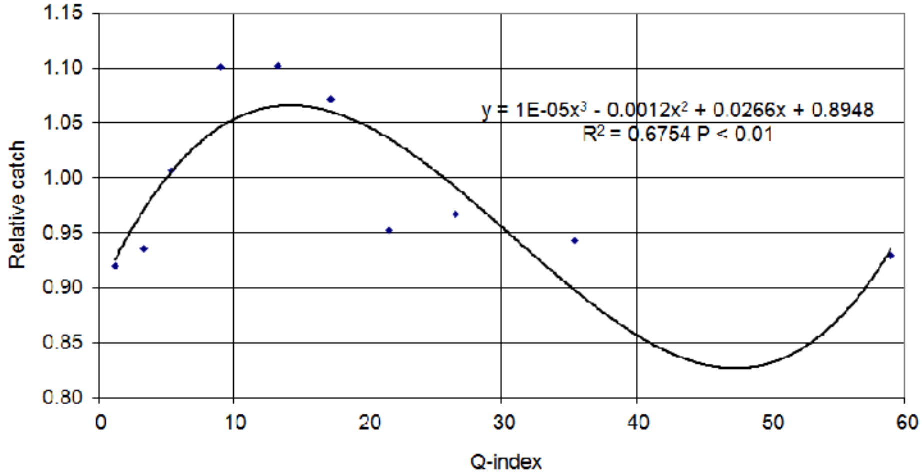


Figure 10 The light-trap catches of the *Sericostoma personatum* Spence depending on the Q-index as a function of moderate solar activity year (1983)

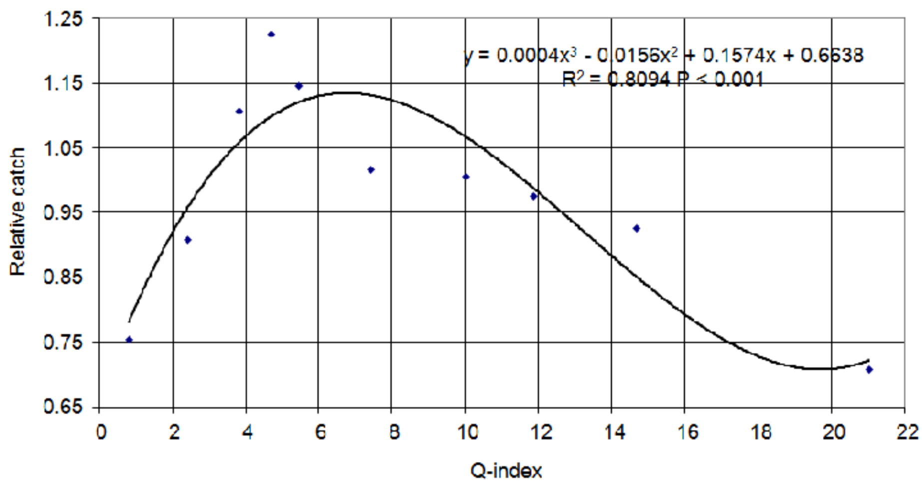


Figure 11 The light-trap catches of the *Odontocerum albicorne* Scopoli depending on the Q-index as a function of strong solar activity year (1982)

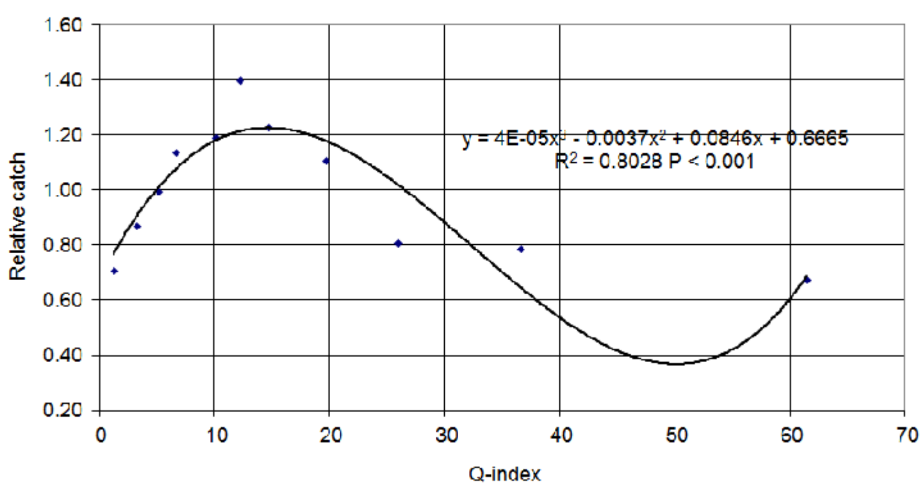
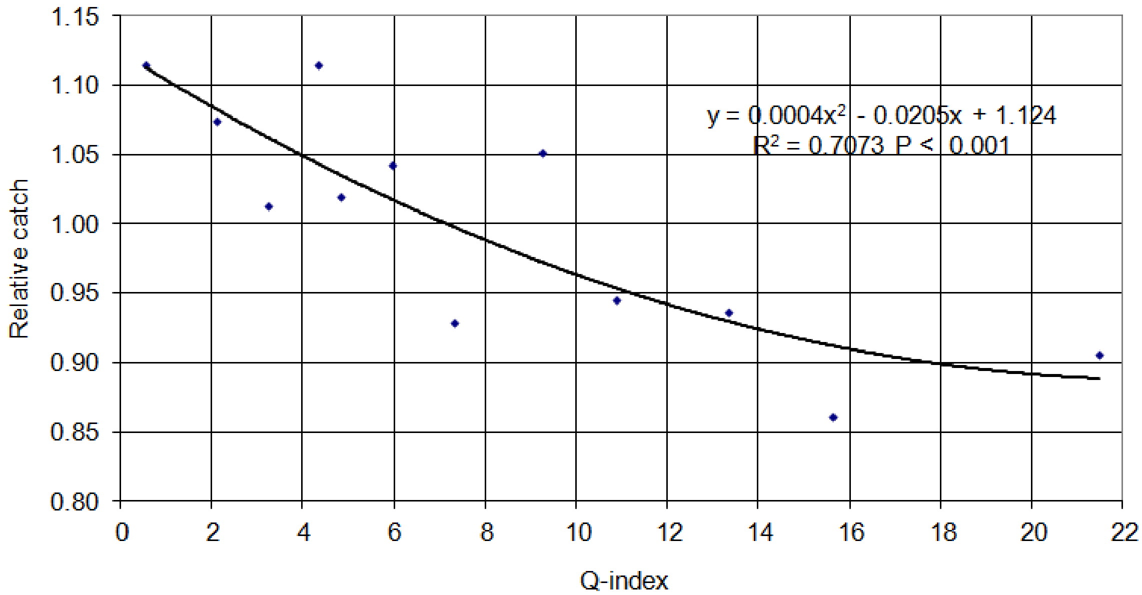


Figure 12 The light-trap catches of the *Odontocerum albicorne* Scopoli depending on the Q-index as a function of moderate solar activity year (1983)



Based on our results, we proved that the light-trap catch of examined species is affected by the solar activity featured by Q-index. However, some species may not react the same way.

Part of the examined species was collected in connection with the increasing the high values of the Q-index, but decrease were observed in part of other species. It can be experienced in some cases the increase of the catch after the decrease of it if the values of the Q-index is high. The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the Q-index, expressing the different lengths and intensities of the solar flares. The different form of behaviour, however, is not linked to the taxonomic position. Further testing will be required to fuller explanation of the results.

ACKNOWLEDGEMENTS

Flare Index Data used in this study were calculated by T. Ataç and A. Özgüç from Bogazici University Kandilli Observatory, Istanbul, Turkey. The Q-index daily data for the period 1980 and 2000 were provided by Dr. T. Ataç. His help is here gratefully acknowledged.

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Acta Phytopathologica et Entomologica Hungarica 36 (1–2), pp. 201–205 (2001)

Light-Trapping of the European Corn Borer (*Ostrinia nubilalis* Hbn.) at Different Values of the Q-index Expressing the Different Intensities of Solar Flares

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The paper deals with connections between solar flare activities and light-trap collection of insects. The authors have worked out the catch data of European corn borer (*Ostrinia nubilalis* Hbn.) adults, as published for the period of 1976–1997 by the Hungarian national light-trap network. The results proved that both the daily and annual catches were significantly modified by the Q-indexes, expressing the different lengths and intensities of the solar flares. On days with high Q-indexes relative to the ones of the average swarming periods, the number of catches are considerably lower. In those years when the Q-index is high, the average individual number and the number of caught moths are lower by 30% as compared to the average number of total cycles (11 years) and the average population density of a given biotope. On the contrary, in years with low Q-indexes an increase as high as 45% can be experienced in the number of individuals collected. Thus, by evaluating the light-trap catches a strong modifying effect of solar flares has to be considered.

Keywords: European corn borer, *Ostrinia nubilalis,* light-trap, solar flares, Q-index.

As part of global solar activity flares, eruptions can be observed in the active regions of the solar surface, that are accompanied by intensive X-ray, gamma- and corpuscular radiations, that reach also the Earth and establish an interaction with its outermost atmosphere, producing thus changes in its electromagnetic conditions (Smith and Smith, 1963).

The Sun eruptions, flares are short (lasting max. 10–20 minutes) shiny spots, temporal areas in the chromosphere of the Sun. Their observation is carried out conventionally in the red (656.3 nanometer wavelength light) of alpha line of hydrogen. At the time of intensive flares the corpuscular emission is thousandfold as compared to a quiet period of Sun. The corpuscles are mostly electrons flying into all directions (also toward the Earth) with a speed of 1500 km^{-1}. These electrically charged corpuscles compose the so-called solar wind that – in contrast to the electromagnetic radiation that reaches the Earth in 8 and a half minutes – reaches our atmosphere in 26–28 hours. On their way to Earth, the flare particles have also to pass the interplanetary space. The magnetic field generated by the galactic cosmic radiation is moderating considerably the effects of flares exerted on the magnetosphere of Earth. Thus, not all flares cause changes in the physical conditions of the upper atmosphere. If, however these changes result from the above-mentioned reasons, the weather becomes temporarily altered and the magnetic field of the corpuscles modifies the undisturbed daily course of the terrestrial magnetic field.

0238–1249/2001/$ 5.00

The flares are classified according to the size of their area as compared to the total solar surface. The flares of primary importance (1) do not reach 250 times the half of on millionth part of the total solar surface. If the flare takes 250–600 times this size, it receives an index number of 2; if greater 600 times than that, it has a significance of 3. Because of their significant energy emissions, the cosmic influence of the flares No. 2 and 3 is the most considerable.

Most daily flare activities are characterised by most authors by index Q that expresses the significance of flares also by their duration. Its calculation is made by the following formula:

$$Q = (i \times t)$$

where i = flare intensity, t = the time length of its existence

Earlier Örményi (1966) calculated and published the flare activity numbers based on similar theoretical principles ("Flare Activity Numbers") for the period of 1957–1965.

The solar activity also exerts influence on life phenomena. In the literature accessible to the authors, however, no publication can be found that would have dealt with the influence of flares on the collection of insects by light-traps. Earlier we have published our studies and demonstrated the influence of hydrogen alpha flares No. 2 and 3 (Tóth and Nowinszky, 1983) on light-trap catches.

Material

The Q-index daily data for the period 1976-1997 were provided by Dr. T. Atac (Bogazici University, Kandilli Observatory and Earthquake Research Institute, Istanbul) and by Dr. J. Verő (Research Institute of Geodesy and Geophysics, Hungarian Academy of Sciences, Sopron). Their help is here gratefully acknowledged.

The collection data of European corn borer (*Ostrinia nubilalis* Hbn.) were taken from the collection of the national light-trap network. The data of traps, operated by the Plant Protection Stations were used with the authorization of Dr. I. Eke (Ministry of Agriculture and Country Development), Dr. M. Tóth and Mrs. Gy. Mohai (Station of Plant Health and Soil Protection, Budapest). Many data were received from Professor Z. Mészáros (University of Horticulture and Food Industry, Budapest).

In course of the period studied: in 81 light-trap stations and 3114 nights 133 419 moth individuals were collected in total. As more than one trap operated on each nights the authors disposed over 40 336 observation data in preparing present paper.

Methods

From the collection data of the European corn borer (*Ostrinia nubilalis* Hbn.) relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 night or 1 hour) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different points.

At the values of Q-index showed considerable differences in course of the respective years, they were preferably expressed as percentages of the averages of swarming periods. In the first step we studied the influence of flare activities on the daily catches. To disclose the latter, the Q/Q average values were co-ordinated with the relative catch data of different observation posts for each day of the catch period. The Q/Q mean values have been contracted into groups (classes), then averaged within the classes the relative catches data pertaining to them.

In subsequent studies we have investigated, whether the constantly changing activities of flares had modified the numbers of trapped European corn borer (*Ostrinia nubilalis* Hbn.) individuals? For this study only the data of those observation posts could be used that had worked throughout at least one total solar activity cycle (1976–1986 or 1986–1997). The light-traps operated through both cycles only on two observation posts; additionally, in the first cycle 11 and in the second further 1 light-trap yielded data from a total period. The total catch of the individual years has been compared with the average catch number of 11 years, so essentially yearly relative catch data (RCy) were calculated. These numbers were yearly compared to the average of Q-index, then in years with low (Q-index average 1–3), medium (Q-index average 3–10) and high (Q-index average higher than 10) flare activity the level of significance of relative catch data (RCy) deviation was tried by t-test.

Results

The connections between Q/Q averages and daily catches of European corn borer (*Ostrinia nubilalis* Hbn.) are presented in *Table 1*. The values of Q-index characteristic for each year are shown in *Table 2*. In the latter the yearly relative catch data (RCy) of the studied species are also presented.

Discussion

From the results several important consequences could be drawn. Between the Q-indexes and maximal values of Q/Q average a negative correlation ($r = -0.715$) could be found, that is significant at 99.9 % level.

As proven by the data of *Table 1,* on those days when the value of Q/Q average surpasses 3, the catch number of European corn borer (*Ostrinia nubilalis* Hbn.) adults significantly regresses. Such high values occur mainly in years in which the Q-index averages are lower than 10. This means that in those years when the flare activity is mostly moderate the rarely occurring high Q-indexes surpass considerably the average. In those years, however, where the average Q-index is higher than 10, the highest Q-index

Table 1

Daily catches of European corn borer (*Ostrinia nubilalis* Hbn.) adults in 1976–1997 at different values of Q/Q average

Q/Q average 1	Average of relative catch 2	Number of data 3
0.00	0.964	9541
0.12	1.051	3144
0.31	1.054	3626
0.51	0.988	4112
0.71	1.048	3673
0.91	0.985	2695
1.43	1.008	8488
2.41	0.987	2666
3.42	1.102	911
4.97	0.870	825
6.82	0.821	321
12.21	0.783	334

Notes: Correlation between Q/Q average and the relative catch: r = –0,8146 (significant on levels higher than 99%)

values surpass much less the average. The unfavourable influence of flare activity, which exceeds considerably the average, is reflected in the decreasing number of daily light-trap catches. Because decreasing catches may be experienced on the first day of strong flare activity, we assume that the success of light-trapping is significantly and negatively influenced by the electromagnetic radiation arriving from the Sun. The decrease of catch numbers cannot be felt at Q/Q average values lower than 4. To these values generally high Q-indexes are attached, at the same time the deviation from the average is lower.

One can suppose that the high flare activity generally decreases the number of caught individuals. The method used by us so far, i.e. the relative daily catches, calculated separately for each year per swarming period of the Lepidopteran is inadequate. By introducing and using the relative yearly catch (RCy) we succeeded to confirm the fact that in the case of high flare activity when the Q-index average was higher than 10 (the average catch number calculated for a period of 11 years, a Sun cycle and characteristic for the given observation point, does barely amount to 70% of the expected individual number collected. In years with low flare activity, however, the catch number exceeds the average at least by 44%.

So, according to our results, changes in Sun flare activity considerably modify both the daily catch of European corn borer (*Ostrinia nubilalis* Hbn.) individuals and the number of individuals present. Both statements are important for plant protection prognostics.

Table 2

Yearly relative catch (RCy) of European corn borer (*Ostrinia nubilalis* Hbn.) adults calculated as functions of Q-index yearly averages

Years	Q-index maximum	Q-index average	Q/Q average maximum	Number of data	RCy average
1986	5.36	0.406	13.20	13	2.079
1996	11.48	0.478	24.02	3	1.052
1976	4.98	0.632	7.88	13	1.294
1997	12.28	0.642	19.13	3	0.443
1995	12.00	0.734	16.35	3	1.423
1994	12.08	0.973	12.42	3	0.734
1985	21.31	1.459	14.61	13	1.467
1987	16.21	2.917	5.56	3	1.289
a		*0.920*		*54*	*1.440*
1977	32.27	3.059	10.55	13	0.788
1983	37.29	3.360	4.03	13	1.163
1984	42.09	3.573	11.78	13	0.863
1988	36.90	6.880	4.37	3	1.280
1992	33.56	8.453	4.88	3	1.642
1993	36.92	9.243	10.99	3	0.634
b		*5.468*		*48*	*0.984*
1978	65.23	10.719	6.09	13	0.653
1979	56.40	12.151	3.46	13	0.536
1980	53.38	15.350	3.39	13	0.330
1981	51.29	15.757	3.12	13	0.737
1982	112.31	16.313	5.77	13	1.088
1989	55.10	16.461	3.33	3	0.766
1990	43.40	16.556	3.57	3	0.620
1991	68.22	19.464	4.44	3	1.115
c		*15.614*		*74*	*0.689*

Notes: Levels of significance:
Between Q-index average and maximum of Q/Q average 99.9%
Between *a–b* lines of RCy values 95.0%
Between *b–c* lines of RCy values 95.0%
Between *a–c* lines of RCy values 99.9%

Literature

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Light-trap catch of moth species of the Becse-type light trap depending on the solar activity featured by Q-index

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Keywords:

solar flares, Q-index, moths, Becse-type light-trap

ISSN 0799-3757

http://caribjscitech.com/

ABSTRACT

The Q-index is the index-number of the solar activity. The study deals with the connection between solar flare activity featured by Q-index and light trap catch of eight Microlepidoptera and twenty two Macrolepidoptera species from a Becse-type light-trap. Nine species were collected in connection with the increasing the high values of the Q-index, but decrease were observed in case of fourteen species. It can be experienced in seven cases the increase of the catch after the decrease of it if the values of the Q-index is high. The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the Q-index, expressing the different lengths and intensities of the solar flares. The different form of behaviour, however, is not linked to the taxonomic position. Further testing will be required to fuller explanation of the results.

INTRODUCTION

Kleczek was the first researcher, who introduced the concept of Q-index (Q = i x t), to use the daily flare activity through quantification of the 24 hours of the day. He assumed that this relationship gives roughly the total energy emitted by the flares. In this relation, "i" represents the intensity scale of importance and "t" the duration (in minutes) of the flare. Some researchers of flare activity using Kleczek's method are given for each day by Kleczek (1952), Knoška & Petrásek (1984), Ataç (1987), Ataç & Özgüç (1998), Özgüç & Ataç (1989).

As part of the global solar activity, accompanied by intensive X-ray, gamma and corpuscular radiation, outbreaks (flares) appear in the vicinity of the active regions on the surface of the Sun. Reaching the Earth, and getting into interaction with its upper atmosphere, these flares change the existing electromagnetic relations (Smith & Smith (1963). The flares, these temporary flashes in the chromosphere of the Sun in the vicinity of sunspots can be observed for a maximum of 10-20 minutes. They can be observed mainly in the 656.3 nm wavelength red light of the H-α line. During the appearance of intensive solar flares, corpuscular emission can be one thousand times stronger than in a quiet state of the Sun. The corpuscles consist mainly of electrons and spread in all directions, including that of the Earth, at a maximum speed of 1 500 $km*s^{-1}$. These electrically charged particles form the so-called solar wind, which, unlike electromagnetic radiation that arrives in 8 and half minutes, reaches the Earth in 26-28 hours. Flair particles, on their way to the Earth, must also pass through interplanetary space. In its turn, the magnetic field of the latter generated by general galactic cosmic radiation can significantly modify the effect of flares on the magnetosphere of the Earth' atmosphere. So not every flare will be induce changes in the physical state of the upper atmosphere. If and when, however, such changes occur, they lead to temporary weather modification and the magnetic field of the charged particles will also affect the quiet daily trend of the magnetic field of the Earth. The intensity of the flares is determined by the area they are observed to occupy in relation to the solar disk as a whole. Flares of first importance are less than 250 times the half of the one millionth of the global surface of the Sun. A flare is of second importance if its area is 250-600 times the unit and it is of importance three if it is more than 600 times the unit. Following from the greater intensity of the flux of energy, second and third importance flares have the most significant cosmic impact. The daily activity of the flares is characterized by the so-called Q index that, used by several researchers, considers both the intensity and period of prevalence of the flares (Nowinszky & Tóth (1987), Nowinszky (2003).

Solar flares are most powerful and explosive of all forms of solar activity and the most important in terrestrial effects. This idea led solar physicists to valuable the daily flare index (Özgüç & Ataç (1989).

Most daily flare activities are characterised by most authors by index Q that expresses the significance of flares also by their duration. Its calculation is made by the following formula:

Q = (i x t) where i = flare intensity, t = the time length of its existence.

Earlier the “Flare Activity Numbers” for years between 1957 and 1965 were worked out, based on similar theoretical basis, and published by Örményi (1966).

The solar activity also exerts influence on life phenomena. In the literature accessible to the authors, however, no publication can be found that would have dealt with the influence of flares on the collection of insects by pheromone traps and light-traps.

Earlier we have published our studies and demonstrated the influence of hydrogen alpha flares No. 2. and 3. on light-trap catches (Tóth & Nowinszky (1983).

We have demonstrated in our previous works that Q-index affect both the pheromone trapping (Puskás *et al*. (2010, Nowinszky & Puskás, 2011), and light trapping effectiveness (Nowinszky & Puskás (2013).

MATERIAL AND METHODS

Data used in this study were calculated by T. Ataç and A. Özgüç from Bogazici University Kandilli Observatory, Istanbul, Turkey. Their help is gratefully acknowledged.

The light-trap was operated by Varga & Mészáros (1973a & 1973b) between 1969 and 1973 on the territory of the Agricultural and Industrial Combine in Bečej, Serbia (Geographical coordinates are: 45°37'05''N and 20°02'05''E) and collected many more insects than the Hungarian Jermy-type traps. The light source of the trap is an IPR WTF 220V, 250W mercury vapour lamp 2 meters above the ground. There is a large collecting cage under the funnel of the trap. The cage contains two perpendicular separation walls made of plastic haircloth dividing the cage into four equal parts. This solution ensured that the tougher bodied and livelier beetles staying at the bottom of the cage couldn't damage the moths and other fragile insects that have climbed up on the separation walls. In the morning the cage was placed in a chest in which a few millilitres of carbon bisulphide had been burnt. The gases thus generated killed the insects quickly and effectively. The light-trap worked every night in the breeding season even in bad weather. Several of this type of traps collecting huge masses of insect material of good quality has been operating in Yugoslavia. Regarded to be dangerous, the use of this type of trap has not been permitted in Hungary.

The moth data of Becse-type light trap were processed and published (Vojnits *et al.* 1971), Mészáros *et al.* (1971). We process 8 Microlepidoptera and 22 Macrolepidoptera species from the total catching data. The names of the species, the years of collecting and the number of individuals are shown in Table 1.

Table 1 Collection data of the examined moths (Lepidoptera) species

Families and scientific names	Collecting years	Number of	
		Individuals	Data
Tortricidae			
Aleimma loeflingiana Linnaeus, 1758 Yellow Oak Button	1969-1972	2824	52
Crambidae			
Evergestis extimalis Scopoli, 1763 Marbled Yellow Pearl	1971-1973	1149	86
Loxostege sticticalis Linnaeus, 1761 Beat Webworm Moth	1970-1973	1196	131
Sitochroa verticalis Linnaeus, 1758 Lesser Pearl	1970-1973	3002	230
Ostrinia nubilalis Hübner, 1796 European Corn-borer	1970-1973	38120	340
Nomophila noctuella Denis et Schiffermüller, 1775 Rush Veneer	1970-1973	14374	243
Pyralidae			
Etiella zinckenella Treitschke, 1822 Lima Bean Pod Borer	1970-1973	3141	129
Homeosoma nebulella Denis et Schiffermüller, 1775 European Sunflower Moth	1969 and 1971	6263	92
Geometridae			
Chiasmia clathrata Linnaeus, 1758	1970-1973	3478	258

Latticed Heath			
Ascotis selenaria Denis et Schiffermüller, 1775 Luna Beauty	1970-1971 and 1973	2159	161
Lymantriidae			
Leucoma salicis Linnaeus, 1758 White Satin Moth	1969-1973	3255	255
Arctiidae			
Hxphantria cunea Drury, 1773 Fall Webworm	1970-1973	4447	234
Spilosoma lubricipeda Linnaeus, 1758 White Ermine	1970-1971	2644	84
Spilosoma urticae Esper, 1789 Water Ermine	1970-1971 and 1973	4634	112
Phagmatobia fuliginosa Linnaeus, 1758 Ruby Tiger	1970-1973	14374	243
Noctuidae			
Agrotis segetum Denis et Schiffermüller, 1775 Turnip Moth	1970-1973	9895	301
Agrotis exclamationis Linnaeus, 1758 Heart & Dart	1970-1973	2348	177
Axylia putria Linnaeus, 1761 The Flamme	1969-1973	2914	179
Noctua pronuba Linnaeus, 1758 Large Yellow Underwing	1970-1973	1755	194

Families and scientific names	Collecting years	Number of	
		Individuals	Data
Xestia c-nigrum Linnaeus, 1758 Setaceous Hebrew Character	1970-1973	28999	326
Discestra trifolii Hufnagel 1766	1970-1973	11381	310

The Nutmeg			
Mamestra brassicae Linnaeus, 1758 Cabbage Moth	1970-1971 and 1973	4187	92
Laconobia suasa Denis et Schiffermüller 1775 Dog's Tooth	1970-1973	4434	189
Laconobia oleracea Linnaeus, 1758 Bright-line Brown-eye	1970-1973	7512	201
Mythimna vitellina Hübner, 1808 The Delicate	1970-1973	3583	180
Heliothis maritima Graslin, 1855 Shoulder-striped Clover	1970-1973	3563	215
Emmelia trabealis Scopoli, 1763 Spotted Sulphur	1970-1973	18678	312
Macdunnoughia confusa Stephens, 1850 Dewick's Plusia	1969-1973	1236	221
Autograha gamma Linnaeus, 1758 Silver Y	1970-1973	6868	349
Tephrina arenacearia Denis et Schiffermüller, 1775 Lucerne Moth	1970-1973	4457	227

From the catching data of the examined species, relative catch (RC) data were calculated for each night. The RC is the quotient of the number of individuals caught during a sampling time unit (1 night) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number, the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps (Nowinszky 2003).

Data on the Q-index were arranged into classes according to Sturges' method (Odor & Iglódi (1987). The relative catch values were assigned into the classes of the Q-index belonging to the given day and then they were summarized and averaged.

RESULTS AND DISCUSSION

Based on our study can be typed the examined species of three types: ascending, descending, ascending then descending.

Our results are shown in Figures 1-3 and Table 2. The characteristic curves associated parameters are indicated in the figures and significance levels are also given.

Figure 2 Light-trap catch of The Delicate (*Mythimna vitellina* Hbn.) depending on the Q-index (Bečej, 1970-1973)

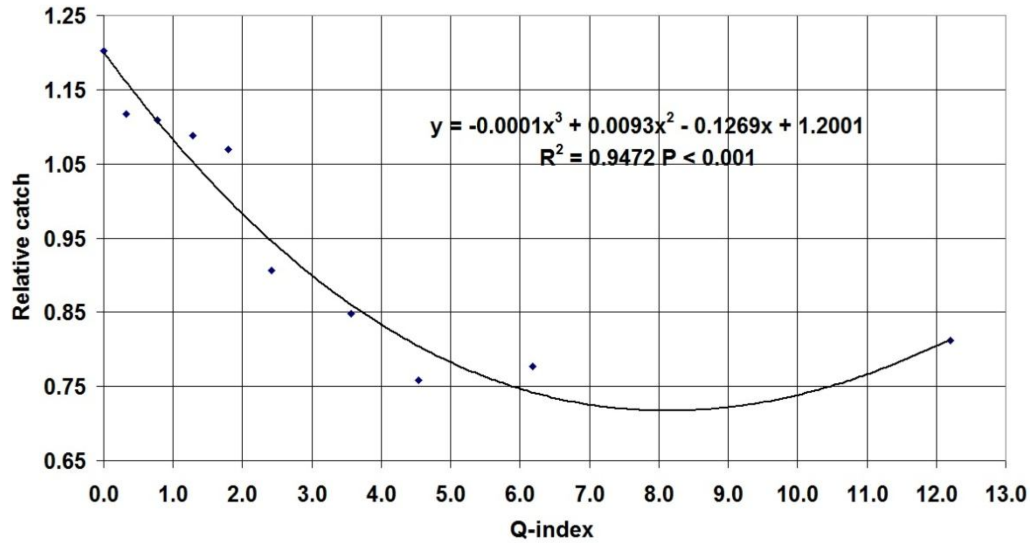
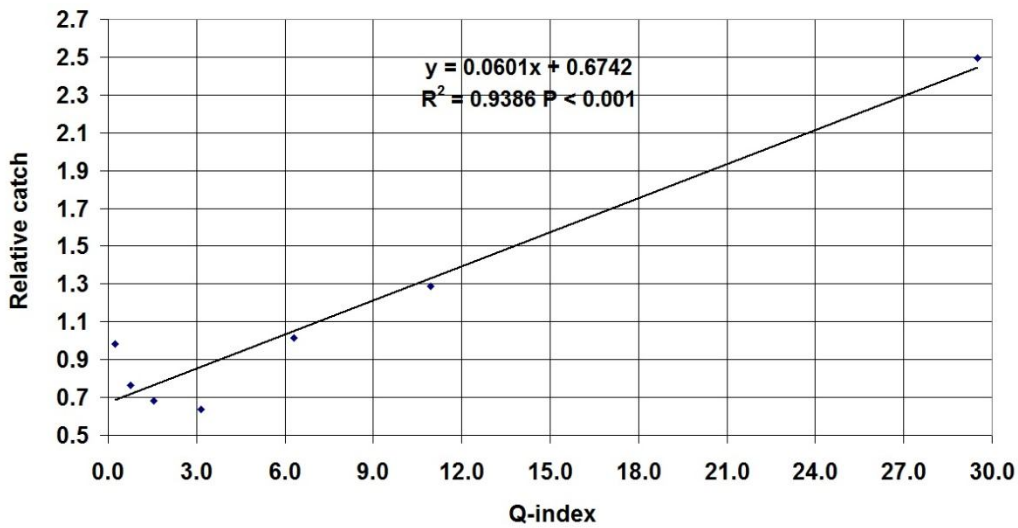


Figure 1 Light-trap catch of Yellow Oak Button (*Aleimma loeflingiana* L.) depending on the Q-index (Bečej, 1969-1972)



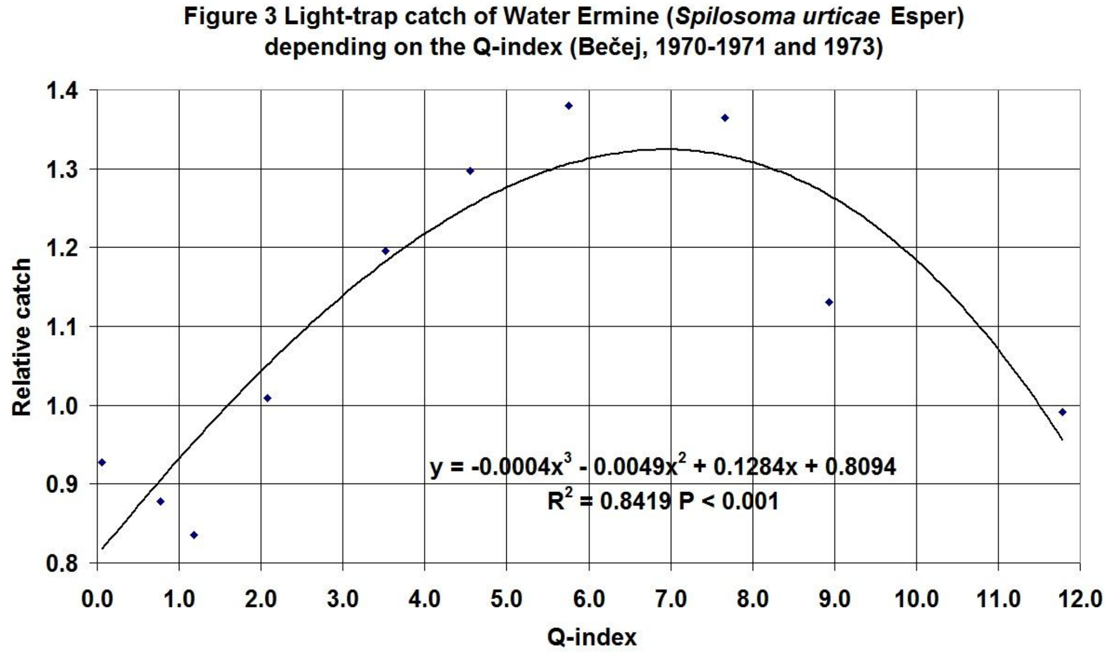


Table 2. The types of light trapping of examined species depending on the Q-index

Scientific names of examined species	Types		
	Ascending	Descending	Ascending then descending
Tortricidae			
Aleimma loeflingiana L.	X		
Crambidae			
Evergestis extimalis Scop.	X		
Loxostege sticticalis L.		X	
Sitochroa verticalis L.	X		
Ostrinia nubilalis Hbn.	X		
Nomophila noctuella Den. et Schiff.	X		
Pyralidae			
Etiella zinckenella Tr.		X	
Homeosoma nebulella Den et Schiff.	X		
Geometridae			
Chiasmia clathrata L.		X	

Ascotis selenaria Den. et Schiff.		X	
Lymantriidae			
Leucoma salicis L.			X
Arctiidae			
Hyphantria cunea Drury		X	
Spilosoma lubricipeda L.		X	
Spilosoma urticae Esp.			X
Phagmatobia fuliginosa L.			X
Noctuidae			
Agrotis segetum Den. et Schiff.	X		
Agrotis exclamationis L.	X		
Axylia putris L.			X
Noctua pronuba L.			X
Xestia c-nigrum L.			X
Discestra trifolii Hfn.		X	
Mamestra brassicae L.			X
Laconobia suasa Den. et Schiff.		X	
Laconobia oleracea L.		X	
Mythimna vitellina Hbn.		X	
Heliothis maritima Grsl.		X	
Emmelia trabealis Scop.		X	
Macdunnoughia confusa Steph.			X
Autographa gamma L.		X	
Tephrina arenacearia Den. et Schiff.		X	

Eight Microlepidoptera and twenty two Macrolepidoptera species were caught by the Becse-type light-trap. Based on our results, we proved that the light-trap catch of examined species is affected by the solar activity featured by Q-index. However, some species may not react the same way. Nine species are collected in connection with the increasing the high values of the Q-index but decrease were observed in case of fourteen species. Seven cases can be experienced the increase of the catch after the decrease of it if the values of the Q-index is high. The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the Q-index, expressing the different lengths and intensities of the solar flares. The different form of behaviour, however, is not linked to the taxonomic position. Further testing will be required to fuller explanation of the results.

Acknowledgements

The research was realized under the reference code TÁMOP-4.2.4.A/2-11/1-2012-0001, which is an emphasized project named National Excellence Program. In this convergence program a system was set up and worked that ensured the support of the national students and researchers. The project was realized by the financial support of European Union and European Social Fund.

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DOI: 10.24369/eANP.2017.14.49.
eActa Naturalia Pannonica 14: 49–56.|00.04.2017 | HU ISSN 2061–3911

Light-trap catch of three moth (Lepidoptera) species at different values of the "Flare Activity Numbers"

László Nowinszky & János Puskás

Abstract: A Hungarian researcher, Örményi calculated and published the "Flare Activity Numbers" for the period of 1957–1961. The FAN index was devised to indicate the intensity of the flare, the serial number of a flare occurring on a given day and the duration of the given flare. We examined the light trapped three moth (Lepidoptera) species from the data of agricultural observation stations. The chosen species are: European Corn-borer (*Ostrinia nubilalis* Hübner, 1796, Fall (Autumn) Webworm (*Hyphantria cunea* Drury, 1773) and Setaceous Hebrew Character (*Xestia c-nigrum*, Linnaeus, 1758). The relative catch (RC) values were calculated from daily trapping data of these species. The values of relative catch were separated according to the characteristics of each day, after it they were summarised and averaged. We made groups according to the connection between catch and flare activity number pairs, and finally we averaged the results. We calculated regression equations for the relative catch of investigated species and flare activity number data pairs. The light-trap catch of the two examined species (*Ostrinia nubilalis* and *Xestia c-nigrum* initially increased by the increase of the value of the FAN together. The behaviour of one of the species (*Hyphantria cunea*) differs from these; that have an only decreasing character of FAN together. Our results proved that "Flare activity numbers" can be used for entomological researches. They may have significance especially in those years in which the Q-index values are not yet available.

Keywords: "Flare activity numbers", light-trap, moths, Hungary.

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Összefoglalás: Egy magyar kutató, Örményi Imre kidolgozta és megjelentette a "Flare Aktivitási Számok"-at az 1957–1961 közötti évekre. A FAN értékek figyelembe veszik a napkitörések (flerek) számát, intenzitását és időtartamát egy-egy adott napon. A mezőgazdasági fénycsapdák anyagából három lepke (Lepidoptera) faj gyűjtési adatait dolgoztuk fel. A kiválasztott fajok a következők: Kukoricamoly (*Ostrinia nubilalis* Hübner, 1796), amerikai fehér medvelepke (*Hyphantria cunea* Drury, 1773) és c-betűs fűbagoly (*Xestia c-nigrum* Linnaeus, 1758). A napi gyűjtési adatokból fajonként relatív fogás (RF) adatokat számítottunk. Ezeket hozzárendeltük az adott napot jellemző FAN számokhoz. Az összetartozó értékpárokból csoportokat képeztünk. A csoportokon belül átlagokat számítottunk a Fan és a fogási értékekből. Ezeket ábrázoltuk és kiszámítottuk a regressziós egyenleteket és azok paramétereit. Két vizsgált faj, *Ostrinia nubilalis* Hbn. és *Xestia c-nigrum* L. fogása magasabb, ha a FAN értéke nagyobb. A *Xestia c-nigrum* L. különbözik ezektől; a fogása csökken, ha a FAN értéke magasabb. Eredményeink bizonyították, hogy "Flare Aktivitás Szám" használható a rovartani kutatásokban. Jelentősége elsősorban azokban az években lehet, amelyekre vonatkozóan még nem állnak rendelkezésre a Q-index értékek.

Introduction

The solar activity contains all the information about the Sun's surface received with different methods. Among them, the most important is the appearance of sunspots, which has been continuously observed since the 18th century phenomenon. The sunspots can be seen on the sun-facing hemisphere of the Earth. Their appearance and their strength frequency are approximately 11.2 years.

The generally accepted index-number of their observable quantity is the Wolf-type relative number (RW), which is calculated according to the following formula:
R_w = constant (10 g + f)
Where: g = the number of observed sunspot groups
f = the number of all sunspots
The value of constant is determined by features of instruments used in detection. After the selection of instruments sunspot relative number determined in any of the world's solar physics observatory can be reduced onto a uniform scale. The Wolf's relative numbers are collected in the Zurich observatory – as the global network centre – and they publish the data one year later.

The use of Wolf's relative numbers has been significant progress in the meteorological researches in the second half of the 20th century. Similarly, significant results were obtained in studies of Wolf's relative numbers and the relationship between plant pathogens. Details of these could not be our goal, but we refer to a previous study of ours (Nowinszky & Tóth 1987), in which we have a detailed overview about this. Some researchers found a contact between some pests and the solar activity.

Martinek (1972) concluded that in a large number of appearance of European Pine Sawfly (*Neodiprion sertifer* Geoffroy) can be found in every 11 year when there is maximum of sunspots. Manninger (1975) had observations during several decades about the gradation of harmful insects. He found relationship between the gradation and the periods with dry and inland water, which have connection to solar activity. He proved that in the second half of the dry periods the drought-loving species, but in the second part of the periods with inland water moisture-loving species had gradation. Klimetzek (1976) examined several pest gradations between 1810 and 1970. He found that strong gradation occurs mainly during minimums and maximums of sunspot. In later years, many researchers developed an index number which takes into consideration the intensity of flares and also their existence period.

Kleczek (1952) used the first time the Q-index for showing the daily flare activity. This daily flare activity is specific characteristic during the whole day.

Q = (i x t)
where i = flare intensity, t = the time length of its existence.

He thought this connection show about the whole energy which arises from the flares. In the above relation "i" means the intensity on scale of importance and "t" shows the period (in minutes) of the flare. Some researchers used the method of Kleczek in connection with flare activity which is determined for every day (Kleczek 1952, Knoška & Petrásek 1984).

Turkish astronomers (Özgüç & Ataç 1989) characterised the daily flare activity for more decades. They used for this characteristic the Q-index. This index shows the significance of flares also by their duration Ataç (1987), Ataç & Özgüç (1998).

The Q-index data are available to researchers from 1966. In addition to our own studies (Nowinszky & Puskás 2001, 2013a, 2013b, Puskás et al. 2010, Nowinszky et al. 2014, 2015) other researchers did not make any examinations dealing with the connection between entomology and Q-index data.

A Hungarian researcher, Örményi (1966) also calculated and published the "Flare Activity Numbers" based on similar theoretical principles as the Q-index for the period of 1957-1961.

Waldmeier (1940) has been executing studies on the frequency, extent ad intensity of flares. He proposed a new method for the definition of the intensity of chromospheric flares. This was based on brightness measurements, taking into account the average intensity of the flares. As a result of these investigations, a new scale of intensities has been established namely classification by Waldmeier: 0.6, 1.0 and 2.0.

For the scale of simplifying the calculations, Örményi (1966) has adopted the proportions 1.0 : 2.0 : 4.0 for the characterization of the intensities of various flares.

An index for chromospheric Hα flare activity is introduced by Örményi (1966). This procedure is expressed by the formula:

$$\text{FAN} = \frac{1}{1440}\frac{\Sigma}{n}1_n \Delta t_n$$

Where: FAN = Flare Activity Number

I = intensity of the flare (one of the values 1, 2 or 4)

n = indicates the serial number of a flare occurring on a given day

Δt_n = the duration of the given flare (minutes)

There were established two light trap networks (agricultural and the other at research institutes) till 1958 which were in operation uniformly with Jermy-type light -traps. From 1961 some light-traps of forestry already were in operation.

Material

We selected trapping data of three species to our investigations in years 1959, 1960 and 1961. These species can be trapped in large number by national light-trap network. The whole material of the selected species has been processed origi-

Ostrinia nubilalis *Hyphantria cunea* *Xestia c-nigrum*
Photos: © I. Fazekas

nated from 31 light-trap station from the territory of Hungary.

We got the trapped examined moth (Lepidoptera) species from the data of agricultural observation stations.

The chosen species are: European Corn-borer (*Ostrinia nubilalis* Hübner, 1796) – data from 28 traps. Fall (Autumn) Webworm (*Hyphantria cunea* Drury, 1773) – data from 31 traps. Setaceous Hebrew Character (*Xestia c-nigrum* Linnaeus, 1758) – data from 22 traps.

All three species fly in large number to the light and they are massively important pests except Setaceous Hebrew Character, which caused serious damage to alfalfa (Mészáros 1972) and grapes (Kadocsa 1938).

All three species have extremely extensive foreign and Hungarian literature. Such review could not be our goal, therefore, only refer to some very important author from the Hungarian researchers.

European Corn-borer (O*strinia nubilalis* Hübner: Jablonowski (1897), Manninger (1949), Nagy (1958), B. Balázs (1965), Mészáros, Z. (1965, 1969), Sáringer (1976), Keszthelyi (2004, 2010), Keszthelyi & Lengyel (2003), Keszthelyi & Sáringer (2003), Keszthelyi & Ács (2005), Pal-Fam et al. (2010).

Fall Webworm (*Hyphantria cunea* Drury): Nagy et al. (1953), Jermy (1957), Kovács & Delyné-Draskovits (1967), Járfás & Viola (1985).

Setaceous Hebrew Character (*Xestia c-nigrum* Linnaeus): Kadocsa (1938), Reichart (1968), Mészáros (1972).

All the Flare Activity Number (FAN) was written off from the study of Örményi (1966).

Methods

The individual number is not the same in the different years and regions concerning to the same species. Because of this relative catch (RC) values were calculated. RC value means the sampling time unit (generally it is one night) and the average individual number in unit time of sampling, the number of generations categorised by the influence of individuals. The values of relative catch were separated according to the characteristics of each day, after it they were summarised and averaged. We made groups according to the connection between catch and flare activity number pairs, and finally we averaged the results. We calculated regression equations for the relative catch of investigated species and flare activity number data pairs (Nowinszky 2003).

We made groups using Sturges' method (Odor & Iglói 1987) for flare activity number data. The RC values were categorised according to the FAN belonging to each day and after it they were summarised and averaged.

Results and Discussion

Our results are shown in Figures 1-3.

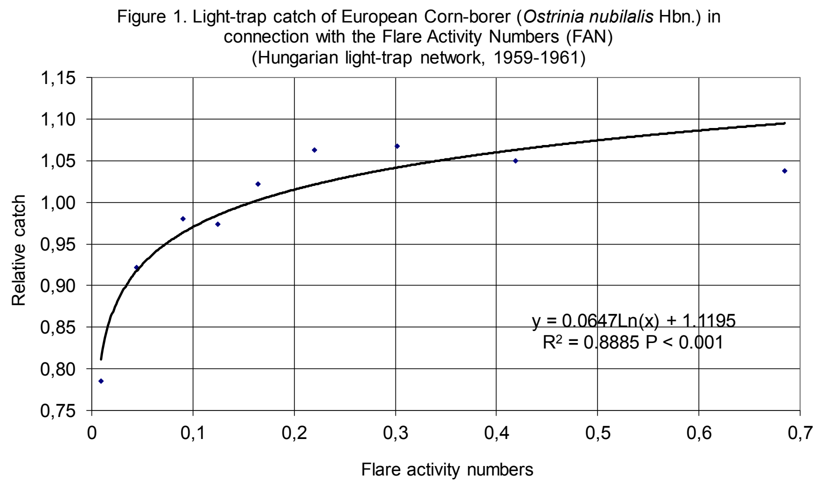
The light-trap catch of the two examined species (*Ostrinia nubilalis* Hbn. and *Xestia c-nigrum* L.) initially increased by the increase of the value of the FAN together. The behaviour of one species (*Hyphantria cunea* Drury) differs from these; that have an only decreasing character of FAN together. In what follows, we present the resulted special nonlinear models and figures for the different behavioural types.

We used logarithmic, second- or third-degree polynomials to show our results, which proved that the FAN could significantly change the daily trapping of insects. We think these results are related to the different lengths and intensities of the solar flares. We could see that the activity change of insects is not in connection with the taxonomic category.

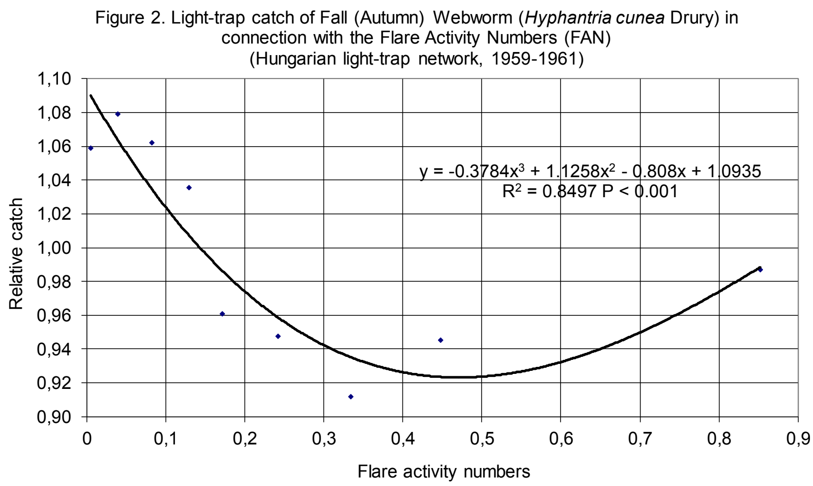
A similar phenomenon has been observed in the relationship between Q-index and various Macrolepidoptera and Microlepidoptera species (Nowinszky et al. 2015). We experienced different behavioural types in examination of different environmental factors and other insect species. The height of the tropopause has different reactions in case of different caddisflies (Trichoptera) species (Nowinszky et al. 2016) and two moth species (*Ostrinia nubilalis* Hbn. and *Xestia c-nigrum* L.) (Nowinszky & Puskás 2013b). The same phenomena was found at the time of pheromone trapping of different Microlepidoptera species (Nowinszky & Puskás 2016).

According to our hypothesis this phenomenon plays a most important role in the undisturbed function in the life of communities. If every species, within all taxon, behave equivalently towards a positive or negative impact on the environment, serious disturbances can be caused in the food networks' function. They could be gradations or significant decreases in the individual number of species. In both cases the relative stability of the life community can change, which is always at the expense of smaller and bigger changes, but there is still balanced.

Our results proved that "Flare activity numbers" can be used for entomological researches. They may have significance in those years primarily, in which is not yet available the Q-index values.

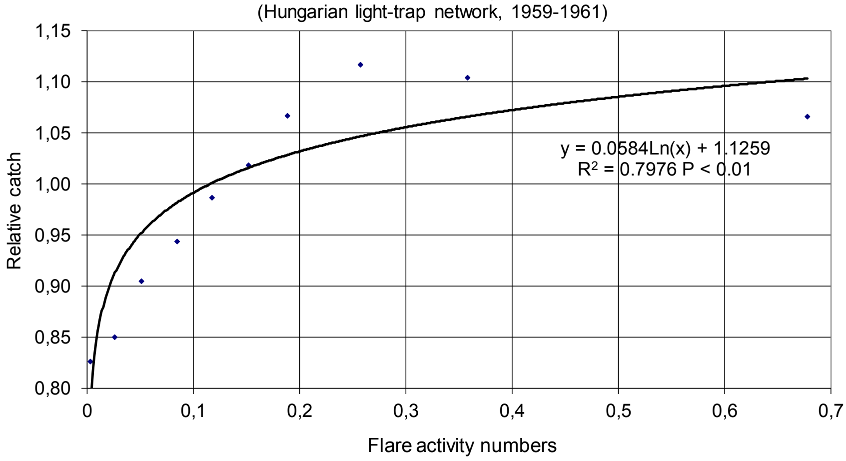


1. ábra. Az *Ostrinia nubilalis* fénycsapdás fogása a Fler Aktivitási Számok függvényében (1959-1961)



2. ábra. A *Hyphantria cunea* fénycsapdás fogása a Fler Aktivitási Számok függvényében (1959-1961)

Figure 3. Light-trap catch of Setaceous Hebrew Character (*Xestia c-nigrum* L.) in connection with the Flare Activity Numbers (FAN) (Hungarian light-trap network, 1959-1961)



3. ábra. A *Xestia c-nigrum* L.) fénycsapdás fogása a Fler Aktivitási Számok függvényében (1959-1961).

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Biological Forum — An International Journal, **3**(1): 32-35(2011) **ISSN : 0975-1130**

The Influence of Solar Terrestrial Effects on Light-Trap Catch of Night Flying Insects

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(Received 15 Jan., 2011 Accepted 15 Feb., 2011)

ABSTRACT : The study revealed a correlation between the ionospheric storms (∑Kf0F2) and light-trap catch of two winter geometrid moth (*Operophthera brumata* L. and *Agriopis aurantiaria* Hbn.). The efficiency of catching the two species by light-trap decreases at the time of negative ionospheric storms and increases during positive ones. The strengthening of atmospheric radio noises (SEA) increases the catch of the Turnip Moth (Agrotis segetum Den. et Schiff).

Keywords : Ionospheric storms, atmospheric radio noises, light-trap, moths.

INTRODUCTION

The solar activity has an important influence on the Earth's atmosphere and life on Earth. As part of the global solar activity, accompanied by intensive X-ray, gamma and corpuscular radiation, outbreaks (flares) appear in the vicinity of the active regions on the surface of the Sun. Reaching the Earth, and getting into interaction with its upper atmosphere, these flares change the existing electromagnetic relations (Smith and Smith, 1963).

The daily activity of the flares is characterized by the so-called *Q* index that, used by several researchers, considers both the intensity and period of prevalence of the flares. According to a verbal message by Tamer Ataç (Bogazici University, Kandilli Observatory and Earthquake Research Institute, Istanbul) it is calculated with the following formula:

$$Q = (i \times t)$$

In which i = flare intensity, t = period of prevalence.

Q-index data, released with significant delay, are not readily accessible for plant protection prognostics. To overcome this disadvantage, we tried to establish a relationship between the atmospheric radio noises (SEA) that can be measured also by the people operating light-traps and light-trap catch results (Nowinszky and Tóth, 1994).

Solar outbreaks are accompanied by intensive *X*-ray, gamma and corpuscular radiation that, reaching the Earth, get into interaction with the upper atmosphere and change electromagnetic conditions (Smith and Smith, 1963). In the course of this electromagnetic storms might break out and the ionization relations of the ionosphere might also undergo transformation.

The corpuscular radiation of the Sun leads to the formation of layers (ion concentration) at varying heights of the ionosphere parallel to the surface of the Earth. At the temperate zone latitudes, there are three well discernible ionospheric layers. Layers *D* and *E* are in the low regions (60-160 km) of the ionosphere while layer F is classed with the high regions (160-250 km, even 1000 km at the time of big storms). Layer F is split into two (F_1 and F_2) at daytime. At night, layers *D*, *E* and F_1 disintegrate, and only layer F_2 remains (Saikó, 1974). The ionospheric disturbances caused by corpuscular radiation appear during solar flares when the Sun emits a vast amount of electrically charged and uncharged particles which entering the atmosphere of the Earth, change the conditions of the ionospheric layers. The changes in layer F_2 appear mainly in fluctuations of ion density and height. Ionospheric layer density is characterized by the boundary frequency of the given layer.

When ionospheric recordings are made, impulses of radio waves of continuously growing frequency are emitted into the atmosphere. The highest frequency reflected by the layer under examination is called boundary frequency (f_0F_2). Influenced by the geomagnetic field, a change takes place in the frequency and polarization of the radio wave emitted (Zeeman effect) which divides into two, sometime three electromagnetic oscillations of different frequencies. The component of a frequency identical to that of the generator is called regular frequency, marked f_0 (Saikó, 1974). We speak of an ionospheric storm when the boundary frequency of layer $F_2(f_0F_2)$ in a given moment digresses at least by 20% from the hourly median value of the given point of time. After Saikó (1966) it is calculated like

$$f_0F_2 \quad \frac{100(f_0F_2 \quad f_0F_2 \text{ med})}{f_0F_2 \text{ med}}$$

According to Saikó's account (1969), Δf_0F_2 value trends were examined simultaneously at six ionosphere observation stations. They were: Freiburg (48°03' N, 07°35' E), Pruhonice (49°59' N, 14°33' E), Belgrade (44°48' N, 20°31' E), Békéscsaba (46°40' N, 21°11' E), Dourbes (50°06' N, 04° 36' E), Juliusruh (54°38' N, 13°23' E). The examinations have clearly shown a sud-den increase of the Δf_0F_2 value after the effect occurred at all six stations. This fact has lead to the conclusion that radiation from the flares can bring about ion condensation also in the F_2 layers over larger areas. Of the impacts of ionospheric storms on the Earth, those influencing the weather have been subjected to closer investigation. In Hungarian literature, Saikó's works (1963 and 1979) provide information on these. Research into disturbances that suddenly make their presence felt in the lower ionosphere is of significance. Investigation is carried out first of all with absorption measuring, as radio waves are greatly absorbed in this layer.

The X-ray radiation of the flare at a wavelength of less than 1nm enhances the ionization of layer *D* positioned at a height of some 70-80 kilometres. This has two simultaneous clear consequences. One is short wave fadeout (SWF). The other increased reflection of the extra long radio waves. As a consequence, extra long wavelength radio noise can be observed permanently, caused by uninterrupted thunderstorms in the tropical zone. At times of ionospheric disturbances the radio noise is of essentially greater intensity. About 8 minutes after the appearance of a solar flare, atmospheric radio noise at 27 kHz (11 km wavelength) suddenly increases (Sudden Enhancement of Atmospherics = SEA). SWF and SEA both occur after every major flare proportionately with the growth of X-ray radiation. The first one kills short wave radio communication for a few hours. At the same time, radio waves in the VHF band that under normal conditions find their way into cosmic space without running into any obstacle may now get reflected as a result of increased ionization of the upper layers of the ionosphere, creating a situation in which will be temporarily possible to receive the signals of distant TV transmitters. Even when the sky is clouded, increased atmospheric radio noise provides a clear indication of a major flare taking place on the surface of the Sun.

Flares of importance one (they are relatively frequent) are followed by SEA in about 10% of all cases, this proportion is 50% in the case of flares of importance two, while the proportion is 90% in the case of the strongest flares, those of importance three. SEA can be observed by very simple radio-technological equipment, even in cloudy weather, provides information easy to handle and is also suitable for an indirect detection of flares (Del Vecchio, 1959). Yet, easy as it is to perform, no SEA observation has so far been carried out in Hungary.

We do not know of publications in either Hungarian or international literature examining the efficiency of collecting insects by light-trap in relationship with ionospheric disturbances or atmospheric radio noise. However, Becker (1964) and Damaschke and Becker (1964) established a negative correlation between atmospheric radio noises and the oxygen intake of termites. Later on, Becker and Gerisch (1977) could prove their effect also on the feeding activ-ity of termites.

MATERIAL AND METHODS

The data we have needed for our calculations (border frequency of the F_2 layer of the iono-sphere (f_0F_2) and the atmospheric radio noise at 27 kHz (SEA) were provided by publications released by the Panská Ves Observatory of the Geophysics Research Institute of the Czechoslovak Academy of Sciences. This observatory is about 25-30 kilometres from Prague. In the view of Béla Szudár (Main Metorological Station, Békéscsaba), it is scientifically justified to cross-check the values measured there with those of the light-trap catches in Hungary (per-sonal communication).

From the material of the national light-trap network we compared the border frequency (f_0F_2) of layer F_2 with the catch data for Winter Moth (*Operophthera brumata* L.) and Scarce Umber (*Agriopis aurantiaria* Hbn.) (Nowinszky *et al.*,1995). Data related to the former species come from the period between 1961 and 1976. We had at our disposal 3 712 observation data of 46290 individuals from 18 observation sites over 837 nights. Regarding the latter species, we processed 1322 observation data of 8614 individuals collected at 44 observation stations over 403 nights in the years 1962-1970.

To examine the effect of SEA we used data pertaining to turnip moth (Agrotis segetum Den. et Schiff.) from the material of the Kecskemét fractionating light-trap and the national light-trap network (Nowinszky *et al.*, 1995). The national light-trap network provided us with 20508 observation data on 32100 individuals collected by 61 light-traps over 2647 nights between 1957 and 1976.

Using Saikó's method (1966), we calculated the difference in the value of the boundary frequency (f_0F_2) of layer F_2 expressed in the percentage of the hour-median (Δf_0F_2) for each hour of each night of the collecting period. Differences over 20% were considered as iono-spheric storms. These were given, also after Saikó (1966), character numbers (*K*) as follows: an observed storm of a negative or positive sign between 20-30% is listed in the 1st, between 30-40% in the 2nd and above 40% in the 3rd class of intensity. The character numbers were summed up by nights ($\Sigma K f_0F_2$) and were then considered as independent variables.

From the catching data of the examined species, relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 night) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number, the RC value is 1 (Nowinszky, 2003).

We averaged by nights the relative catch values (RC) from the various observation sites then correlated these to the sum-totals of the character numbers. We arranged the pairs of values in classes, and then averaged them. To reveal the assumed connection we made correlation calculations.

SEA nightly averages showed significant differences in the years between 1957-1976, therefore we expressed them in the percentage of the average of the swarming periods. We arranged in classes the values gained in this way together with the related catch values, then averaged them and made correlation calculations. We correlated the hourly catch data received from Kecskemét with the percentage values of the changes in SEA as compared to the previous hour, and then applied the procedure outlined above.

RESULTS AND DISCUSSION

The relationship between the ΣKf_0F_2 and the light-trap catch of the Winter Moth (*Opero-phthera brumata* L.) and the Scarce Umber (*Agriopis aurantiaria* Hbn.) content the Fig. 1 and Fig. 2. Fig. 3 shows the catching results of Turnip Moth (*Agrotis segetum* Den. et Schiff.) from the data of national light-trap network depending on the SEA. The same results seem from the data of Kecskemét fractionating light-trap in Fig. 4. Each figure also includes the results of the calculations of significance.

Fig. 1
Light-trap catch of the Winter Moth (*Operophthera brumata* L.) depending on the ΣKf_0F_2

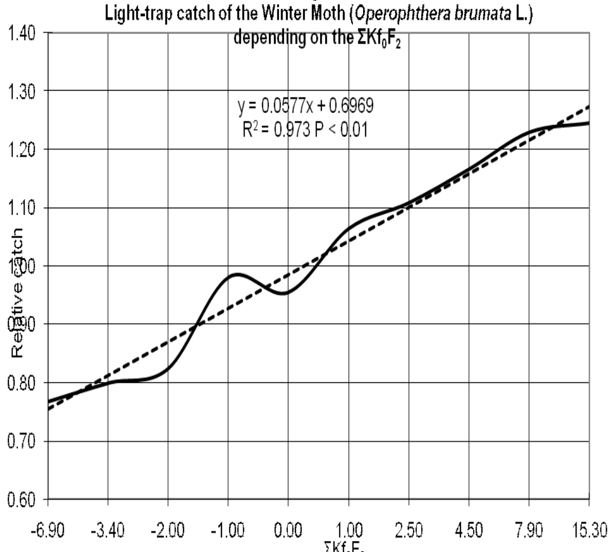


Fig. 2
Light-trap catch of Scarce Unber (*Agriopis aurantiaria* Hbn.) depending on the ΣKf_0F_2

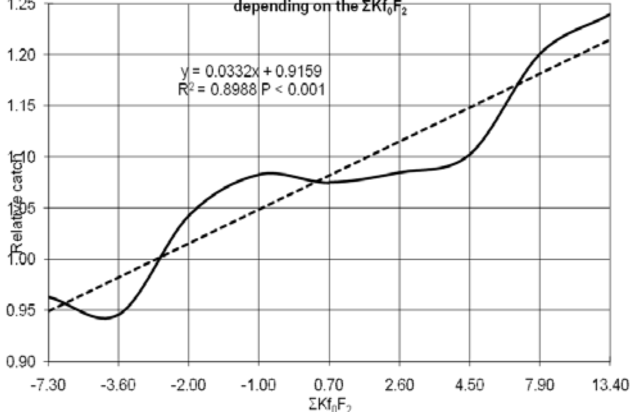


Fig. 3
Light-trap catch of Turnip moth (*Agrotis segetum* Den. et Schiff.) depending on the SEA (National light-trap network, 1961-1976)

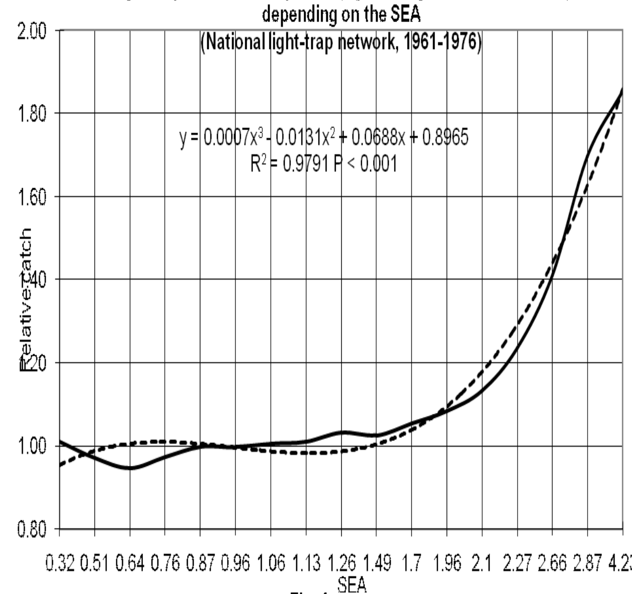
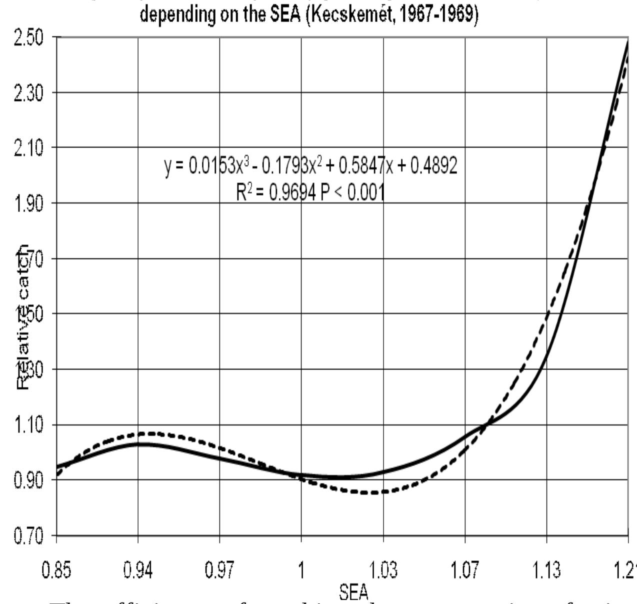


Fig. 4
Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) depending on the SEA (Kecskemét, 1967-1969)



The efficiency of catching the two species of winter geometrid moth by light-trap decreases at the time of negative ionspheric storms and increases during positive ones. Surprisingly, the strengthening of atmospheric radio noises suitable for the indirect detection of solar outbreaks is accompanied by an almost instantly discernible intensification of the flying activity of insects. The same thing can be observed in the course of a night, namely, the catch will rise whenever the intensity of radio noises strengthens from one hour to the other, and will become more moderate when it weakens. There is also a positive correlation between the SEA maximum for the night.

In the case of strong solar outbreaks the catch by light-trap can reflect even if with great distortions the size of the different populations. And with solar activity increasing and de-creasing in a periodicity of 11 years, in the evaluation of catch data it might be worth while to consider the relationship we have revealed. The simple and moderately expensive task of collecting the SEA data required for further investigation could also be organized by the institu-tions running the light-traps.

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Nature & Environment
Vol. 19 (2), 2014: 173-178
Website: www.natureandenvironment.com

ISSN (Print) : 2321-810X
ISSN (Online) : 2321-8738

RESEARCH ARTICLE

Light-Trap Catch of Moth Species of the Becse-Type Light Trap in Connection With the Height of the Tropopause

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Received: 13th May 2014, Revised: 11th June 2014, Accepted: 28th June 2014

ABSTRACT

In present study we examined the connection between height of tropopause and the light-trap catch moth species. The data of 8 Microlepidoptera and 26 Macrolepidoptera species were caught from the material of a Becse-type light-trap between1969 and 1973 Groups were made for data of the height of tropopause. The relative catch values of the examined species were categorised according to the characteristics of tropopause on each day, after it these values were summarised, averaged and depicted. We defined the parameters of the regression equations. Most species are collected in connection with the increasing the height of the tropopause, but decrease was observed only in case of three species. Often can be experienced the increase of the catch after the decrease of it if the values of the tropopause height is high. The different form of behaviour, however, is not linked to the taxonomic position.
Key Words: *Becse-type Light trap, Tropopause*

INTRODUCTION

The tropopause is a surface separating the lower layers of the atmosphere (troposphere) from the upper layers (stratosphere). It is of varying height. In the presence of very cold air masses from the Arctic it may be a mere 5 kilometres, while in the presence of sub-tropical air it may grow to 16 kilometres. Sometimes there are two or three tropopauses one above the other.

The former one, however, as investigations were carried out during the summer months, never occurred; even in the lower 9 km of the tropopause height was only very rarely observed. The incidence of subtropical air masses with a high tropopause was significantly more frequent.

We have demonstrated in our previous works that large regions prevailing weather conditions affect both the pheromone trapping (Károssy *et al.* 2009 Nowinszky and Puskás, 2003), and light trapping effectiveness (Károssy *et al.* 1990, Nowinszky et al . 1992, 1995, 1999, Nowinszky and Puskás, 2002, Keszthelyi *et al.* 2005, 2006).

We did not find any communications dealing with this topic in the literature apart from our own works. In recent years, some studies have already been published for different moth species, which could also prove the above hypothesis (Örményi *et al.*, 1997, Puskás and Nowinszky 2000, Puskás *et al.* 2,003, Nowinszky and Puskás 2013). We do not know any studies dealing with the contact of tropopause height and the light trapping only own papers.

MATERIAL AND METHODS

Data on the height of the tropopause were taken from the Year Books of National Weather Service of Budapest Central Meteorological Institute.

The light-trap operated by Varga and Mészáros (1973a, 1973b) between 1969 and 1973 on the territory of the Agricultural and Industrial Combine in Bečej, Serbia (Geographical coordinates are: 45°37'05"N 20°02'05"E) collects many more insects than the Hungarian Jermy-type traps do. The light source of the trap is an IPR WTF 220V, 250W mercury vapour lamp 2 meters above the ground. There is a large collecting cage under the funnel of the trap. The cage contains two perpendicular separation walls made of plastic haircloth dividing the cage into four equal parts. This solution ensured that the tougher bodied and livelier beetles staying at the bottom of the cage couldn't damage the moths and other fragile insects that have climbed up on the separation walls. In the morning the cage was placed in a chest in which a few millilitres of carbon bisulphide had been burnt. The gases thus generated killed the insects quickly and effectively. The light-trap worked every night in the breeding season even in bad weather. Several of this type of traps collecting huge masses of insect material of good quality has been operating in Yugoslavia. Regarded to be dangerous, the use of this type of trap has not been permitted in Hungary.

The moth data of Becse-type light trap were processed and published (Vojnits *et al.*, 1971, Mészáros *et al.* 1971). This light-trap operated in Bečej Agricultural and Industrial Combine in the years 1969-1973. We process 8 Microlepidoptera and 26 Macrolepidoptera species from the total catching data. The names of the species, the years of collecting and the number of individuals are shown in Table 1.

Table 1: Collection data of the examined moths (Lepidoptera) species

Families and scientific names	Common names	Collecting years	Number of	
			Individuals	Data
Tortricidae				
Aleimma loeflingiana Linnaeus, 1758	Yellow Oak Button	1969-72	2824	52
Crambidae				
Evergestis extimalis Scopoli, 1763	Marbled Yellow Pearl	1971-73	1149	86
Loxostege sticticalis Linnaeus, 1761	Beat Webworm Moth	170-73	1196	131
Sitochroa verticalis Linnaeus, 1758	Lesser Pearl	1970-73	3002	230
Ostrinia nubilalis Hübner, 1796	European Corn-borer	1970-73	38120	340
Nomophila noctuella Denis et Schiffermüller, 1775	Rush Veneer	1970-73	14374	243
Pyralidae				
Etiella zinckenella Treitschke, 1822	Lima Bean Pod Borer	1970-73	3141	129
Homeosoma nebulella Denis et et Schiffermüller, 1775	European Sunflower Moth	1969 and 71	6263	92
Geometridae				
Timandra comae Schmidt, 1931	Blood-vein	1970-73	4263	185
Chiasmia clathrata Linnaeus, 1758	Latticed Heath	1970-73	3478	258
Ascotis selenaria Denis et Schiffermüller, 1775	Luna Beauty	1970-71 and 1973	2159	161
Lymantriidae				
Leucoma salicis Linnaeus, 1758	White Satin Moth	1969-73	3255	255
Arctiidae				
Hxphantria cunea Drury, 1773	Fall Webworm	1970-73	4447	234
Spilosoma lubricipeda Linnaeus, 1758	White Ermine	1970-71	2644	84
Spilosoma urticae Esper, 1789	Water Ermine	1970-71 and 1973	4634	112
Phagmatobia fuliginosa L.	Ruby Tiger	1970-73	14374	243
Noctuidae				
Agrotis segetum Denis et Schiffermüller, 1775	Turnip Moth	1970-73	9895	301
Agrotis exclamationis Linnaeus, 1758	Heart & dart	1970-73	2348	177
Axylia putria Linnaeus, 1761	The Flamme	1969-73	2914	179
Noctua pronuba Linnaeus, 1758	Large Yellow Underwing	1970-73	1755	194
Xestia c-nigrum Linnaeus, 1758	Setaceous Hebrew Ch	1970-73	28999	326
Discestra trifolii Hfnufnagel, 1766	The Nutmeg	1970-73	11381	310
Mamestra brassicae Linnaeus, 1758.	Cabbage Moth	1970-71 and 1973	4187	92
Laconobia suasa Denis et Schiffer, 1775	Dog's Tooth	1970-73	4434	189
Laconobia oleracea Linnaeus, 1758	Bright-line Brown-eye	1970-73	7512	201
Mythimna turca Linnaeus, 1761	Double Line	1969-71 and 1973	1324	88
Mythimna vitellina Hübner, 1808	The Delicate	1970-73	3583	180
Mythimna pallens Linnaeus, 1758	Common Vainscot	1969-70 and 1972-73	3689	202
Heliothis maritima Graslin, 1855	Shoulder-striped Clover	1970-73	3563	215
Emmelia trabealis Scopoli, 1763	Spotted Sulphur	1970-73	18678	312
Macdunnoughia confusa Stephens, 1850	Dewick's Plusia	1969-73	1236	221
Autograha gamma Linnaeus, 1758	Silver Y	1970-73	6868	349
Autographa pulchrina Haworth, 1809	Beautiful Golden Y	1969 and 1972-73	1163	109
Tephrina arenacearia Denis et Schiffermüller, 1775	Lucerne Moth	1970-73	4457	227

From the catching data of the examined species, relative catch (RC) data were calculated for each night. The RC is the quotient of the number of individuals caught during a sampling time unit (1 night) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number, the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps (Nowinszky, 2003).

Data on the height of the tropopause were arranged into classes according to Sturges' method (Odor and Iglódi 1987). The relative catch values were assigned into the classes of the tropopause belonging to the given day and then they were summarized and averaged.

RESULTS AND DISCUSSION

Based on our results, we proved that the light-trap catch of examined species is affected by the height of tropopause. However, some species may not react the same way. Most species are collected in connection with the increasing the height of the tropopause, but decrease was observed only in case of three species. Often can be experienced the increase of the catch after the decrease of it if the values of the tropopause height is high. The different form of behaviour, however, is not linked to the taxonomic position.

A low tropopause is related the presence of cold and high tropopause the presence of warm types of air, while insect activity is increased by warm and reduced by cold air. An over 13 km height of the tropopause often indicates a subtropical air stream at a great height. This has a strong biological influence. These results may lead us to assume that the electric factors in the atmosphere also have an important role to play, mainly when a stream of subtropical air arrives at great height. On such occasions the 3Hz spherics impulse number shows a decrease, while cosmic radiation of the Sun will be on the increase (Örményi, 1984). The preponderance of negative ions in polar air reduces activity, while the preponderance of positive ions in subtropical maritime air may spur flight activity (Örményi, 1967).

Fig. 1: Light-trap catch of Setaceous Hebrew Character (*Xestia c-nigrum* L.) depending on the height of tropopause (Becse, 1970-1973)

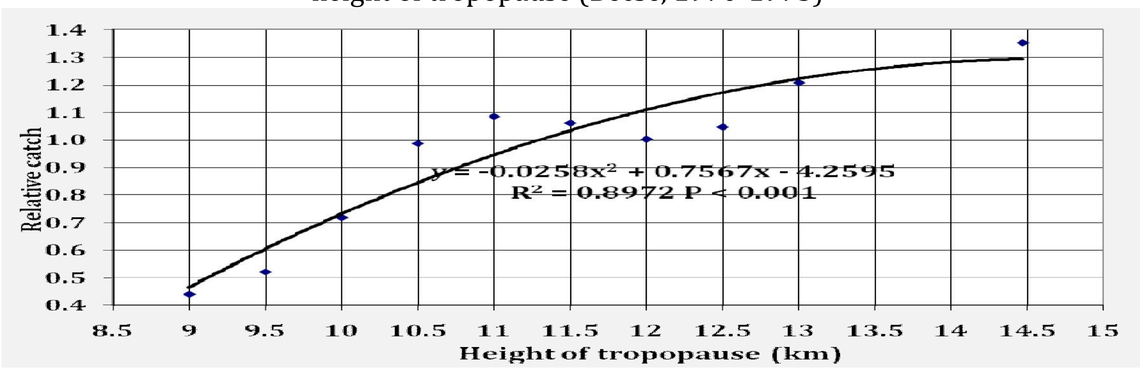

Fig. 2: Light-trap catch of Beet Webworm Moth (*Loxostege sticticalis* L.) depending on the height of tropopause (Becse, 1970-1973)

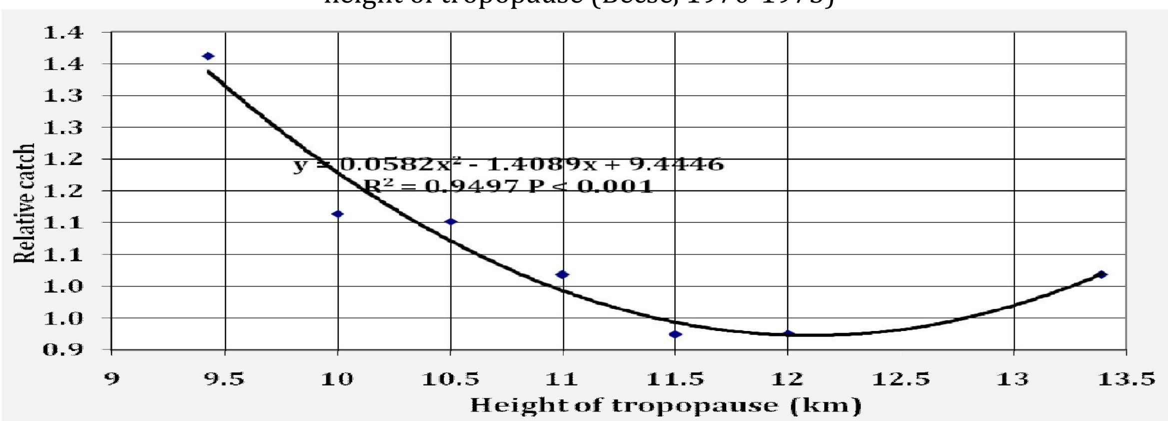

Fig. 3: Light-trap catch of Rush Veneer (*Nomophila noctuella* Den. et Schiff.) depending on the height of tropopause (Becse, 1970-1973)

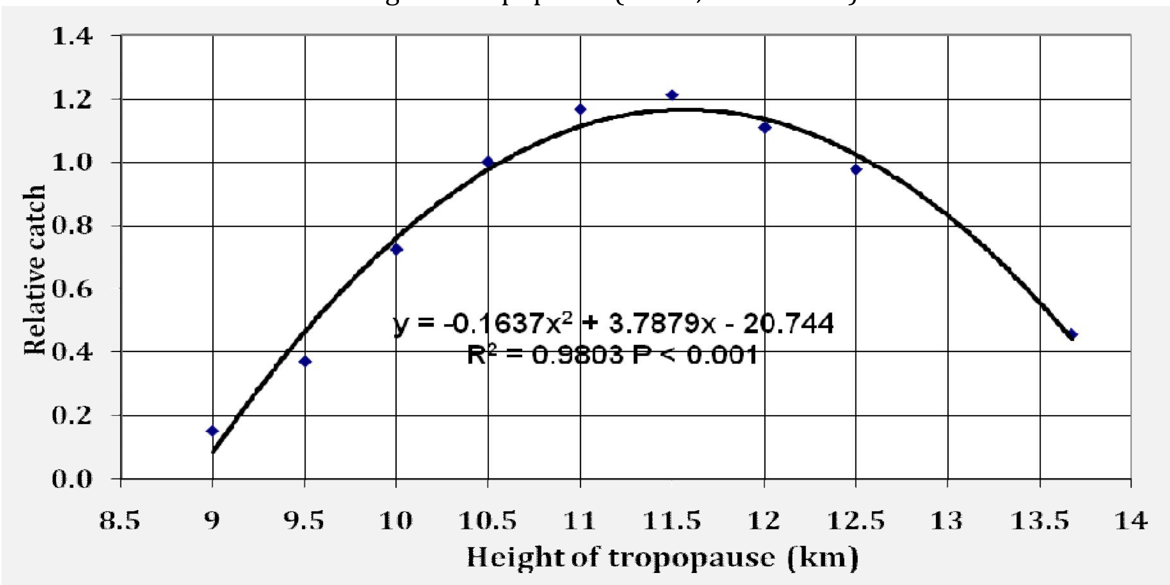

Table 2: The relative catch of the examined species depending on the height of tropopause, parameters of equations with the significance levels

Families — Species	Increasing or decreasing catch	Height of tropopause (km)											
		≤ 9	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14 ≤
		Parameters of equations and significance level											
Tortricidae													
Aleimma loeflingiana L.	Decreasing		1.07			1.00	0.98	0.99					
Yellow Oak Button		$y = 0.0242x^2 - 0.5666x + 4.2976$ $R^2 = 0.9886$ $P < 0.01$											
Crambidae													
Evergestis extimalis Scop.	Increasing	0.76	0.93		0.99	1.12	0.92	1.04		1.63			
Marbled Yellow Pearl		$y = 0.038x^3 - 1.257x^2 + 13.842x - 49.7$ $R^2 = 0.9033$ $P < 0.01$											
Loxostege sticticalis L.	Decreasing	1.36		1.11	1.10	1.02	0.92	0.93		1.02			
Beat Webworm Moth		$y = 0.0582x^2 - 1.4089x + 9.4446$ $R^2 = 0.9497$ $P < 0.001$											
Sitochroa verticalis L.	Increasing Decreasing	0.38		0.72	0.86	0.94	1.16	1.16			0.87		
Lesser Pearl		$y = -0.0895x^2 + 2.1744x - 12.073$ $R^2 = 0.9751$ $P < 0.001$											
Ostrinia nubilalis Hbn.	Increasing	0.07	0.19	0.86	0.73	0.83	1.00	1.17	1.33	1.18	1.34		1.55
European Corn-borer		$y = -0.0367x^2 + 1.1043x - 6.8226$ $R^2 = 0.924$ $P < 0.001$											
Nomophila noctuella Den. et Schiff.	Increasing Decreasing	0.15	0.37	0.73	1.00	1.17	1.22	1.11	0.98		0.76		
Rush Veneer		$y = -0.1637x^2 + 3.7879x - 20.744$ $R^2 = 0.9803$ $P < 0.001$											
Pyralidae													
Etiella zinckenella Tr.	Increasing		0.89		0.90	0.91	1.07	1.02	1.13		1.44		
Lima Bean Pod Borer		$y = 0.0307x^2 - 0.5906x + 3.7256$ $R^2 = 0.9565$ $P < 0.001$											
Homeosoma nebulella Den. et Schiff.	Increasing	0.23		0.81	0.98	1.16	1.05	1.03	1.05	1.26			
European Sunflower Moth		$y = 0.0499x^3 - 1.7551x^2 + 20.536x - 78.931$ $R^2 = 0.981$ $P < 0.001$											
Geometridae													
Timandra comae Schmidt	Increasing	0.47		0.79	1.13	1.09	1.03	0.94	1.05			1.13	
Blood-vein		$y = 0.034x^3 - 1.2227x^2 + 14.602x - 56.818$ $R^2 = 0.8967$ $P < 0.01$											
Chiasmia clathrata L.	Increasing Decreasing	0.35	0.59	0.97	1.16	1.17	1.05	0.95	0.90	0.92	0.90		0.89
Latticed Heath		$y = 0.0252x^3 - 0.9471x^2 + 11.735x - 46.854$ $R^2 = 0.903$ $P < 0.0 01$											
Ascotis selenaria Den. et Schiff.	Increasing Decreasing	0.29		0.86	1.26	1.36	1.09	0.89	0.81	0.86			0.80
Luna Beauty		$y = 0.0424x^3 - 1.5936x^2 + 19.677x - 78.807$ $R^2 = 0.8676$ $P < 0.001$											

Table 3: The relative catch of the examined species depending on the height of tropopause, parameters of equations with the significance levels

Families — Species	Increasing or decreasing catch	Height of tropopause (km)											
		≤ 9	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14 ≤
		Parameters of equations and significance level											
Lymantriidae													
Leucoma salicis L.	Increasing	0.60		0.79	0.97	1.02	1.05	1.00	1.03	1.25			
White Satin Moth		$y = 0.0308x^3 - 1.0755x^2 + 12.527x - 47.695$ $R^2 = 0.9714$ $P < 0.001$											
Arctiidae													
Hxphantria cunea Drury	Increasing		0.96		1.00	1.01	1.06	1.04	0.94		0.72		
Fall Webworm	Decreasing	$y = -0.0451x^2 + 1.0059x - 4.5747$ $R^2 = 0.9488$ $P < 0.001$											
Spilosoma lubricipeda L.	Increasing			0.69		0.86	0.96	1.16			1.35		
White Ermine		$y = 2.369Ln(x) - 4.8002$ $R^2 = 0.9737$ $P < 0.001$											
Spilosoma urticae Esper	Increasing		0.78		0.87	0.90	1.04	1.14		1.25			
Water Ermine		$y = 0.1409x - 0.6054$ $R^2 = 0.9739$ $P < 0.001$											
Phagmatobia fuliginosa L.	Increasing	0.08	0.37	0.73	1.00	1.17	1.22	1.11	0.96		0.46		
Ruby Tiger	Decreasing	$y = -0.1675x^2 + 3.8818x - 21.326$ $R^2 = 0.9844$ $P < 0.001$											
Noctuidae													
Agrotis segetum Den. et Schiff.	Increasing	0.20	0.63	0.77	1.00	0.99	1.07	1.08	1.20	1.11		0.60	
Turnip Moth	Decreasing	$y = -0.0925x^2 + 2.227x - 12.247$ $R^2 = 0.9644$ $P < 0.001$											
Agrotis exclamationis L.	Increasing	1.00		0.98	1.04	1.13	1.08	1.03	0.86	0.76	0.77		0.80
Heart & dart	Decreasing	$y = 0.0164x^3 - 0.6026x^2 + 7.2508x - 27.537$ $R^2 = 0.8224$ $P < 0.001$											
Axylia putria L.	Increasing	0.69		0.86	0.88	1.10	1.09	1.21	0.96			0.90	
The Flamme	Decreasing	$y = 0.0038x^3 - 0.185x^2 + 2.8128x - 12.511$ $R^2 = 0.7839$ $P < 0.01$											
Noctua pronuba L.	Increasing		0.94		1.19	1.17	1.15	0.98	0.85		0.49		
Large Yellow Underwing	Decreasing	$y = -0.0935x^2 + 2.0309x - 9.8692$ $R^2 = 0.971$ $P < 0.001$											
Xestia c-nigrum L.	Increasing	0.44	0.52	0.72	0.99	1.09	1.06	1.03	1.05	1.21		1.35	
Setaceous Hebrew Character		$y = -0.0258x^2 + 0.7567x - 4.2595$ $R^2 = 0.8972$ $P < 0.001$											
Discestra trifolii Hfn.	Increasing	0.37		1.08	0.96	0.97	0.90	0.97	1.03	1.24			1.72
The Nutmeg		$y = 0.0352x^3 - 1.2356x^2 + 14.437x - 55.167$ $R^2 = 0.9072$ $P < 0.001$											

Table 4: The relative catch of the examined species depending on the height of tropopause, parameters of equations with the significance levels

Families — Species	Increasing or decreasing catch	Height of tropopause (km)											
		≤ 9	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14 ≤
		Parameters of equations and significance level											
Noctuidae													
Mamestra brassicae L.	Increasing	0.40		0.58	0.74	1.03	1.23	1.18	1.15				1.33
Cabbage Moth		$y = -0.0512x^2 + 1.4055x - 8.3002$ $R^2 = 0.9425$ $P < 0.001$											
Laconobia suasa Den. et Schiff.	Increasing	0.18		1.00	0.95	1.08	1.01	1.11	0.95	0.96			1.28
Dog's Tooth		$y = 0.0412x^3 - 1.5217x^2 + 18.587x - 74.076$ $R^2 = 0.932$ $P < 0.001$											
Laconobia oleracea L.	Increasing	0.68		1.00	1.16	1.23	1.05	0.92		0.77			
Bright-line Brown-eye	Decreasing	$y = 0.0531x^3 - 1.9012x^2 + 22.441x - 86.333$ $R^2 = 0.9579$ $P < 0.001$											
Mythimna turca L.	Increasing		0.76		0.77	1.06	1.13	1.24	1.09	0.70	0.55		0.69
Double Line	Decreasing	$y = 0.0311x^3 - 1.1961x^2 + 15.104x - 61.703$ $R^2 = 0.6078$ $P < 0.05$											
Mythimna vitellina Hbn.	Increasing	0.56	0.72	0.81	0.92	0.98	0.95	1.05	1.04	1.41		1.42	
The Delicate		$y = -0.0012x^2 + 0.1858x - 0.9612$ $R^2 = 0.9085$ $P < 0.001$											
Mythimna pallens L.	Increasing	0.59		0.70	0.81	0.83	1.03	1.12	1.26		1.55		
Common Vainscot		$y = 0.2272x - 1.584$ $R^2 = 0.9847$ $P < 0.001$											
Heliothis maritima Graslin	Increasing	0.26		0.73	0.82	0.84	0.96	1.04	1.21	1.45	1.52		
Shoulder-striped Clover		$y = -0.0237x^2 + 0.7922x - 4.9714$ $R^2 = 0.9402$ $P < 0.001$											
Emmelia trabealis Scop.	Increasing	0.06	0.29	0.69	0.71	0.94	1.07	1.14	1.11	0.82	1.19	1.75	2.85
Spotted Sulphur		$y = 0.0297x^3 - 1.0562x^2 + 12.587x - 49.342$ $R^2 = 0.9606$ $P < 0.001$											
Macdunnoughia confusa Steph.	Increasing	0.64		0.99	1.19	1.29	1.03	0.93	0.92		0.80		
Dewick's Plusia	Decreasing	$y = 0.0338x^3 - 1.2264x^2 + 14.657x - 56.652$ $R^2 = 0.9397$ $P < 0.001$											
Autograha gamma L.	Increasing	0.54	0.68	1.01	1.10	0.95	1.01	0.99	1.12	1.07		1.25	
Silver Y		$y = 0.0185x^3 - 0.6695x^2 + 8.0473x - 31.14$ $R^2 = 0.8748$ $P < 0.001$											
Autographa pulchrina Haw.	Increasing	0.35		0.71	0.94	1.07	1.12	1.10		1.15			
Beautiful Golden Y		$y = -0.097x^2 + 2.3747x - 13.346$ $R^2 = 0.9773$ $P < 0.001$											
Tephrina arenacearia Den. et Schiff.	Increasing	0.23		0.79	0.85	0.86	0.96	1.05	1.29	1.39			1.77
Lucerne Moth		$y = 0.2526x - 1.9103$ $R^2 = 0.942$ $P < 0.001$											

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Global Journal of Medical research
Veterinary Science and Veterinary Medicine
Volume 13 Issue 2 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)

Light-Trap Catch of the European Corn-Borer (Ostrinia Nubilalis Hübner) and Setaceous Hebrew Character (Xestia C-Nigrum L.) in Connection with the Height of Tropopause

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Abstract- In present paper we examined the connection between height of tropopause and the light-trap catch two moth species.

The data of European Corn-borer come from the Hungarian national light-trap network between 1959 and 1973, and the Setaceous Hebrew Character come from the forestry light-trap network between 1961-1970.

Groups were made for data of the height of tropopause. The relative catch values of the examined species were categorised according to the characteristics of tropopause on each day, after it these values were summarised, averaged and depicted. We defined the parameters of the regression equations. We have found a close positive correlation between the height of the tropopause and relative catch of Setaceous Hebrew Character, but only the lowest and highest values of the tropopause reduce or rather increase of the light trap catch of the European Corn-borer.

Keywords: *light trapping, tropopause, ostrinia nubilalis, xestia c-nigrum.*

GJMR-GClassification : *FOR Code: WC 900, WA 360*

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I. Introduction

The tropopause is a surface separating the lower layers of the atmosphere (troposphere) from the upper layers (stratosphere). It is of varying height. In the presence of very cold air masses from the Arctic it may be a mere 5 kilometres, while in the presence of sub-tropical air it may grow to 16 kilometres. Sometimes there are two or three tropopauses one above the other. A low tropopause is related the presence of cold and high tropopause the presence of warm types of air, while insect activity is increased by warm and reduced by cold air. An over 13 km height of the tropopause often indicates a subtropical air stream at a great height. This has a strong biological influence. These results may lead us to assume that the electric factors in the atmosphere also have an important role to play, mainly when a stream of subtropical air arrives at great height. On such occasions the 3Hz aspheric impulse number shows a decrease, while cosmic radiation of the Sun will be on the increase [Örményi, 1984]. The preponderance of negative ions in polar air reduces activity, while the preponderance of positive ions in subtropical maritime air may spur flight activity [Örményi, 1967]. The warm air increases the activity of the insects; the cold reduces it on the other hand.

This fact will change the number of insects collected by light-trap. We published it already in the recent past the efficiency of his light-trap catch in connection with the height of the tropopause of the Heart and Dart (Agrotis exclamationis L.), the Common Cockchafer (Melolontha melolontha L.), the Turnip Moth (Agrotis segetum Den. et Schiff.) and Fall Webworm Moth (Hyphantria cunea Drury) [Puskás and Nowinszky, 2000], [Örményi et al., 1997] and Puskás and Nowinszky (2011). However we know of no other study besides our investigating the relationship between the height of tropopause and light trapping. In our present work we have examined the light-trap catch of European Corn-borer (Ostrinia nubilalis Hübner) and Setaceous Hebrew Character (Xestia c-nigrum L.) as a function of the height of the tropopause, too.

We found in our former studies that the light trapping efficiency of parallel increases if the tropopause height is about 13 kilometres. However, the tropopause is even higher values in the collection of different species can be seen continue to increase, but also decrease. Therefore, we refer to our earlier studies where the effects of air masses influencing the collection were investigated (Nowinszky et al, 1997; Örményi et al, 2003). In these studies the subtropical air masses were divided on the basis of their origin and the path as follows:

Sub-tropical air; Azores air moving from W and WSW; Continental sub-tropical air arriving from the Middle East from SE; Saharan air from the Middle East from SE (observing in the upper layers only); Saharan air from across the Mediterranean Sea; Saharan air from across the Black Sea and Warm air from the Black Sea.

It has been stated that the subtropical air masses, observed in the high altitudes, differently affect the efficiency of light-trap collection according to whether they come from that route over Hungary. The light-trap catch of Turnip Moth (Agrotis segetum Den. et

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Schiff.) and Heart & Dart (Agrotis exclamationis L.) is high during subtropical residence time of air masses, but during the Saharan air mass residence time it is low. It is just opposed the results to the Fall Webworm Moth (Hyphantria cunea Drury) light trapping catch.

II. Material

Data for Budapest on the height of the tropopause have been collected from the Annals of the Central Meteorological Institute of the Hungarian Meteorological Service. Because area of Hungary is 93 036 km2 only, so this data is valid for the entire territory of the country (Örményi et., 1997).

The development of light-trap network began in 1952 in Hungary. The traps were used in research institutes, for plant protection and forestry purpose. The three type light trap network works with uniformly Jermy trap which is still working.

The national light-trap network over the past decades, enormous and inestimable scientific worth of insect material is provided for entomological research and plant protection practice. We selected two moth species from this huge data from for the present work. They comprise:

- European Corn-borer (Ostrinia nubilalis Hübner 1769) (Lepidoptera: Pyraustinae) from the all collecting material of all light-traps between 1958 and 1973.

Setaceous Hebrew Character (Xestia c-nigrum Linnaeus 1758) from the materials of all forestry light-traps between 1961 and 1970. The examined species and their catching data can be seen in Table 1

Insert near here Table 1

The stations of light-traps, their geographical coordinates and the examined years can be seen in Table 2

Insert near here Table 2

III. Methods

Than the number of individuals of a given species in different places and different observation years is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago (Nowinszky, 2003).

The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals If The number of specimens taken from the average of the same, the relative value of catch: 1. The relative catch allows the processing of collecting aggregate data from different years and observation locations (Nowinszky, 2003).

From the collection data pertaining to European Corn-borer (Ostrinia nubilalis Hbn.) and Setaceous Hebrew Character (Xestia c-nigrum L.) we calculated relative catch values (RC) by light-trap stations and by swarming. Following we arranged the data on the height of the tropopause in classes.

Relative catch values were placed according to the features of the given day, then RC were summed up and averaged. The data are plotted for each species and regression equations were calculated for relative catch of examined species and tropopause data pairs.

IV. Results

The results are shown in the Figure 1 and Figure 2.

Insert near here Figure 1 and Figure 2

V. Discussion

In our above cited study (Puskás and Nowinszky, 2011), significant positive correlations were established at each of the three species' light-trap catch studied in contention with the height of tropopause (Common Cockchafer (Melolontha melolontha L.) and Heart and Dart (Agrotis exclamationis L.) specimens, but only the lowest and highest values of tropopause reduce or rather increase of the light trap of the Fall Webworm Moth (Hyphantria cunea Drury).

Our results show that the light-trap catch of European Corn-borer) (Ostrinia nubilalis Hbn), rising to 14.5 km tropopause height increases, but higher values have been greatly reduced. In contrast, the light-trap catch of Setaceous Hebrew Character (Xestia c-nigrum L.) after the initial modest rise 13 km from rising strongly as a whole in the tropopause height of 15 km. This result is contrary to the findings of earlier works (Nowinszky et al,, 1997) while the latter confirms. The reason of the contradiction can be explained, that the European Corn-borer (Ostrinia nubilalis Hbn.) in subtropical air masses residence at the time of very hot nights have reduced flight activity.

This hypothesis is based on the ability of a still unpublished result as the light-trap catch of species increased, however, measured to the 21 o'clock evening temperatures up to 25 °C, but at higher temperatures the catch decreased by nearly half value.

We do not know yet every detail of how effects the height of the tropopause the catch results. Further researches will hopefully lead to a clear answer.

VI. Acknowledgements

We thank Anikó Nagy, assistant lecturer at National University of Public Service for help with the statistical analysis of the study.

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Table 1 : Catching data of examined species

Species	Light-traps	Years	Number of Moths	Data	Nights
Ostrinia nubilalis Hbn.	49	15	70 203	11 573	1 648
Xestia c-nigrum L.	21	9	39 101	4 583	1 047

Table 2 : The stations of Plant protection light-traps, their catching years of and geographical coordinates

Light-trap stations	Years	Geographical coordinates	
		Latitude	Longitude
Plant protecting light-traps			
Andorháza-Pacsa	1959–1971	46°43'N	17°00'E
Badacsony	1968	46°48'N	17°30'E
Balassagyarmat	1968-1973	46°43'N	17°00'E
Budapest-Rókushegy	1959-1968	47°28'N	19°09'E
Celldömölk	1968	47°15'N	17°09'E
Csopak	1959-1973	46°58'N	17° 55'E
Fácánkert	1959–1973	46°26'N	18°44'E
Gyöngyös	1959–1973	47°46'N	19° 55'E
Győr	1959–1964	47°41'N	17° 37'E
Hegyeshalom	1965–1973	47°54'N	17°09'E
Hódmezővásárhely	1959–1973	46°25'N	20°19'E
Kállósemjén	1959–1973	47°51'N	47°51'E
Kaposvár	1964–1973	46°21'N	17°47'E
Kenderes	1960–1973	47°13'N	20°43'E
Mikepércs	1959–1973	47°26'N	21°38'E
Miskolc	1959–1973	48°06'N	20°47'E
Mohora	1959–1973	47°59'N	19°20'E
Nagytétény	1959–1973	47°23'N	18°58'E
Pápa	1968–1973	47°19'N	47°19'E
Szederkény	1959–1973	45°59'N	18°27'E
Tanakajd	1959–1973	47°1'N	16°44'E
Tarhos	1959–1973	46°48'N	21°12'E
Tass	1959–1973	47°00'N	19°01'E
Toponár	1959–1962	46°21'N	17°47'E
Vasvár	1968	47°03'N	16°48'E
Velence	1959 –1973	47°14'N	18°39'E
Zalaegerszeg	1972–1973	46°50'N	16°50'E

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Table 3 : The stations of Forestry and Research Institute light-traps, their catching years of and geographical coordinates

Light-trap stations	Years	Geographical coordinates	
		Latitude	Longitude
Forestry light-traps			
Bakóca	1969-1970	46°12'N	17°59'E
Budakeszi	1961-1970	47°30'N	18°56'E
Erdősmecske	1969-1970	46°10'N	18°30'E
Felsőtárkány	1961-1970	47°58'N	20°25'E
Gerla	1967-1970	46°40'N	21°05'E
Gyulaj	1969-1970	46°30'N	18°17'E
Kőkút	1969-1970	46°11'N	17°34'E
Kömörő	1969-1970	48°01'N	22°35'E
Makkoshotyka	1961-1970	48°21'N	21°31'E
Mátraháza	1961-1970	47°46'N	19°55'E
Répáshuta	1962-1970	48°02'N	20°31'E
Sopron	1962-1970	47°41'N	16°34'E
Szakonyfalu	1967-1970	46°51'N	16°13'E
Szentpéterfölde	1968-1970	46°37'N	16°45'E
Szombathely	1962-1970	47°14'N	16°37'E
Tolna	1961-1970	46°25'N	18°46'E
Tompa	1962-1970	46°12'N	19°32'E
Vårgesztes	1962-1970	47°28'N	18°23'E
Zalaerdőd	1969-1970	47°03'N	17°08'E
Research Institute light-traps			
Badacsony	1968	46°48'N	17°30'E
Budatétény	1960-1970	47°24'N	19°09'E
Kecskemét	1961-1968	46°54'N	19°41'E
Keszthely	1960–1971	46°46'N	17°15'E
Kisvárda	1959-1968	48°13'N	22°04'E
Kompolt	1959–1968	47°44'N	20°14'E
Martonvásár	1961	47°19'N	18°47'E
Sopronhorpács	1959–1968	47°29'N	16°44'E
Tarcal	1964–1968	48°07'N	21°20'E

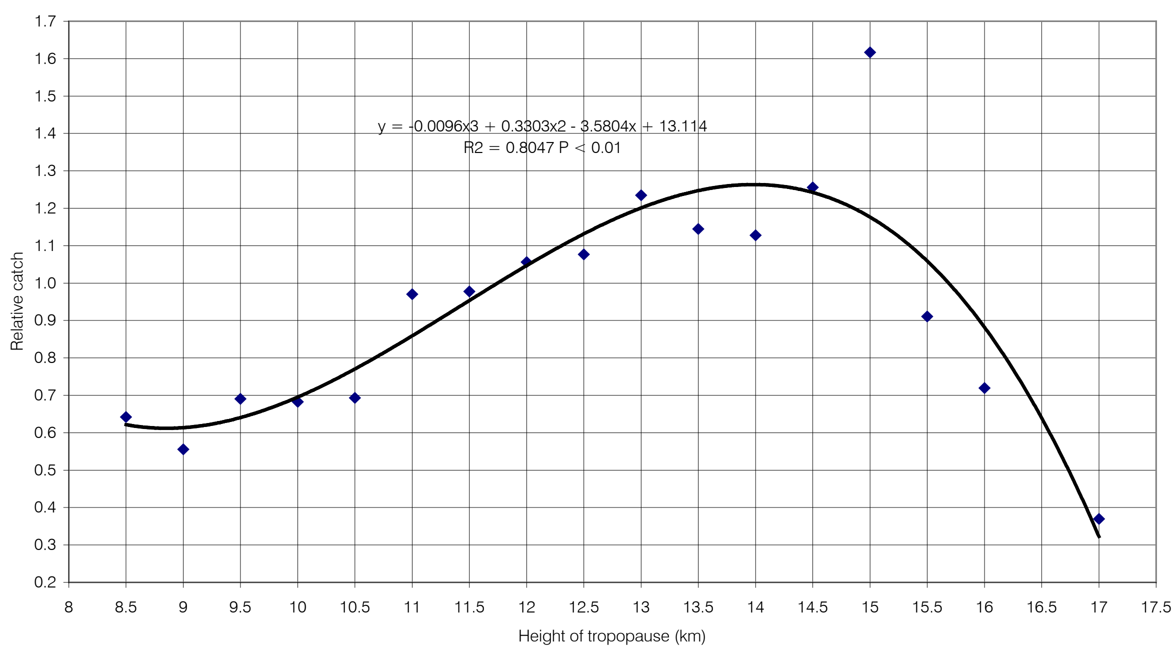

Figure 1 : Light-trap catch of European Corn-borer (Ostrinia nubilalis Hlon.) depending on the height of tropopause between 8.5 and 17 kilometres

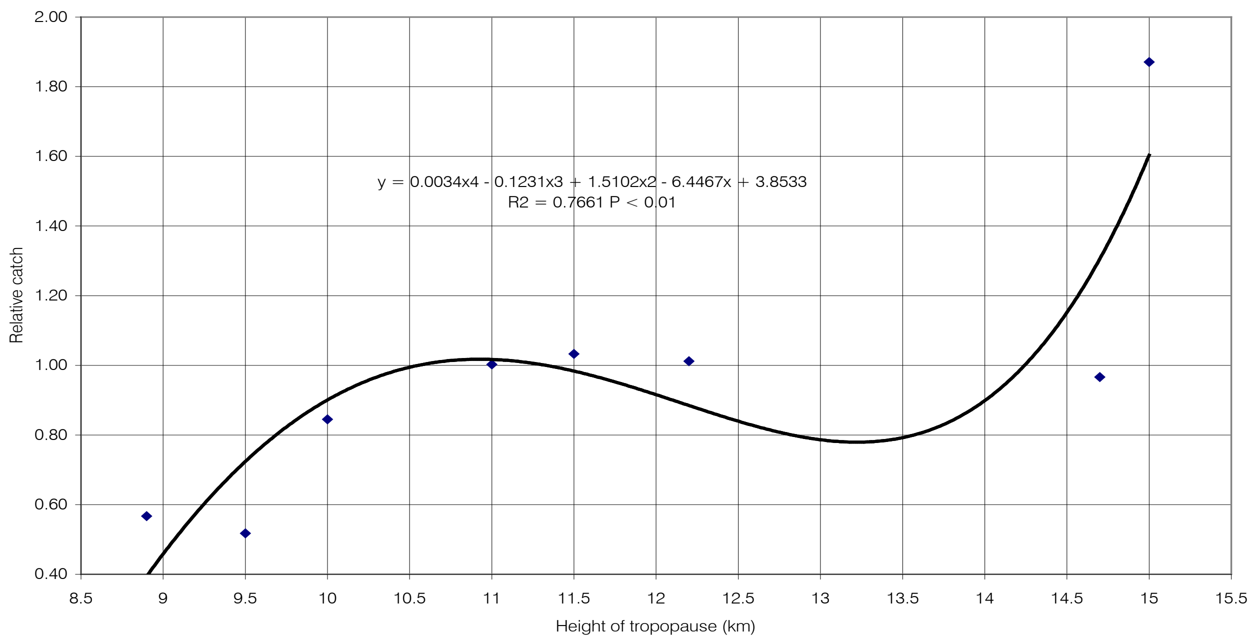

Figure 2 : Light-trap catch of the Setacoeus Hebrew Character (Xestia c-nigrum Linnaeus) depending on the height of tropopause between 1961 and 1970

Molecular Entomology 2015, Vol.6, No.3, 1-7
http://me.biopublisher.ca

Research Report Open Access

The Efficiency of Light-Trap Catches of Caddisfly (Trichoptera) Species in Connection with the Height of Tropopause in Hungary (Central Europe)

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Molecular Entomology, 2015, Vol.6, No.3 doi: 10.5376/me.2015.06.0003
Received: 16 Mar., 2015
Accepted: 05 May., 2015
Published: 18 May., 2015

Preferred citation for this article:
Nowinszky et al., 2015, The Efficiency of Light-Trap Catches of Caddisfly (Trichoptera) Species in Connection with the Height of Tropopause in Hungary (Central Europe), Molecular Entomology, Vol.6, No.3 1−7 (doi: 10.5376/me.2015.06.0003)

Abstract The study deals with the effectiveness of light traps in catching 25 species of caddisfly (Trichoptera) in connection with the height of tropopause. According to our results the catch of some species rises, in contrast other reduce in relation to the height of the tropopause. The results can be written down with second- or third-degree polynomials. Further testing will be required to provide a fuller explanation of the results.
Keywords Caddisflies; Light-trap; Height of tropopause

Introduction

The changes in midlatitude air mass circulation are caused by a rise in the height of the tropopause, and other factors as increased moisture content in the atmosphere (Lorenz and DeWeaver 2007). If there are changes in the air mass circulation it must be changes in the elements of the weather such as temperature, air humidity, air pressure, wind speed and direction.

The tropopause is the dividing surface between the lower layers of atmosphere (troposphere) and upper atmosphere layers (stratosphere). The height of tropopause varies.

The changes in tropopause height more weather elements contains a complex way: air temperature, humidity, strength of wind, air pressure, precipitation.

It is only 5 km when cold arctic air is above the surface, but it can be 16 km height at the presence of subtropical air masses.

A low tropopause is related the presence of cold and high tropopause the presence of warm types of air, while insect activity is increased by warm and reduced by cold air. An over 13 km height of the tropopause often indicates a subtropical air stream at a great height. This has a strong biological influence. These results may lead us to assume that the electric factors in the atmosphere also have an important role to play, mainly when a stream of subtropical air arrives at great height. On such occasions the 3Hz spherics impulse number shows a decrease, while cosmic radiation of the Sun will be on the increase (Örményi 1984). The preponderance of negative ions in polar air reduces activity, while the preponderance of positive ions in subtropical maritime air may spur flight activity (Örményi 1967).

The first situation did not appear, because our investigation was in the summer months, even the lower value of 8 km was only observed 6 times. Incidence of subtropical air masses with high tropopause was significantly more frequent.

As the changes in tropopause height causes also changes in the weather in the lower layers of air in large areas, we examined the efficiency of the catch of the light traps in connection with changes in the tropopause height. We did not find communications dealing with this topic in the literature apart from our own works. In recent years, some studies have already been published for different moth species and we could prove the above hypothesis (Örményi et al. 1997, Puskás and Nowinszky 2000, Puskás et al. 2003, Nowinszky and Puskás 2013). Our research has recently been extended to examine the light trapping of caddisflies (Trichoptera) species in the context of the tropopause height. These results will be demonstrated in this paper.

1 Material and Method

We collected the daily data of tropopause height (in km) values from the Library of the Hungarian Meteorological Service (Budapest) for the years 1980 to 2000, between May and September. We made our own light trap collections at 8 sites between 1980 and 2000 (Table 1), during the summer months over a 10 year period (May to September) on all nights. The determination of the specimens was made by Otto Kiss. In this study we used the data from the most frequently captured 25 species. We also used the *Oecetis ochracea* Curtis daily data collection from Újhelyi (1971), which originated from material taken by seven agricultural light traps, which was identified by Újhelyi (Table 1).

The list of analysed species can be seen in Table 2 with collecting sites and years. The species are listed in taxonomic order (Table 2). The taxonomic classification follows Kiss (2003).

Each collection was made using a standard Jermy-type light-trap. The lamp was operated 200 cm above the ground; the light source was a 100W tungsten filament bulb. A metal roof protected the light source and also the caught insects from rain. Chloroform was used as the killing agent. The traps were in operation from sunset till sunrise. Determination of trapped insects and data logging was undertaken in the morning.

We calculated relative catch values for each species at each of its sites. The relative catch was defined as the quotient of the number of individuals of a species caught during a sampling time unit (1 night) compared against the average number of individuals of that species expected for a sampling unit of the same length at that site, calculated over the whole of its flight period. For example when the actual catch was equal to the average individual number captured, the relative catch value was 1 (Nowinszky 2003).

Data on the height of the tropopause organized into groups as used by Sturges (Odor and Iglói 1987) method. The relative catch values of each analysed species were grouped according to the daily height of tropopause and then the values were summarized and averaged.

2 Results and Discussion

Our results are shown in Table 3 and Figures 1-2. The characteristic curves and associated parameters are indicated in the figures and significance levels are also given.

Table 1 The geographical coordinates of the collection sites and collection years in Hungary, Europe

Collection sites	*Years*	*Geographical*	
		Latitude	*Longitude*
Own collection sites			
Szilvásvárad	1980-81	48°64'N	20°23'E
Bükk, Vöröskő Valley	1982-83	48°34'N	20°27'E
Nagyvisnyó	1984	48°08'N	20°25'E
Dédestapolcsány	1988	48°08'N	20°25'E
Szarvaskő	1989	47°59'N	20°51'E
Uppony	1992	48°13'N	20°25'E
Zemplén	1998	48°45'N	21°48'E
Szolnok	2000	47°10'N	20°11'E
Data of Újhelyi (1971) from collection sites below			
Hódmezővásárhely	1960	46°25'N	20°19'E
Kenderes	1960	47°13'N	20°43'E
Kisvárda	1960	48°13'N	22°04'E
Kompolt	1960	47°44'N	20°14'E
Mikepércs	1960	47°26'N	21°38'E
Tarhos	1960	46°48'N	21°12'E
Velence	1960	47°14'N	18°39'E

Table 2 Collection data of the analysed caddisfly (Trichoptera) species from Hungary, Europe

Examined species	*Year*	*Trap*	*Individuals numbers*	*Data*
Rhyacophilidae				
Rhyacophila nubila Zetterstedt, 1840	1	1	450	118
Rhyacophila fasciata Hagen, 1859	2	2	436	137
Rhyacophila obliterata Mc Lachlan, 1867	1	1	285	44
Glossosomatidae				
Glossosoma conformis Neboiss, 1963	1	1	504	90
Agapetus ochripes Curtis, 1834	1	1	2466	90
Hydroptilidae				
Agraylea sexmaculata Curtis, 1834	1	1	1642	112
Ecnomidae				
Ecnomus tenellus Rambur, 1842	1	1	2193	103
Polycentropodidae				
Neureclipsis bimaculata Linnaeus, 1758	3	2	1607	96
Plectrocnemia conspersa Curtis, 1834	1	1	126	77
Hydropsychidae				
Hydropsyche instabilis Curtis, 1834	6	4	27542	432
Hydropsyche contubernalis Mc Lachlan, 1865	1	1	12012	138
Hydropsyche bulgaromanorum Malicky, 1977	1	1	22500	94
Limnephilidae				
Limnephilus affinis Curtis, 1834	1	1	717	103
Limnephilus flavicornis Fabricius, 1787	1	1	87	30
Limnephilus rhombicus Linaeus, 1758	2	2	3758	157
Ecclisopteryx madida Mc Lachlan, 1867	2	2	393	103
Potamophylax nigricornis Pictet 1834	2	1	9128	168
Halesus digitatus Schrank, 1781	1	1	1030	57
Goeridae				
Goera pilosa Fabricius, 1775	1	1	995	112
Silo pallipes Fabricius, 1781	6	5	2685	348
Sericostomatidae				
Sericostoma personatum Kirby & Spence, 1862	2	1	2158	209
Odontoceridae				
Odontocerum albicorne Scopoli, 1763	5	3	2202	372
Leptoceridae				
Athripsodes albifrons Linnaeus, 1758	1	1	799	112
Oecetis ochracea Curtis, 1825	2	8	8581	279
Ceraclea dissimilis Stephens 1836	1	1	933	101

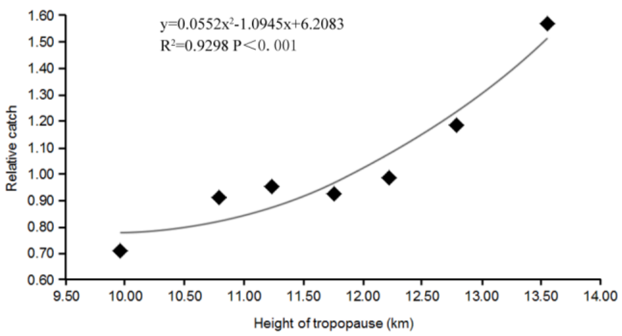

Figure 1 Light-trap catch of *Goera pilosa* Fabricius depending on the height of tropopause (Uppony, 1992)

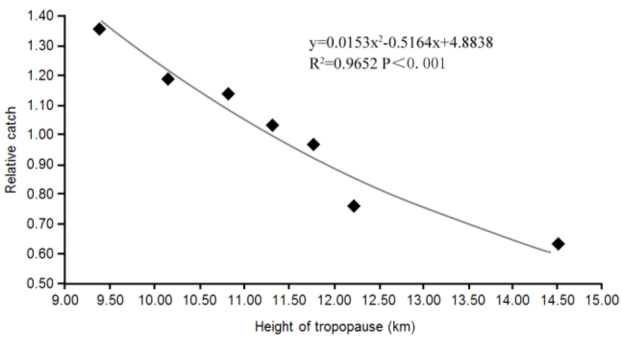

Figure 2 Light trap catch of *Limnephilus affinis* Curtis depending on the height of tropopause (Szolnok, 2000)

The figures show that the light trap catches vary between families in relation to the height of the tropopause. The tropopause height in the lower air layers is associated with different weather situations. Insects, such as caddisflies also change the flight activity of responding to changing weather conditions. Low tropopause is linked to the presence of cold, but high tropopause with hot air masses. The hot air can increase the insect activity and cold air causes the opposite. If there is a link to tropopause height other factors may have an influence.

The tropopause height above 13 km often indicates the type of subtropical air inflow at high altitude and it has a strong biological effectiveness. Atmospheric electrical factors may also have a role, especially during the high-altitude subtropical air inflow. In this case, for example, 3 Hz spherics pulses are reduced, while the solar cosmic rays increase (Örményi 1984). The atmospheric ions may also have a significant role (Örményi 1967). The arctic air may decrease flight activity factor due to the dominance of negative ions, but the dominance of positive ions in the subtropical air could be a factor in increasing flight activity.

The light-trap catch of species of *Rhyacophilidae*, *Goeridae* and *Odontoceridae* rise as the height of the tropopause increases. It seems, warm subtropical air, belonging to high tropopause, favours active flight of these species, which is reflected in the high light trap catch. In contrast, the catches of species of *Glossosomatidae*, *Hydroptilidae*, *Ecnomidae*, *Limnephilidae*, *Sericostomatidae Leptoceridae* are reduced if the tropopause height increases. The flight of these species could be reduced by the presence of warm air.

The light-trap catch of species of *Polycentropodidae* and *Hydropsychidae* genus varies. If the height of the tropopause increased there was a corresponding increase in the catch of *Neureclipsis bimaculata* L. (caught in 1982 and 1983), but a decrease in the year 2000 catch.

It is remarkable that from the trapped 10 species near Szolnok in 2000, the catch of nine species decreased when the tropopause is high and there is only one increase.

Our results show that the relationship between the light trap catch of the species examined compared with the tropopause height can be almost written down with second and third-degree polynomials. It is striking that no one genus contains such species, that the relationship between the collection and tropopause height can be characterized only with second- or third-degree polynomial. However, it is surprising that the results of *Neureclipsis bimaculata* L. coming from 1982 and 1983 collection can be described with third degree polynomial, but the collection results originating from 2000 can be written down with a second-degree polynomial. In contrast, the light-trap catches of *Oecetis ochracea* Curtis individuals in connection with the tropopause height in 1960 and also in 2000 were characterized by the same curve.

The connection between weather and tropopause is not completely known, therefore we hope later investigations will provide a fuller explanation about the causes of the results we obtained.

Acknowledgement

We would like to kindly thank the Library of the Hungarian Meteorological Service for their help.

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Table 3 Selected values of some species and the parameters of equations with the significance levels

Families – Species – Collecting sites and years	Increasing or decreasing catch	Height of tropopause (km)											
		≤ 9	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14 ≤
		Parameters of equations and significance level											
Rhyacophilidae													
Rhyacophila nubila Zetterstedt, 1840	Increasing	0.65		0.86	0.89	0.91	0.87	0.95	1.09	1.26	1.52		
Uppony, 1992		$y = 0.0323x^2 - 0.561x + 3.1217$ $R^2 = 0.9485$ $P < 0.001$											
Rhyacophila fasciata Hagen, 1859	Increasing	0.56		0.97	0.96	1.00	1.03		1.04				
Szilvásvárad, 1980, Szarvaskő, 1989		$y = 0.037x^3 - 1.3151x^2 + 15.532x - 59.96$ $R^2 = 0.9424$ $P < 0.001$											
Rhyacophila obliterata Mc Lachlan, 1867	Increasing	0.77			0.88	0.92	0.92	1.09		1.86			
Szilvásvárad, 1980		$y = 0.071x^2 - 1.4105x + 7.763$ $R^2 = 0.9504$ $P < 0.001$											
Glossosomatidae													
Glossosoma conformis Neboiss, 1963	Decreasing	1.23		1.19	1.06	1.04	0.88	0.87	0.88				0.95
Zemplén, 1998		$y = 0.0219x^2 - 0.5992x + 4.9601$ $R^2 = 0.8413$ $P < 0.01$											
Agapetus orchipes Curtis, 1834	Decreasing	1.34			1.21	1.05	1,24	0.93	0.83				0.46
Szarvaskő, 1998		$y = -0.0133x^2 + 0.1625x + 0.9871$ $R^2 = 0.9156$ $P < 0.001$											
Hydroptilidae													
Agraylea sexmaculata Curtis, 1834	Decreasing	1.38		1.10	0.97	0.93	0.99	1.04	0.92				0.81
Szolnok, 2000		$y = 0.0178x^2 - 0.5183x + 4.584$ $R^2 = 0.7984$ $P < 0.01$											
Ecnomidae													
Ecnomus tenellus Rambur, 1842	Decreasing	1.00		1.00	1.21	1.12	0.98	0.82				0.92	
Szolnok, 2000		$y = 0.0189x^3 – 0.6611x^2 + 7.5423x – 27.12$ $R^2 = 0.5615$ $P < 0.05$											
Polycentropodidae													
Neureclipsis bimaculata Linnaeus, 1758	Decreasing		1.26	1.02	1.10	1.02	0.94	0.89					0.94
Szolnok, 2000		$y = 0.0251x^2 - 0.6687x + 5.3362$ $R^2 = 0.8101$ $P < 0.01$											
Plectrocnemia conspersa Curtis, 1834	Decreasing	1.23		0.95	0.94	0.98	1.05	1.05	0.90				
Szarvaskő, 1989		$y = -0.0719x^3 + 2.44x^2 - 27.484x + 103.71$ $R^2 = 0.9965$ $P < 0.001$											

Table 3 Selected values of some species and the parameters of equations with the significance levels (continuation)

Families – Species – Collecting sites and years	Increasing or decreasing catch	Height of tropopause (km)											
		≤ 9	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14 ≤
		Parameters of equations and significance level											
Hydropsychidae													
Hydropsyche instabilis Curtis, 1834	Increasing	0.59	0.83	0.99	0.99	1.05	1.00		1.14		1.35		
Szilvásvárad 1980, Bükk 1981, 1982, 1983, Dédestopolcsány 1988, Szarcaskő, 1989		$y = 0.0206x^3 - 0.7299x^2 + 8.6626x - 33.458$ $R^2 = 0.981$ $P < 0.001$											
Hydropsyche contubernalis Mc Lachlan, 1865	Increasing	1.08		1.04	0.96	0.92	0.90		1.02			1.12	
Szolnok, 2000		$y = 0.0039x^3 - 0.1147x^2 + 1.0789x - 2.1958$ $R^2 = 0.7514$ $P < 0.01$											
Hydropsyce bulgaromanorum Malicky, 1977	Decreasing	1.54		1.29	1.24	0.89	0.77	0.76					0.92
Szolnok, 2000		$y = 0.0665x^2 - 1.7495x + 12.212$ $R^2 = 0.9214$ $P < 0.001$											
Limnephilidae													
Limnephilus affinis Curtis, 1834	Decreasing	1.37		1.20	1.13	1.03	0.97	0.77				0.63	
Szolnok, 2000		$y = 0.0153x^2 - 0.5164x + 4.8838$ $R^2 = 0.9652$											
Limnephilus flavicornis Fabricius, 1787	Decreasing	1.30			0.96	1.11	1.06	1.03		0.30			
Szilvásvárad, 1980		$y = -0.0557x^2 + 0.997x - 3.052$ $R^2 = 0.7189$ $P < 0.05$											
Limnephilus rhombicus Linaeus, 1758	Decreasing	1.44		0.93	1.13	1.04	1.06	0.90		0.89			
Szilvásvárad, 1980 Bükk, 1982		$y = -0.0303x^3 + 1.0662x^2 - 12.482x + 49.659$ $R^2 = 0.7499$ $P < 0.05$											
Ecclisopteryx madida Mc Lachlan, 1867	Decreasing												
Nagyvisnyó, 1984 Uppony, 1992		$y = -0.0119x^3 + 0.4411x^2 - 5.4833x + 23.753$ $R^2 = 0.9432$ $P < 0.001$											
Potamophylax nigricornis Pictet 1834	Decreasing		1.05	1.00	1.05	0.99	1.03	0.96	0.75				
Bükk, 1982, 1983		$y = -0.0385x^3 + 1.2435x^2 - 13.354x + 48.693$ $R^2 = 0.9486$ $P < 0.001$											
Halesus digitatus Schrank, 1781	Decreasing	1.15			1.09	1.09	1.10	1.12			0.93		0.20
Szolnok, 2000		$y = -0.0359x^2 + 0.7437x - 2.6629$ $R^2 = 0.9414$ $P < 0.001$											
Goeridae													
Goera pilosa Fabricius, 1775	Increasing		0.72		0.92	0.96	0.94	0.99	1.19		1.57		
Uppony, 1992		$y = 0.0552x^2 - 1.0945x + 6.2083$ $R^2 = 0.9298$ $P < 0.001$											

Table 3 Selected values of some species and the parameters of equations with the significance levels (continuation)

Families – Species – Collecting sites and years	Increasing or decreasing catch	Height of tropopause (km)											
		≤ 9	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14 ≤
		Parameters of equations and significance level											
Goeridae													
Silo pallipes Fabricius, 1781	Increasing	0.77	0.87	0.89	0.99	0.98	1.07	1.05	1.06	0.92		0.99	1.38
Szilvásvárad 1980, 1981, Nagyvisnyó 1984, Szarvaskő 1989, Zemplén 1998		$y = 0.0072x^3 - 0.261x^2 + 3.1637x - 11.751$ $R^2 = 0.8653$ $P < 0.001$											
Sericostomatidae													
Sericostoma personatum Kirby & Spence, 1862	Decreasing	1.26	0.96	1.11	1.05	1.05	0.97	0.89	0.39				
Bükk, 1982, 1983		$y = -0.0583x^3 + 1.9446x^2 – 21.597x + 80.836$ $R^2 = 0.968$ $P < 0.001$											
Odontoceridae													
Odontocerum albicorne Scopoli, 1763	Increasing	0.80		0.70	0.99	1.05	1.08	1.00	0.90		1.28		
Szilvásvárad, 1980, Bükk, 1982 Nagyvisnyó, 1984		$y = 0.0087x^3 - 0.2966x^2 + 3.4308x - 12.519$ $R^2 = 0.7088$ $P < 0.05$											
Leptoceridae													
Athripsodes albifrons Linnaeus, 1758	Decreasing		1.06	1.15	1.23	1.01	0.77	0.81					1.06
Szolnok, 2000		$y = -0.0053x^2 + 0.0031x + 1.6521$ $R^2 = 0.9153$ $P < 0.05$											
Oecetis ochracea Curtis, 1825	Decreasing	1.18		1.16	1.04	0.97	1.01	0.92		0.99			
Data of Újhelyi (1971), Szolnok, 2000		$y = 0.0143x^3 - 0.4547x^2 + 4.712x - 14.763$ $R^2 = 0.8507$ $P < 0.001$											
Ceraclea dissimilis Stephens 1836	Decreasing		1.51	1.30	1.10	0.88	0.76	0.75					0.85
Szolnok, 2000		$y = 0.071x^2 - 1.8694x + 12.971$ $R^2 = 0.9886$ $P < 0.00$											

Research Article

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Global Journal of Research and Review
ISSN 2393-8854

2017
Vol. 4 No. 2: 20

DOI: 10.21767/2393-8854.100020

Light Trapping of Coleoptera, Lepidoptera and Heteroptera Species in Relation to the Altitude of the Tropopause

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Abstract

The subject of our study is the success of light-trap catch of some insects (Coleoptera, Lepidoptera and Heteroptera) in Relation to the Altitude of the Tropopause. Groups were formed according to the height of the tropopause. The relative catch values of the investigated insects were grouped according to the heights of tropopause every day. Then we summarised, averaged and showed these values. We found a strong positive correlation between all of the investigated species and the altitude of tropopause.

Keywords: Tropopause; Light trapping; Coleoptera; Lepidoptera; Heteroptera

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Received: May 30, 2017; **Accepted:** June 04, 2017; **Published:** June 14, 2017

Citation: Nowinszky L, Puskás J, Kiss M. Light Trapping of Coleoptera, Lepidoptera and Heteroptera Species in Relation to the Altitude of the Tropopause. Glob J Res Rev. 2017, 4:2.

Introduction and Literature Background

Different changes can be noticed in the moderate zone air mass circulation, because there is a rise in altitude of the tropopause, and other factors also cause changes in the atmosphere (temperature, humidity, air pressure, speed and direction of wind) [1].

Troposphere is the separation surface between the troposphere and the stratosphere. Its height is greatly changeable at different times. The changes in altitude of tropopause contain more weather elements in accumulated form: air temperature, humidity, strength and direction of wind, air pressure and precipitation. In the presence of very cold air masses from the Arctic it may be five kilometres only, while in the presence of sub-tropical air it may grow to 16 kilometres. If the height of tropopause is more than 13 km, this fact often comes with subtropical air stream in the high. In this case very strong biological influence can be seen.

According to Örményi [2] the electric factors in the atmosphere have a significant influence, when subtropical air stream arrives at great altitude. During those days the 3Hz aspheric impulse number decreases, but cosmic radiation of the Sun will increase.

This fact will cause changes in the number of caught insects. It is well known that the activity of insects always increase in warm air, but decrease in cold one.

The predominance of negative ions cause decrease in the insect activity in the polar air, while the predominance of positive ions may increase the flight activity in the subtropical marine air [3].

As the changes in tropopause height cause significant changes in the weather in the lower part of atmosphere, we examined the efficiency of light-trap catch in relation with changes in the tropopause altitude.

In recent times we published some results about the relation between the efficiency of the light trapping and the height of the tropopause. We published the results with next insects: the Heart and Dart (*Agrotis exclamationis* L.), the Common Cockchafer (*Melolontha melolontha* L.), the Turnip Moth (*Agrotis segetum* Den. et Schiff.) and Fall Webworm Moth (*Hyphantria cunea* Drury) [4-6]. According to our results the subtropical air masses influenced differently the efficiency of trapping if these masses were found in the high. The result of light trapping of Turnip Moth (Agrotis segetum Den. et Schiff.) and Heart & Dart (Agrotis exclamationis L.) is high when subtropical air masses can be found, while the opposite influence can be seen if Saharan air mass arrived, because the catch is low. The catch result of Fall Webworm (Hyphantria cunea Drury) is the opposite. We made former investigations with light-trap catch of some species (European Corn-borer (*Ostrinia nubilalis* Hübner), Setaceous Hebrew Character (*Xestia c-nigrum* L.) and caddisfly (Trichoptera) species) to examine the connection with the tropopause height [7,8].

We could find only our publications in the literature which deals with similar investigations.

The height of the global-mean tropopause shows a steady increase since 1979 in re-analyses of numerical weather forecasts. In model simulations with anthropogenic forcing, changes in tropopause height can be detected roughly 20 years earlier than changes in surface temperature [9].

We think it is important to investigate the insects's response in relation with the changes of the height of tropopause.

Material

Data of the height of tropopause in Budapest were found in the Annals of the Central Meteorological Institute of the Hungarian Meteorological Service.

We used the catch data of the Hungarian Agricultural and Forestry light-trap network. All the catch was made with Jermy-type light traps. The collection data are shown in **Table 1.**

The *Serica brunnea* Linnaeus is widespread species in the Carpathian Basin [10] wrote in his study the forest species of Hungarian forestry light-trap network were detected in the Bakony and Vértes Mountains and the sand in Danube-Tisza.

It can be found everywhere in the Carpathian Basin, but their damage is only significant in some regions.

The *Rhisotrogus aestivus* Olivier is collectible en masse mainly at sandy soils in Hungary (Kiskunság, Nyírség and around Budapest). Its swarming is expected in May [11,12]. It is mainly spread on sand soils. The larvae cause damage to sugar beet and potatoes.

The *Plutella xylostella* L. spread all over the world [13]. The most important host plants are the cabbages and rape.

The *Hypomecis punctinalis* Scopolilt is very common in places in Hungary. The most important host plants are the oak (Quercus) and birch (Betula).

The material of caught bug species was not determined yet, but the majority belonged to these species: *Lygus rugulipennis* Poppius, 1911 (European Tamished Plant Bug) and *Lygus pratensis* Linnaeus, 1758 (Tamished Plant Bug) [14].

Methods

The Jermy-type light trap consists of a frame, a truss, a cover, a light source, a funnel, and a killing device. All the components are painted black, except for the funnel, which is white. A metal ring holds the funnel and a zinc coated tin are attached to the steel frame. The lid has a diameter of 100 cm. The top diameter of the funnel is 32 cm, the bottom is 5 cm and the height is 25 cm. The light source was a 100W normal light bulb which was laid under a metal cover (0:1 m) at 200 cm above the ground. Most traps were operated without a bow and the insect material was fed by a funnel under the bulb into a bowl. In each case, chloroform was used as a killer. Traps were held every night from April to October. An automatic turn-on/switched-off technique provided the capture of both twilight and night insects. The light-traps are operational from 6 pm. (UT) to 4 a.m. every night of the year, regardless of weather, or the time of sunrise and sunset. All the insects trapped during the course of a night go into the same collecting jar [15]. So a single set of data will represent the nightly catch result at the given observation site [16].

Basic data were the number of individuals caught by one trap in one night. The number of basic data exceeded the number of sampling nights because in most collecting years more light-traps operated synchronously [16].

The size of the populations of different observers are in different places, and the modifying factors are not the same all the time and location of the trapping, it is easy to see that the same number of items you can capture an entirely different proportion of two different observers place or time, the population studied. To solve this problem, the application offers to the relative catch values [16]. The relative catch (RC) is for a given sampling unit time (one hour or one night) and number average equivalent-time sampling unit relative to the number of generations before-bassoon individuals divided. If the number of specimens is equal to the average value of the relative catch is 1.

The relative catch data were classified into the appropriate phase angle groups. The phase angle groups and the corresponding catch data were organized into classes. Their number was determined according to Sturges' method [17] using the following formula:

$k=1+3.3 * 1g\ n$

Where: k=the number of groups, n=the number of observation data.

The relative catch values were sorted according to the respective diurnal values of the height of tropopause and then averaged and depicted. The figures also show the confidence intervals.

Results and Discussion

Our results are visible in **Figures 1-5**. The illustrated Figures show that the collection results of the different species are similar in connection with the height of the tropopause. Various tropopause heights have different weather conditions in the lower air layers [18]. In summer the cool air decreases the flying activity of insects in contrast, it is growing in warm air.

We have discovered a close positive correlation between the height of the tropopause and the number of light trapped of all

Table 1 The number and observing data of the examined species.

Species	Years	Traps	Individuals	Data	Nights
Coleoptera, Scarabaeidae *Serica brunnea* Linnaeus, 1758 Brown Chafer	1969-1974	8	7,713	499	288
Coleoptera, Scarabaeidae *Rhizotrogus aestivus* Olivier, 1789	1969-1974	8	1,820	223	139
Lepidoptera, Plutellidae *Plutela xylostella* Linnaeus, 1758 Diamond-back Moth	1962-1966	26	4,602	534	353
Lepidoptera, Geometridae *Hypomecis punctinalis* Scopoli, 1763 Pale Oak Beauty	1962-1969	1	11,818	797	797
Heteroptera, Miridae *Lygus sp.*	1980-1998	14	51,953	3,339	1,728

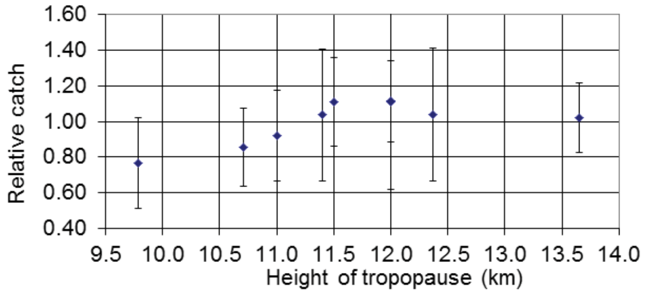

Figure 1 Light-trap catch of Brown Chafer (*Serica brunnea Linnaeus*) in connection with the height of tropopause.

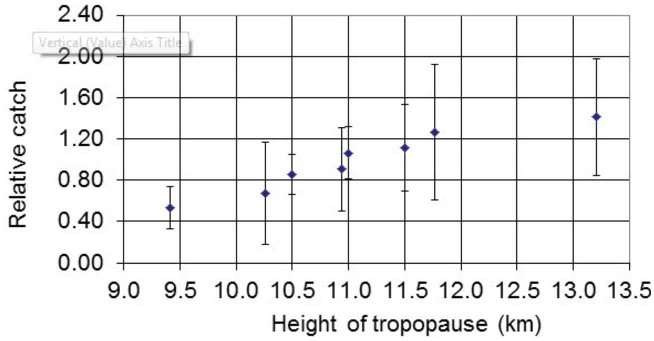

Figure 2 Light-trap catch of *Rhizotrogus aestivus* Olivier in connection with the height of tropopause.

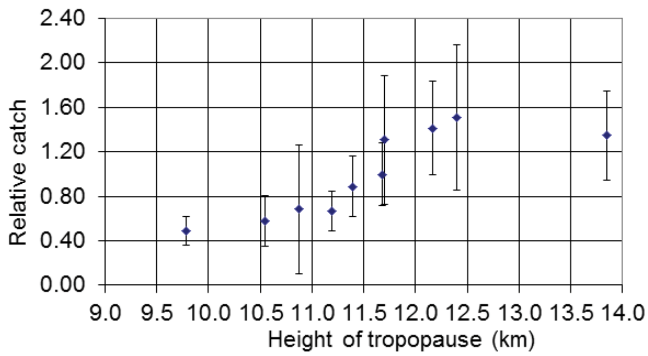

Figure 3 Light-trap catch of Diamond-back Moth (*Plutella xylostella Linnaeus*) in connection with the height of tropopause.

five species. The catch, however, is slightly different from species to species and peaks ranged from 10.5-13.6 km. This behaviour is not linked to the taxonomic position. However, our previous works gave somewhat different results in the current one. The higher values of tropopause cause higher catching results for the following species:

Lepidoptera: Noctuidae: *Xestia c-nigrum* L., First rising then falling: Lepidoptera: Crambidae: *Ostrinia nubilalis* Hbn [7].

Coleoptera: Melolontidae: *Melolontha melolontha* L., Lepidoptera: Noctuidae: *Agrotis exclamationis* L., Trichoptera: Limnephilidae: *Goera pilosa* Fabr [19].

Conversely, the higher values of tropopause were lower for the following species: Lepidoptera: Crambidae: *Loxostege sticticalis* L., *Nomophila noctuella*, Den. et Schiff. [19], Trichoptera: Limnephilidae: *Limnophilusa affinis* Curtis [8].

The relationship between the height of the tropopause and the weather of lower air is not fully known. Our past works results are partially contradicted by our present results. The cause of this controversy must be further explored.

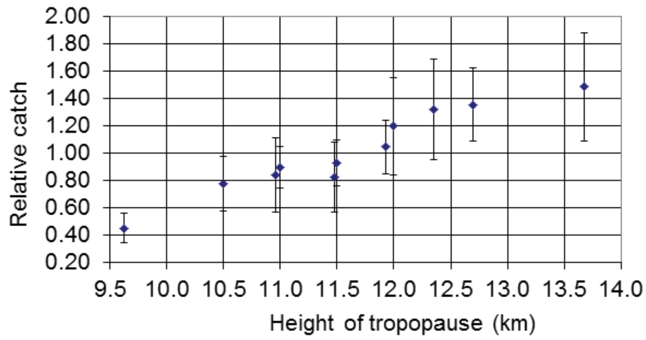

Figure 4 Light-trap catch of Pale Oak Beauty (*Hypomecis punctinalis* Scopoli) in connection with the height of tropopause.

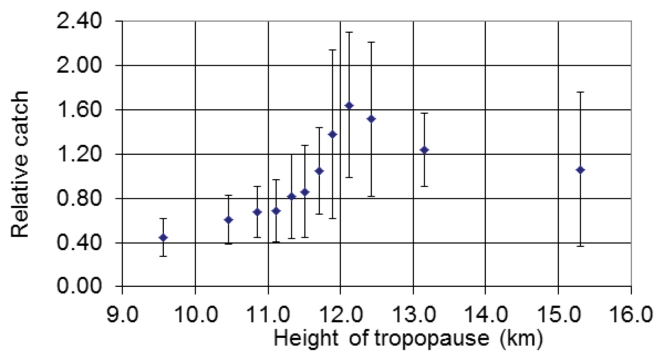

Figure 5 Light-trap catch of Lygus sp. in connection with the height of tropopause.

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Sonderdruck aus Bd. 91 (1981), H. 4, S. 403–411

Zeitschrift für angewandte Entomologie

VERLAG PAUL PAREY · SPITALERSTRASSE 12 · D-2000 HAMBURG 1

Common effect of geomagnetism and change of moon phases on light-trap catches of fall webworm moth (*Hyphantria cunea* Drury)

By M. Kiss, I. Ekk, G. Tóth, S. Szabó and L. Nowinszky

Abstract

A correlation was found between the summarized values of horizontal component change of the geomagnetic field-strength measured at night, and the amount of light-trap catches of fall webworm moth (*Hyphantria cunea* Drury). It was stated that the change of geomagnetic field strength significantly, but in the various moon-phases differently, influces the catches. On this basis of above tests a new hypothesis has been elaborated for the spatial orientation of insects. Results of the study may be used in plant protection forecasting too.

1 Introduction and survey of literature

Catches of light-trap can be influenced by several environmental factors. Their role is to be determined for both entomological basic research and plant protection practice. Several studies are devoted to study weather factors both in foreign and Hungarian literature. Much less attention is paid, on the other hand, to the analysis of the effect of cosmic factors. Cosmic factors are of the same characters on a relatively large area at a given time. Therefore they have their effect in the time and not in the space. Thus it is indispensable to know their role modifiyng the catch for data of insects trapped at different time.

This paper deals with the common effect of change of geomagnetic field-strength and the various moon-phases modifying the insect catch.

Studying some species of termites (Isoptera), beetles (Coleoptera), flies (Diptera), orthopterans (Orthoptera), and hymenopterans (Hymenoptera), Becker (1964) found that they orient according the natural magnetic field. Way of their mobility is North-South, rarely East-West. Their original way of movement could be modifyed by artificial magnetic field.

Chernyshev (1965) observed that counts of light-trapped insects increased significantly during magnetic perturbation. He also studied (1968) the change of biological rhythme of the species *Trogoderma glabrum* Herbst. (Coleoptera: Dermestidae) in a function of the perturbation of magnetic field. Assessment was based upon the K-index values over 4 (i. e. above 40 γ) measured at 6,9 o'clock p. m. and at the midnight, as well as at 3 o'clock a. m. of local time. He supported that the biological rhythme of the species under study is influenced by factors corresponding to the perturbations of magnetic field.

Mletsko (1969) carried out his trials in the Moscow botanic garden on a 100 m^2 area covered with asphalt. He used adults of ground beetles (*Broscus cephalotes* L. and *Pterostichus vulgaris* L.; Coleoptera: Carabidae). Insects

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Z. ang. Ent. 91 (1981), 403–411

ISSN 0044-2240 / InterCode: ZANEAE

were placed in the middle of the area and their way of movement were studied by compass. The insects flew several meters uncertainly, and after this they oriented towards a given direction, with an accuracy of ± 5 grades at daylight and ± 60 grades at night respectively. The author's hypothesis is that, the orientation follows the terrestrial magnetic field. The orientation shows the same trend the whole day and it does not change at night, when there is no sunlight.

Schneider (1962–1975) dealt with the orientation of European cockchafer (*Melolontha melolontha* L.). He proves that this beetle perceives the magnetic, electrostatic and gravitational fields, the so-called "ultraoptic informations". Its orientation mostly takes place along the vector of the geomagnetic field-strength. The orientation changed when he placed the beetles in a strong electrostatic or electromagnetic field. Effect of changes of the gravitational field was supported by experiments using with high volume lead-brick. Thus the spatial orientation has changed. With the change of natural fields aperiodic biological rhythms could be induced in the insects.

Similar results were achieved by Günther (1977) with *Melolontha melolontha*. According to him the insects uses geomagnetism and cosmic gravitational waves, besides the topocentric silhouettes for the orientation too.

Later Tshernyshev (1972) says that light-trap catches of some coleopteran and lepidopteran species increase with the geomagnetic perturbation. On the contrary, activity of other lepidopteran and several dipteran species is reduced by this phenomenon. He found high correlation between the δH and ΣK values and the number of trapped insects.

Studying of few-spotted ermel, *Hyponomeuta rorellus* Hb., (Lepidoptera: Hyponomeutidae) it was found by Pristavko and Karasov (1970), on the other hand, a correlation between C and ΣK values respectively, and the number of trapped insects.

In the most northern region of Finland, with very high geomagnetic latitude, Iso-Ivari and Koponen (1976) studied the effect of geomagnetism on the volume of insects caught by light-trap. They used in their experiments the K-index values measured three-hourly and the ΣK and δH values. Geomagnetic data and the meteorological factors were compared with night catches. They were used to show the connections, the Pearson product-moment correlation. In case of different insect orders, a poor correlation was found.

2 Material

2.1 Short data on geomagnetism

The average field strength of the Earth as a magnetic dipole is 33.000 γ (1 $\gamma = 10^{-5}$ Gauss $= 10^{-9}$ Tesla [nt]). The geomagnetic field strength can be decomposed into three components: H – horizontal, Z – vertical and D – declination components. With regard to the entomologic trials the extent of total field strength, on the one hand, and the value of horizontal component, on the other, are important because, insects fly rather horizontally than vertically.

It is well known that the magnetic poles and the geographic one of the Earth do not coincide, therefore besides the geographic coordinates, the geomagnetic latitudes and longitudes are to be distinguished; and these coordinates are characteristic for the geomagnetic reasons of a given geographic coordinate. The geomagnetic parameters are significantly different on various regions of Earth's surface at a given time. As an average of 300 km distance may result in significantly different characteristics along the geomagnetic meridian.

The geomagnetic measuring data of a single observatory in the case of Hungary supply sufficient information for the whole country: i. e. the parameters measured along the magnetic meridian (direction: North-West to South-East) in function of time. These measurements are made at Nagycenk, near Sopron in the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences. The distance along the magnetic meridian never exceeds 300 km.

Values of local horizontal component for our research have been taken from a series of observations carried out at Nagycenk (Western Hungary) description of which can be found in: Observatoriumsberichte des Geophysikalischen Forschungslaboratoriums der UAdW in Sopron, 1962–1966; Geophysical Observatory Reports of the Geodetical and Geophysical Research Institute of the HAS in Sopron, 1967–1976. Data on the field strength changes of the horizontal geomagnetic component are given for each 3-hour-period in a scale from 0 to 9, where the scale unit is 7 γ = 7 nT. The scale is linear.

Table 1. The connection found between the geomagnetism and the RA of fall webworm moth

ΣH 1	N 2	$\bar{x}$ 3	σ 4	$\frac{\bar{x}}{\sigma}$ 5	F values 6	sing. level 7	3-p-m-a[1] 8	Note[2] 9
0	128	2.63	3.0379	0.865	5.08	99.9		
1	179	2.40	3.0370	0.775	5.08	99.9	2.63	
2	253	2.85	4.2732	0.667	10.05	99.9	2.77	
3	288	3.06	4.7899	0.639	12.63	99.9	2.93	
4	177	2.87	3.2978	0.870	5.99	99.9	2.94	
5	253	2.89	4.0770	0.709	9.15	99.9	3.15	
6	203	3.70	4.6101	0.803	11.70	99.9	3.07	
7	178	2.62	3.5517	0.738	5.95	99.9	2.96	
8	183	2.55	3.5196	0.725	6.82	99.9	2.72	
9	144	2.98	5.6024	0.531	17.28	99.9	2.84	
10	113	2.98	3.9379	0.757	8.54	99.9	3.01	
11	128	3.08	4.0280	0.765	8.93	99.9	2.68	
12	72	1.98	2.4772	0.798	3.38	99.9	2.60	
13	79	2.75	4.4341	0.620	10.82	99.9	2.41	
14	64	2.50	3.6392	0.690	7.29	99.9	3.19	
15	63	4.33	4.6069	0.940	11.69	99.9	3.49	
16	48	3.65	4.5755	0.800	11.53	99.9	3.72	
17	39	3.18	3.7923	0.839	7.92	99.9	3.33	
18	32	3.16	3.6944	0.856	7.51	99.9	3.29	
19	31	3.52	5.0858	0.692	14.24	99.9	3.06	
20	22	2.49	3.1347	0.794	5.41	99.9	3.04	belongs to ΣH = 20.3
21	14	1.23	1.4804	0.831	1,21	n.s.		
22	20	3.10	3.3684	0.920	6.25	99.9	2.58	
23	14	1.46	1.5068	0.970	1.25	n.s.		
24	11	2.15	2.4553	0.876	3.32	99.9	2.30	belongs to ΣH = 23.7
25	26	1.64	2.3432	0.700	3.02	99.9	3.14	
26	26	5.63	5.8774	0.959	19.02	99.9	3,79	
27	14	4.11	10.1572	0.405	56.80	99.9		
28	5	0.66	1.0560	0.628	1.63	n.s.	4.12	belongs to ΣH = 27.7
29	2	0.63	0.2262	2.785	35.50	90.0		
30	19	2.62	3.1750	0.825	5.55	99.9	3.18	belongs to ΣH = 29.3
31	9	2.82	3.8415	0.733	8.12	99.9		
32	5	0.86	0.9470	0.908	2.03	n.s.	3.16	belongs to ΣH = 31.7
33	0	0	0	–	–	–		
34	2	4.05	3.8537	1.048	8.18	99.9	4.85	belongs to ΣH = 33.3
35	8	7.67	7.1570	1.070	28.20	99.9	5.50	
36	7	4.79	3.7051	1.293	7.56	99.9		

Sum and mean N = 2859 $\bar{\bar{x}} = 2.9331$ $\sigma_{\bar{x}} = 1.3477$

[1] three-points moving averages from the values of column 3. – [2] note to column 8.
n.s. means that no significance have been found

2.2 Light-trap data

Trials were carried out with the fall webworm moth (*Hyphantria cunea* Drury, Lepidoptera: Arctiidae), and the catches of five observing station (Gerla, Kúnfehértó, Tolna, Tompa and Celldömölk) were used. These five stations belong to the national light-trap network. Flights with more than 40 lepidopterans of the 14 years observation period (1963–1976) have been taken into consideration. Flights of the first and second generations were considered together. Thus altogether 86 flights were worked out.

2.3 Methods

Data on catches of different flights must have been comparable. Therefore relative abundances (RAs) calculated from the number of insects trapped at night, and the values of nightly ΣH are formed together to become a data pair. Mean value, standard deviation and variation coefficient have been formed from the RAs of the catches belonging to the same ΣH values. The F value (FISHER's test) and significance levels have been determined. The no significant data have been excluded by variance analysis (table 1).

Then by the help of least-squares method a quadratic regression equation were calculated. After three-points average of calculated regression curve of the RAs of catches was plotted against ΣH values (fig. 1).

The RAs of catches are taken into a contingency table too following the moon-phases and night values of ΣH. Four columns and five rows have been formed on the basis of the light change of the Moon and the night values of ΣH, respectively (see table 2 and fig. 2). The interpretation of the colums and rows of the table 2:

Colums of

full Moon = 28th, 29th, 30th, 1st, 2nd, 3rd day
last quarter = 4th, 5th, 6th, 7th, 8th, 9th, 10th day
new Moon = 11th, 12th, 13th, 14th, 15th, 16th, 17th, 18th, 19th, 20th day
first quarter = 21st, 22nd, 23rd, 24th, 25th, 26th, 27th day

Rows of

0–6; 7–13; 14–20; 21–26; and 27–36 night values of ΣH.

3 Results

It may be seen from fig. 1 that the RA of the catches is almost the same up to ΣH = 10. Further increase of the ΣH values causes more and more fluctuations in RAs of catches. The variation coefficients are practically the same, therefore data are independent. On this basis, the samples of low and high quantity can be compared to each other.

The use of the moving averages resulted in decrease of components with high frequency. The resultant of the remained components with low frequency showed characteristic waves along the trend-line. Interpretation of the waves will be discussed later.

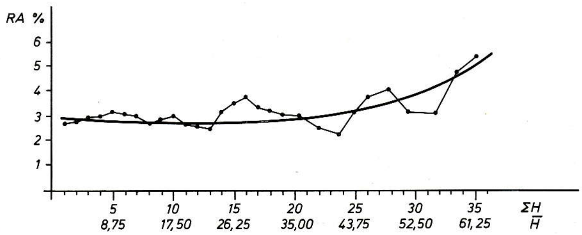


Fig. 1. The RAs of fall webworm moth catched as a function of nightly ΣH (three-points average). The equation of regression curve is: $RA_{\%} = 2{,}91 - 0{,}014\ (\Sigma H) + 0{,}0014\ (\Sigma H)^2$

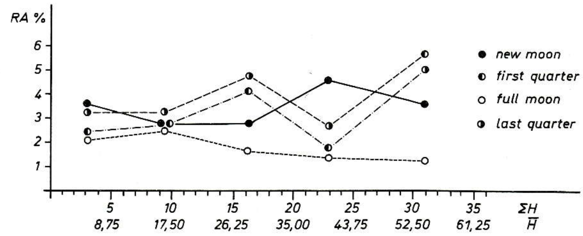


Fig. 2. The RAs of fall webworm moth as a function of moon phases and ΣH together

Using jointly the figs. 1 and 2, the range of change of the geomagnetic field strength can be read. This range refers to the minimum catches of different moon-phases:

full moon	28–33 ΣH/49–58 nT/
first and last quarters	20–25 ΣH/35–44 nT/
new moon	10–15 ΣH/18–26 nT/

The interpretation of the waves mentioned above: The mean values of the range in the change of geomagnetic field strength are characteristic for the four moon-phases, and coincide with the minimum values of fig. 1.

4 Discussion

4.1 Discussion of results

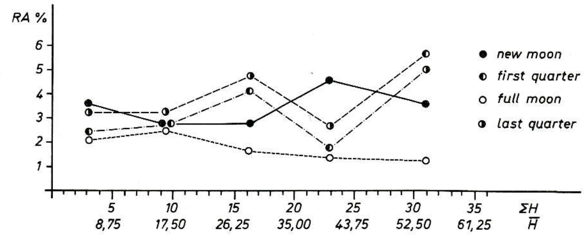
The trend-line of the correlation between the night ΣH value of change of the geomagnetism and the RAs of *Hyphantria cunea* population is slightly increasing. It is however obvious that in the higher ΣH ranges two minimum values of the data are appeared. The minimum values cannot be interpreted by themselves, only in relation to the moon-phases. The slightly increasing trend-line is not characteristic for any of the moon-quarters, it has to be understood as their mean values.

It can considerably be stated that without taking the moonphases into consideration, the only thing that can be said for a flight period is that higher catch belongs to relatively high night ΣH values.

Light-trap catches of several years may lead to know the mobility range of the horizontal geomagnetic field strength, in which the catch shows minimums in each moon-phases.

On the basis of our research, we try now to answer the question that has also been put by WILLIAMS, the catch is in proportion to the population and the activity. We think that the catch is in proportion to the population density, the activity and the catch area and is inversely proportional to the orientation safety.

The population density is the number of adults being born and dying, or arriving and leaving, at a given period of time around the light-trap station. WILLIAMS pointed out the effect of the various weather factors modifying the flight activity. We suppose that besides the weather factors, the cosmic factors used by insects for orientation modify also the flight activity. We object therefore the hypothesis of WILLIAMS (publ. 1936), i. e. the moonlight decrease the flight activity of insects, and we believe that both of moonlight and change of geomagnetic field strength increase the flight activity.



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Previously we have proved in a study (NOWINSZKY et al. 1979) the effect increasing the activity of the polarized light component reflected by the moon. The factor essentially modifying the catch is the size of the catch area. This probably according to WILLIAMS (1936) and WILLIAMS, SINGH and EL- ZIADY (1959), too. This suggestion was confirmed by the authors of this paper in 1979.

4.2 A hypothesis for the orientation safety

JERMY (1972) finds that moonlight increases safety of spatial orientation of insects, and that is why light-traps catch less beetles at full moon. Several research workers showed that insects can use at the same time many factors for their orientation, and according to SZÉKY (1977) they can even "classify" them.

Let us suppose that the orientation safety increases to a certain extent with the increase of impulse for flight, and that reaction to several impulses at the same time also increases the orientation safety. It is subsequently probable that some change inside a given range of the geomagnetic field strength unambiguosly increases the orientation safety.

In the case of the light intensity the situation is quite different. Increase of the moonlight intensity, of course induce increase in orientation safety. But, on the other hand, the artifical light (e. g. the light-trap) reduces it. It is not probable that an insect flying at night could make any difference between the natural light (the moon) and the artifical one, therefore the light of the trap gives it information for orientation, there were the insect feels more attractive the light of the lamp than that of the moon (NOWINSZKY et al., 1979). But the lamp, contrasted with moon, is not in the infinite space for the insect. So the insect reaches the lamp on a spiral way (BUDDENBROCK's theory, 1917) if it wants to fly keeping an angle the direction of the flight changes, consequently

Table 2. The two-way analysis between the RA of fall webworm moth, and the geomagnetism, the moon phases respectively (Contingency table)

ΣH	Moon phases	Full moon	Last quarter	New moon	First quarter	Sum
	Σ	468.95	1223.56	1762.53	906	4361.14
0– 6	N	221	382	504	374	1481
	$\bar{x}$	2.19	3.2	3.5	2.42	2.94
	Σ	452.42	592.57	837.67	569.41	2452.07
7–13	N	176	187	319	215	897
	$\bar{x}$	2.57	3.17	2.62	2.65	2.73
	Σ	88.24	333.52	348.55	223.61	993.92
14–20	N	52	70	123	54	299
	$\bar{x}$	1.7	4.76	2.83	4.14	3.32
	Σ	41.92	88.14	159.47	22.91	312.44
21–26	N	31	32	35	13	111
	$\bar{x}$	1.35	2.75	4.56	1.76	2.81
	Σ	28.73	86.81	78.03	51	244.57
27–36	N	23	17	22	9	71
	$\bar{x}$	1.25	5.11	3.55	5.67	3.44
	Σ	1080.26	2324.6	3186.35	1772.93	8364.14
Sum	N	503	688	1003	665	2859
	$\bar{x}$	2.15	3.38	3.18	2.67	2.92

the insect "against its intention" does not follow its direction, and loses its way.

Based on our experiments it can be taken for sure that the light and its polarized component, as well as the variation of the horizontal field strength of geomagnetism mean information on orientation for fall webworm moth. Taking the above hypothesis and the consequences of fig. 2 into consideration one can try to answer the question: what is the explanation for the values of RAs obtained from the catches for various moon-phases (table 2).

At full moon the light intensity is adequate for the orientation of the insect. This fact increases the flight activity, but decreases the size of the catch area. As a result of both contrary effects catch is reduced compared to the other moon phases. Low change of the geomagnetic field strength does not significantly influences yet the activity and does'nt mean good information on orientation, therefore make no increase in the safety of orientation.

With the increase of ΣH value the activity and the orientation safety increase as well, and the catch area is still the smallest. Thus the number of the trapped adults is the lowest. The optimal range of the horizontal component-change means security for the insect at full moon, against being lost, that is being trapped.

At new moon the intensity of natural light is minimal; there is no light at new moon phase, so the insect mainly uses the geomagnetism for its orientation. That means also that increase of activity takes place at lower ΣH values. The optimal range for orientation safety is also at lower ΣH values. At time of new moon therefore a slight range of the geomagnetic field strength can make the orientation uncertain, and that is true also because the moonlight at this phase does not provide information on orientation. The catch area is the largest at new moon. As a result of the effect of all the factors it can be stated that the number of trapped adults exceeds those trapped at full moon.

At time of the first and last quarters, the intensity of the moonlight is much smaller than at full moon, but the light is partly polarized, and the polarization is maximal. The catch area is smaller than at time of new moon, but larger than at full moon. Besides moonlight and change of geomagnetism, the polarized component of the moonlight may orient the insect. It may be seen on fig. 2 that increase of activity can be observed at lower ΣH values, than at full moon, but nevertheless at higher values than at new moon. It is evident that the degree of increase is much higher than in the other moon phases. This phenomenon is contributed to the effect of the polarized light, because it seems to be a new orientating factor compared with the time of full moon and new moon.

The optimal ΣH range necessary for the orientation safety, and the subsequent increase of the catches can also be placed between the values of full moon and new moon. We think that the increase of activity induced by polarized light is the most important of the effect of all orientating factors. That is why the number of trapped adults is the highest in these phases. Some differences can be observed between the catches of the first and the last quarters, though some phases may be similar. The moon is above the horizon during first half of night at first quarter, and in a second one at last quarter. That means that for insects flying before midnight (i. e. at evening) the time of last quarter reaches the light effects of new moon, while the first quarter means those of near the full moon. The higher number of insects trapped at the last quarter indirectly proves that most adults of *Hyphantria cunea* fly before midnight.

As our studies have been carried out for fall webworm moth, the hypotheses concern also mainly this species. But since the effect of the moonlight intensity, the polarized light and the changes of geomagnetism is proved also for other species, we supposed that similar laws are valid for the trapping of other species.

It follows from our results that the modifying effects of the light intensity and the polarized light reflected from the moon as well as the change of horizontal component of local geomagnetic field strength must be taken into consideration at the assessment of the number of adults captured by light-trap.

Zusammenfassung

Über allgemeine Wirkungen des Geomagnetismus und des Mondphasenwechsels auf die Lichtfallenfänge von Hyphantria cunea Drury

Es wurde eine Korrelation zwischen den Summenwerten des Wechsels der geomagnetischen Feldstärke (Messungen nachts) und den Lichtfallenfängen von *H. cunea* gefunden. Es zeigte sich, daß der Wechsel der geomagnetischen Feldstärke in signifikanter – aber mit der Mondphase wechselnder – Weise die Lichtfangergebnisse beeinflußte. Auf dieser Grundlage wird eine neue Hypothese zur räumlichen Orientierung von Insekten aufgestellt. Die Ergebnisse der vorliegenden Untersuchungen können für die Schädlingsprognose von Nutzen sein.

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Light trapping of Turnip Moth (*Agrotis segetum* Den. et Schiff.) connected with vertical component of geomagnetic field intensity

A vetési bagolylepke (*Agrotis segetum* Den. et Schiff.) fénycsapdás fogása a földmágneses térerő vertikális komponensével összefüggésben

(Lepidoptera: Noctuidae)

Nowinszky László & Puskás János

Abstract – The study deals with the change of light-trap catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.), in connection with the vertical component of geomagnetic field and the moon phases. The numbers of specimens caught by generation relative catch values were calculated. These hourly relative catch data were assigned to the hourly values of vertical component of geomagnetic field. They were separated by the moonlit and moonless hours of the four quarter of the Moon (New Moon, First Quarter, Full Moon and Last Quarter) were classified. We correlated the hourly catch results pertaining to the hourly values of both the vertical component and moonlit or moonless hours of four moon quarters. After that we made correlation calculations to demonstrate the assumed connection. Our calculations have shown that in the period of the New Moon when there is no measurable moonlight, the higher values of the vertical component are accompanied by a falling relative catch. In the other moon phases, i.e. in the First Quarter, Full Moon and the Last Quarter, growing values of the vertical component are accompanied by an increasing catch in both the moonlit and moonless hours.

Összefoglalás – A tanulmány a vetési bagolylepke (*Agrotis segetum* Den. et Schiff.) fénycsapdás fogásának eredményességét vizsgálja a holdfázisok és a földmágneses térerő vertikális komponensével összefüggésben. A befogott lepkék számából relatív fogás értékeket számítottunk. A relatív fogás a mintavételi időegységben (egy óra) befogott egyedek és a mintavételi időegység átlagos egyedszámának a hányadosa. A relatív fogás adatokat óránként hozzárendeltük a földmágneses térerő vertikális komponensének óránkénti adataihoz. Az adatpárokat szétválasztottuk a négy holdnegyed és ezeken belül a holdfény nélküli és a holdfényes órák szerint. A továbbiakban korrelációszámításokat végeztünk a feltételezett kapcsolat kimutatására. Számításaink azt mutatják, hogy az eltérő holdfázisokban és holdfényes és holdfény nélküli órákban eltérő a vertikális térerő fénycsapdás fogásra gyakorolt befolyása. Újholdkor, amikor nincs mérhető holdfény, a fénycsapdás fogás csökken a vertikális térerő magasabb értékeivel párhuzamosan. Holdtöltekor és első- és utolsó negyed holdfény nélküli óráiban a vertikális komponens növekedéséve párhuzamosan növekszik a fogás. Holdfényes órákban nem egyértelmű a földmágneses térerő befolyása.

Keywords – Lepidoptera, Noctuidae, *Agrotis segetum*, Turnip Moth, Geomagnetic field, lunar month, Hungary

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Introduction and literature background

It has been known for decades that different species of insects perceive geomagnetism, besides they use it for spatial orientation. A number of laboratory experiment and comprehensive reports deal with the physiological fundamentals and means of orientation of insects. These were summarised particularly in one of our studies (Tóth and Nowinszky1994), so here are referred only to the most important studies. Iso-Iivari and Koponen (1976) studied the effect of geomagnetism on light-trap catches of insects in the northernmost part of Finland. In their experiments they used the K-index values measured three-hourly, and the ΣK and δH values. A poor, but significant correlation was found between the geomagnetic parameters and the number of insects caught. Studying the few spotted ermel (*Hyponomeuta rorellus* Hbn.) Pristavko and Karasov (1970) found correlation between the C and SK values and the number of collected individuals. In a later study (Pristavko and Karasov 1981) they

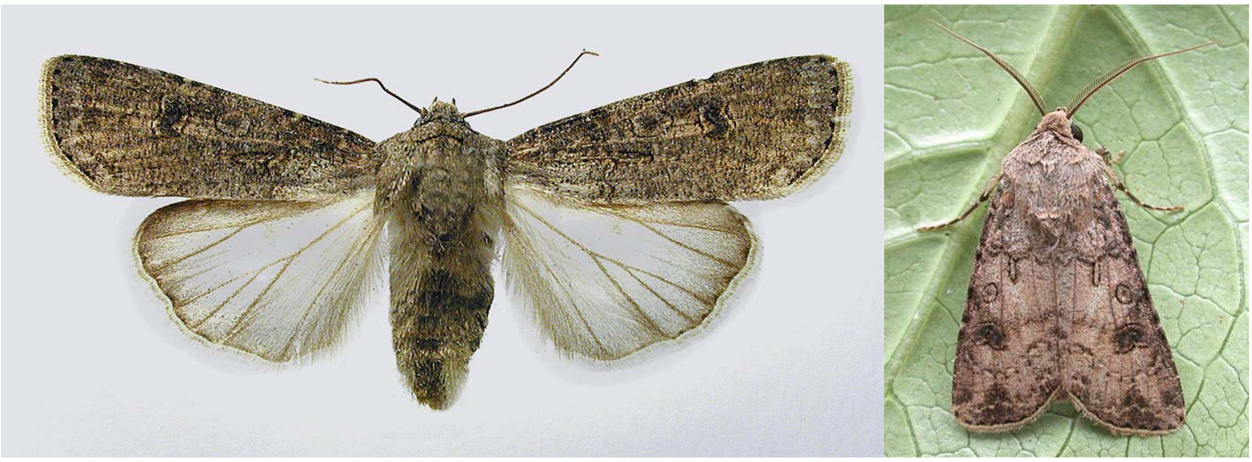

Fig. 1. *Agrotis segetum,* adult

found that ΣK had a greater influence on the flying activity of the above species at the time of geomagnetic storms. The influence is significant even in the years in which ΣK is not higher than 16-26. According to another interesting observation, if ΣK is 26, an increase of the flying activity follows the same day. With ΣK = 27-30, it happens the next day, and with ΣK = 33-41, only on the second or third day.

Studying termites (*Heterotermes indicola* Wasmann) Becker and Gerisch (1977) found a stronger correlation between the activity and the vertical component of geomagnetism (Z) than with K indices.

Tshernyshev and his colleagues have given a series of accounts of the results of their laboratory and light-trap experimentation's with different species of insects in order to reveal connection between geomagnetism and certain phenomena of life. During geomagnetic storms in Turkmen, Tshernyshev (1966) observed a multiplied increase in the counts of light-trapped beetles and plant bugs. He found a high positive correlation between the horizontal component and the volume of the trapped insects. It was impossible to show any influence of the alternating magnetic field on the activity of flies at low temperatures (22 degrees Celsius) in laboratory circumstances (Tshernyshev and Danilevsky 1966), but a significant raise was observed at 29 degrees. Tshernyshev (1968) studied the changes of biological rhythm of *Trogoderma glabrum* Herbst as a function of the perturbations of magnetic field. Assessment was based upon the K-index values over 4 (i.e. over 40 γ) measured at 6 p.m. and 9 p.m., as well as at 3 a.m. He proved that the biological rhythm of the species under study is influenced by factors corresponding to the perturbations of magnetic field. It is also his observation (1965) that the amount of light-trapped insects rises considerably during magnetic perturbations. Later, however, Tshernyshev (1971 and 1972) says that, while the light-trap catches of some *Coleoptera* and *Lepidoptera* species increase during magnetic field perturbations that of other *Lepidoptera* and *Diptera* species is reduced by the phenomenon. Again, Tshernyshev and Afonina (1971) observed the same: the activity of certain species of moths and beetles was increased by a weak and changing magnetic field in the laboratory, but in some cases the activity was reduced. A summary of contemporary knowledge of the relation between geomagnetism and the activity of insects based on international literature and his studies was given by Tshernyshev in a comprehensive study in 1989.

The examinations of the last decade have also proved some Lepidoptera species, such as *Noctua pronuba* L. (Baker and Mather 1982) and *Agrotis exclamationis* L. (Baker, 1987) use both the Moon and the geomagnetism for their orientation and, on top of all that, they are able to integrate these two kinds of information. During cloudy nights, the imagines of *Noctua pronuba* L. orientated with the help of geomagnetism. In this case, too, they preferred the direction they had chosen when orienting by the Moon and the stars. In our earlier works (Kiss et al. 1981; Nowinszky and Tóth 1983; Tóth and Nowinszky 1994), on the basis of data obtained by light-trap catches, it was found that both the Moon and the geomagnetism play part in the orientation of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) and the fall webworm moth (*Hyphantria cunea* Drury). Namely, the light-trap catches of the above mentioned species are dissimilarly affected by the increase or decrease of geomagnetic field strength in different moon phases.

Material

The average field strength of the Earth as a magnetic dipole is 33 000 gamma. 1 gamma = 10^{-5} Gauss = 10^{-9} Tesla = 1 nanotesla (nT). Geophysical literature uses gamma as a unit. Geomagnetic field strength can be decomposed into three components: H = horizontal, Z = vertical and D = declination components. The magnetic and the geographic poles of the Earth do not coincide, therefore besides the geographic co-ordinates; the geomagnetic latitudes are to be distinguished, too. These latter are characteristic of the geomagnetic conditions of a given geographic location. The geographic parameters are extraordinarily different in various regions of the Earth's surface at a given moment of time. Approximately, a distance of 300 kms along the geomagnetic meridian may result in significantly differing characteristics. Regarding Hungary, the geomagnetic data measured at one single observatory supply sufficient information for the whole country. These measurements are made at Nagycenk, near Sopron, in the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences, and at Tihany, in the Observatory of the Hungarian Loránd Eötvös Geophysical Institute.

For our research, the values of the vertical component (V) of geomagnetic field strength were taken from the yearbooks of the latter institute, in which varying values of 41 800 nT-t or those surpassing a higher basic level are published yearly.

There were used the data of Turnip Moth (*Agrotis segetum* Den. et Schiff.) from a fractioning light-trap from a three-year period. This special light-trap system was established and operated by József Járfás in Kecskemét-Katonatelep, between 1967 and 1969.

The fractioning light-trap had as its light source three F-33 type fluorescent tubes; one installed above the other, 120 cm long each, with colour temperature of 4300 ºK. The trapping time was between 6 p.m. and 4 a.m. (UT) daily. The storing bottles were changed every hour by a changing device. József Járfás identified the collected insects separately, according to hours, levels and species. There was neither difference between moths coming from first and second generation nor ones caught on different levels. Although each swarming was examined separately, the results were got after the joint evaluation.

Methods

We could work with values above 41 800 nT when the light-trap catch data were worked up, because there was no significant difference between the values of vertical component of geomagnetic field intensity in years 1967–1969.

Relative catch (RC) values were calculated from the number of caught samples of Turnip Moth (*Agrotis segetum* Den. et Schiff.) for each generation. It was established in our former works (Kiss et al. 1981; Tóth and Nowinszky 1994) it is not expedient to examine the influence of geomagnetism for trapping independently of light conditions. That is why the relative catch data were separated to cases with moonlight and without it according to Moon phase-angle around the four quarters of the moon.

The Moon phase-angle values were calculated for the 12 p. m. (UT) during all the nights in the swarming time of each species. There were made 30 phase-angle groups from the 360 phase-angle values of whole lunation. The notation of group with phase-angle values surrounding of Full Moon (0° or 360°) ± 6° is 0. The notation of groups from 0 through the First Quarter to New Moon is -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The notation of groups from Full Moon through the Last Quarter to New Moon is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The notation of phase group with New Moon is ±15. The following phase-angle groups are in the characteristic quarter of moon: Full Moon (-2 – +2), Last Quarter (3 – 9), New Moon (10 – -10) and First Quarter (-9 – -3).

There was made a comparison between the hourly light-trap catch results of Turnip Moth (*Agrotis segetum* Den. et Schiff.) and the hourly values of vertical component. There were made groups for the connected value pairs. The geomagnetic and relative catch values were averaged in each group, and weighted moving average was calculated using our own method (Nowinszky 1994) and relative catch values. After it correlation calculations were made to show the supposed connections.

Results and Discussion

The weighted moving average belonging to the vertical component values of Turnip Moth (*Agrotis segetum* Den. et Schiff.) is shown in Table 1.

Our results are almost the same as the results of our above-mentioned former work (Tóth and Nowinszky, 1994), in which the influence of horizontal component of geomagnetic field intensity was examined for some species and also the Turnip Moth (*Agrotis segetum* Den. et Schiff.).

At New Moon, when there is no measurable moonlight, decreasing relative catch can be found with higher values of vertical component. At the time of other moon phases, in surrounding of First Quarter, Full Moon and Last Quarter when there is no moonlight, the relative catch increases linearly with the increasing values of horizontal component. In those hours, when there is moonlight, the difference is that the catch decreases on the higher values of vertical component. This decrease could not be recognised in the examination of horizontal component. It seems in the period of lunation when during a part of night the presence of Moon can give orientation information for moths; the insects' orientation can be helped firstly by light stimulus although the Moon is not above the horizon. The geomagnetic field intensity can increase the insects' flight activity, but the light stimulus is most important factor in orientation, so trapping is more successful. Surrounding of New Moon when insects cannot get any information from the Moon for their orientation during the whole night, it can be supposed the increasing geomagnetic field intensity gets bigger part in the orientation in contradiction to light stimulus, which increases the safety of orientation. Recently, a similar correlation was detected the horizontal component of the geomagnetic field and the light-trap catch of the Turnip Moth (Nowinszky and Puskás, 2011).

Table 1.Relative catch of turnip moth (*Agrotis segetum* Schiff.) on hourly values of above 41 800 nT vertical component (Z) of geomagnetic field intensity

Hours without moonlight new moon			Hours without moonlight full moon, first- and last quarter			Hours with moonlight independently from moon phases		
Z	RC	N	Z	RC	N	Z	RC	N
91.5	2.195	22	87.3	0.462	87	88.8	0.873	67
94.3	1.857	21	93.5	0.600	84	95.4	1.012	69
96.5	1.124	27	95.8	0.654	113	97.0	1.104	57
98.8	0.702	31	97.5	0.805	164	98.0	1.256	63
100.7	0.626	35	99.4	0.839	150	99.0	1.145	83
102.0	0.567	16	101.0	0.902	121	100.0	1.134	41
103.0	0.714	27	102.7	0.894	103	101.0	0.999	62
104.0	0.756	25	102.7	0.894	103	101.0	1.061	75
109.9	0.836	31	108.2	1.073	81	106.2	0.821	62
			124.8	1.449	62	110.5	0.642	53
$y = -8.2303\ln(x) + 38.939$ $R^2 = 0.6045$ $P < 0.05$			$y = 0.0268x - 1.8589$ $R^2 = 0.9782$ $P < 0.001$			$y = -0.0031x^2 + 0.5981x - 28.082$ $R^2 = 0.8535$ $P < 0.01$		

Note: N = number of observing data

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Acta entomologica serbica, 2016, 21: 39-47

UDC 595.783:550.83(497.11)
DOI: 10.5281/zenodo.159421

CHANGES IN THE NUMBER OF MACROLEPIDOPTERA INDIVIDUALS AND SPECIES CAUGHT BY LIGHT-TRAP, IN CONNECTION WITH THE GEOMAGNETIC Kp AND M-INDEX

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Abstract

The authors studied the number of Macrolepidoptera individuals and species caught by light-trap, in relationship with the geomagnetic Kp and M-index.

A correlation was found between the averaged geomagnetic M-index values measured at night, and the number of individuals and species caught by light-trap in the Kámon Botanic Garden (Hungary).

KEY WORDS: Light-trap, moths, geomagnetic Kp and M-index

Introduction

It has been known for decades that the insects detect the geomagnetic field, and even can use it as a three-dimensional orientation. A number of laboratory experiments and comprehensive studies are devoted to the physiological bases of perception and the ways of orientation (Wehner & Lobhart, 1970; Kirschvink, 1983; Wehner, 1984 & 1992; Jahn, 1986).

The magnetic field of the earth is an omnipresent, reliable source of orientational information. A magnetic compass has been demonstrated in 18 species of migrating birds (Wiltschko & Wiltschko, 1996).

It is known that the geomagnetic field can influence animal migration and homing. The magnetic field detection by animals is known as magnetoreception and it is possible due to behaviour is the magnetic alignment where animals align their bodies to the geomagnetic field (Belova & Acosta-Avalos, 2015).

Magnetoreception in the animal kingdom has focused primarily on behavioural responses to the static geomagnetic field and the slow changes in its magnitude and direction as animals navigate/migrate (Prato et al., 2016).

Becker (1964) has found that certain species of termites (Isotermes), beetles (Coleoptera) flies (Diptera), orthopteroids (Orthoptera), and hymenopterans (Hymenoptera), found that they orient according the natural magnetic field. Way of their mobility is North-South, rarely East-West. Their original way of movement could be modified by artificial magnetic field.

Mletzko (1969) carried out his experiments with specimens of ground beetles *(Broscus cephalotes* L., *Carabus nemoralis* Mull. and *Pterostichus vulgaris* L.) on a 100 square meter asphalt coated area in the Moscow botanical garden.

Iso-Ivari & Koponen (1976) studied the impact of geomagnetism on light trapping in the northernmost part of Finland. In their experiments they used the K index values measured in every three hours, as well as the ΣK and the δH values.
Examinations over the last decades have also confirmed that some Lepidoptera species, such as the Large Yellow Underwing *(Noctua pronuba* L.) (Baker & Mather, 1982) and the Heart & Dart (*Agrotis exclamationis* L) (Baker, 1987) are guided by both the Moon and geomagnetism in their orientation, and they are even capable of integrating these two sources of information.

Using hourly data from the material of the Kecskemét fractionating light-trap, we have examined the light trapping of the Turnip Moth *(Agrotis segetum* Den. et Schiff.), the Heart & Dart *(Agrotis exclamationis* L.) and the Fall Webworm Moth *(Hypantria cunea* Drury) in relationship with the horizontal component of the geomagnetic field strength (Kiss *et al*., 1981).

According to the authors of recent publications (Srygley & Oliveira, 2001; Gillet & Gardner, 2009; Samia *et al.,* 2010) the orientation/navigation of moths at night may becomes not by the Moon or other celestial light sources, but many other phenomena such as geomagnetism.

Material

The Forest Research Institute operated a JERMY-type light-trap in Kámon Botanic Garden (Szombathely, Hungary) between 1962 and 1970. The geographical coordinates of this Botanic Garden are 47°25'66"N and 16°60'36"E.

All Macrolepidoptera species and individuals were identified from the catch of this period. This Jermy-type light-trap operated continuously in all the years, except on snowy winter days and a few malfunctioning nights.

There were caught altogether the specimen of 549 different Macrolepidoptera species by light-trap during 9 years.

The number of caught species, individuals and yearly swarming are shown in Table. We worked up only the catch data of early and late summer aspects, because only some individuals of some species were caught by the light-trap in spring and autumn aspects.

Table I. Light-trap collecting data of early and late summer aspects in Kámon Botanic Garden of Szombathely, Hungary as well as the number of caught species and swarming.

Years	Early and late summer aspects (1st May to 31st October)	
	Number of species	Number of individuals
1962	291	3359
1963	300	5446
1964	303	2562
1965	146	919
1966	113	599
1967	229	4096
1968	226	2364
1969	268	3670
1970	268	4268

We applied only the collecting data of early and late summer aspects 1st May to 31st October because in both the spring and autumn aspects few species and specimens were caught by light-trap.

The average field strength of the Earth as a magnetic dipole is 33.000 γ (1 γ = 10^{-5} Gauss = 10^{-9} Tesla [nanoTesla]). The geomagnetic field strength can be decomposed into three components: H -horizontal, Z - vertical and D - declination components. With regard to the entomologic trials the extent of total field strength, on the one hand, and the value of horizontal component, on the other, are important because, insects fly rather horizontally than vertically.

It is well known that the magnetic poles and the geographic one of the Earth do not coincide, therefore besides the geographic coordinates, the geomagnetic latitudes and longitudes are to be distinguished; and these coordinates are characteristic for the geomagnetic reasons of a given geographic coordinate. The geomagnetic parameters are significantly different on various regions of Earth's surface at a given time. As an average of 300 km distance may result in significantly different characteristics along the geomagnetic meridian (Nowinszky and Tóth, 1987).

The K-index scale summarises geomagnetic activity at an observatory by assigning a code, an integer in the range 0 to 9 (0 being the least active field and 9 the most active field). The K-index is quasi-logarithmic local index of the 3-hourly range in magnetic activity relative to an assumed quiet-day curve for a single geomagnetic observatory site. First introduced by Bartels (1935), it consists of a single-digit 0 thru 9 for each 3-hour interval of the universal time day (UT). The planetary 3-hour-range index Kp is the mean standardized K-index from 13 geomagnetic observatories between 44 degrees and 60 degrees northern or southern geomagnetic latitude. The scale is O to 9 expressed in thirds of a unit, e.g. 5- is 4 2/3, 5 is 5 and 5+ is 5 1/3. This planetary index is designed to measure solar particle radiation by its magnetic effects.

We collected the Kp index data from the data.noaa.gov website.

The geomagnetic data measured along the magnetic meridian (direction: North-West to South-East) in function of time. These measurements are made at Nagycenk, near Sopron in the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences. The geographical coordinates of Observatory are 47° 38' N; 16° 43' E. Its distance from the Kámon Botanic Garden (Szombathely) is 43 km.

The observatory is situated about 10 km to E from the city Sopron and 60 km SE from Vienna, on the southern shore of Lake Fertő. The observatory lies on thick conductive sediment and it is surrounded by the Fertő-Hanság National Park.

Values of local horizontal component, M-index for our research have been taken from a series of observations carried out at Nagycenk (Western Hungary) description of which can be found in: Observatoriumsberichte des Geophysikalischen Forschungslaboratoriums der UAdW in Sopron, 1962-1966; Geophysical Observatory Reports of the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences in Sopron, 1967-1976. Data on the field strength changes of the horizontal geomagnetic component are given for each 3-hour-period in a scale from 0 to 9, where the scale unit is 7 γ = 7 nT. The scale is linear.

The value of C9-index does not have dependence of the local time, but it can globally characterize the geomagnetic activity. The magnetic index (M), measured in three hours, has a local character. This index is determined and published by the Geophysical Observatory of Hungarian Academy of Science (HAS), named István Széchenyi. The magnetic index has strong dependence to the local time and it is typical of medium width. The magnetic disturbances can be found only in less number, which are typical at the equatorial and polar zone. According to Prof. József Verő (member of HAS) in the case of a local phenomenon, such as the investigated moths' flight, the M-index is much more usable than any other global indices, because it expresses the local conditions (J. Verő, personal communication).

The M-index was determined between 1962 and 1991, and was published in Observatory's Reports. The M-index can be 0-9 integer value. It is a linear scale with 7 nT (nanoTesla) steps and it reaches the 9 degree level at >63 nT (J. Szendrői, personal communication).

Methods

We summarized and averaged the four published M-index values for every night. The number of caught species and individuals was also averaged.

According to the method of Sturges (Odor & Iglói,1987) we arranged the data of M-index, species and individuals into classes. All data were averaged, and then Kp and M-index, each species and individuals were plotted.

The results obtained are plotted. We determined the regression equations, the significance levels which were shown in the figures. The relationship with second degree parabola was best characterized.

We calculated the determination coefficients of parabolic curves and their significance levels by way of Manczel (1983).

Results and Discussion

Our results are shown in Figures 1-4.

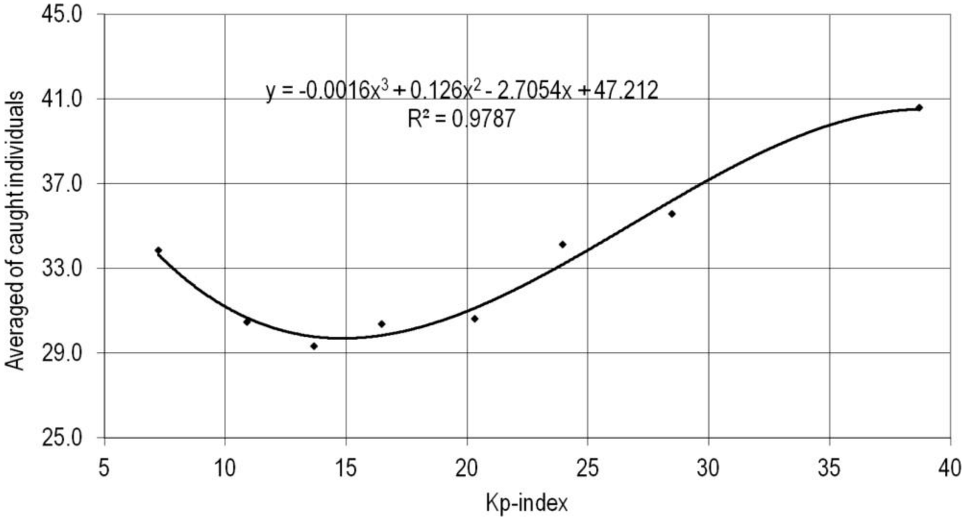

Figure 1. Averaged number of light trapped Macrolepidoptera individuals in connection with geomagnetic Kp-index in summer aspects (Kámon Botanic Garden, 1962-1970).

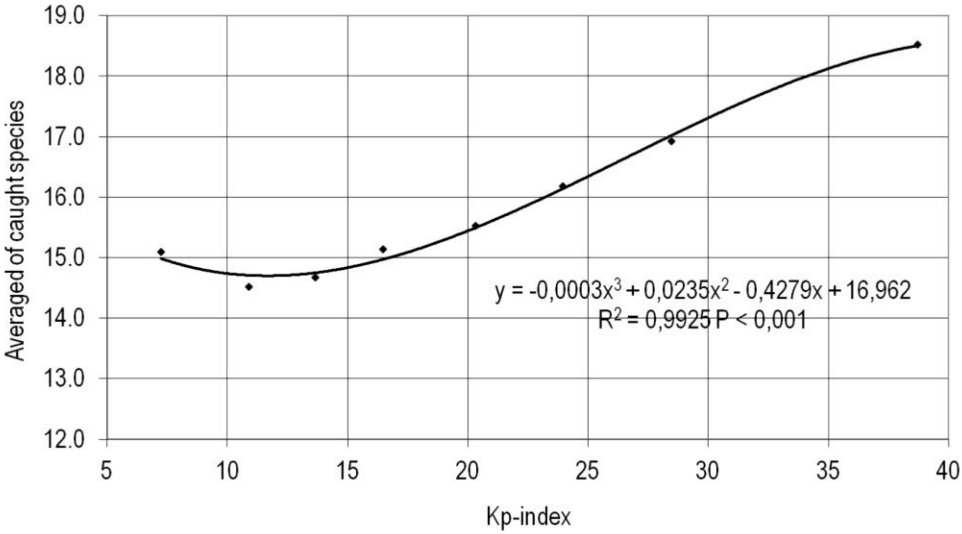

Figure 2. Averaged number of light trapped Macrolepidoptera species in connection with geomagnetic Kp-index in summer aspects (Kámon Botanic Garden, 1962-1970).

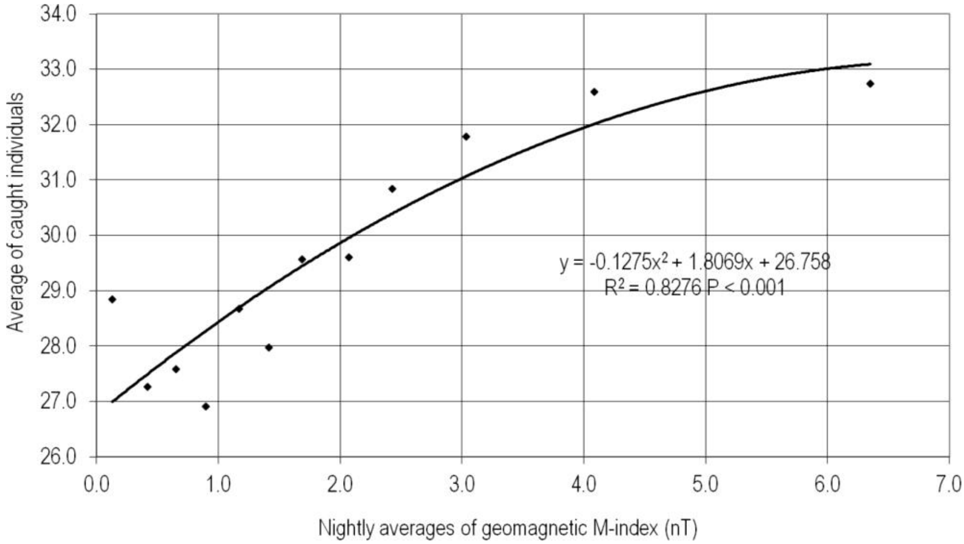

Figure 3. Averaged number of light trapped Macrolepidoptera individuals in connection with geomagnetic M-index (Kámon Botanic Garden, 1962-1970).

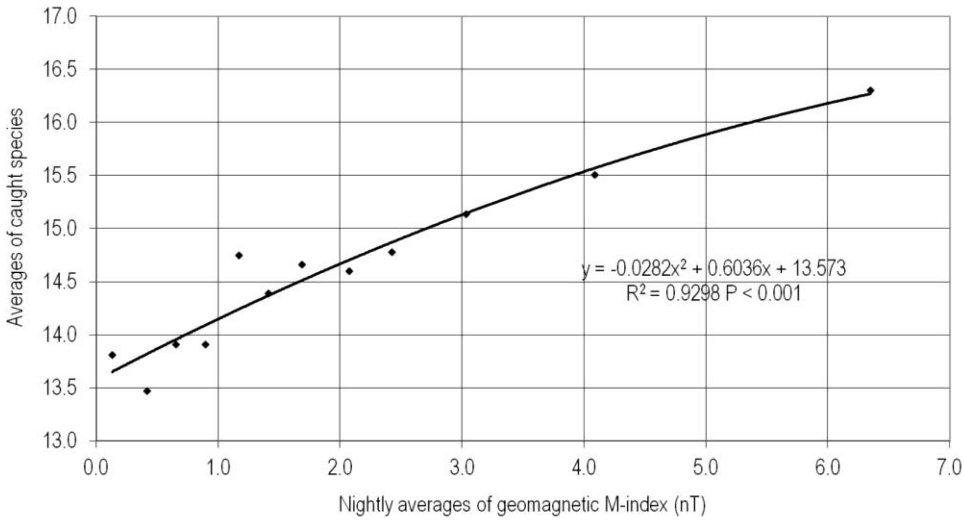

Figure 4. Averaged number of light trapped Macrolepidoptera species in connection with geomagnetic M-index in summer aspects (Kámon Botanic Garden, 1962-1970).

Only a few researchers reported the results of their researches about the relationship between light-trap catch and geomagnetism in the earlier decades and the recent past.

Mletzko (1969) found the insects flew several meters uncertainly, and after these they oriented towards a given direction, with an accuracy of + 5 grades at daylight and + 60 grades at night respectively. The author's hypothesis is that, the orientation follows the terrestrial magnetic field. The orientation shows the same trend the whole day and it does not change at night, when there is no sunlight.

Pristavko & Karasov (1970) studying of Willow Ermine Moth, Y*ponomeuta rorellus* Hbn. (Lepidoptera: Yponomeutidae) were found a correlation between C and ΣK values respectively, and the number of trapped insects.

Tshernyshev (1972) observed that light-trap catches of some beetle (Coleoptera) and moth (Lepidoptera) species increase with the geomagnetic perturbation. On the contrary, activity of other moth (Lepidoptera) and several flies (Diptera) species is reduced by this phenomenon. He found high correlation between the öH and ΣK values and the number of trapped insects.
Iso-Ivari & Koponen (1976) found a weak but significant correlation between the geomagnetic parameters and the number of specimens of the various orders of insects caught. Significant correlation was found only for Lepidoptera and Hymenoptera Parasitica (negative) and for Simuliidae (positive).

In the recent past we managed to prove that the vertical component of the geomagnetic field strength influenced differently the light-trap catch of Turnip Moth (*Agrotis segetum* Denis et Schiffenmüller) in the four quarters of the Moon when there were periods with moonlight and without it.

The study of Nowinszky *et al.* (2015) deals with the change of light-trap catch of twelve caddisfly (Trichoptera) species of Danube and Tisza rivers in connection with the geomagnetic horizontal component (H-index). The catch of nine species increased in parallel with increasing values of the H-index, but the catch of two species declined. There was one species which has decreasing catch at River Danube, but it was increasing at River Tisza.
Our new results demonstrate that low values of geomagnetic Kp and M-index depress both the number of species and individuals in the summer aspects. In contrast, higher values can rise in number of caught species and individuals.
Growth of the geomagnetic field strength may generate an intensification of the flying activity consequently the light-trap catch of insects. Growth of the geomagnetic field strength may generate an intensification of the flying activity of insects.
Our results confirm the statement of previous researches; the insects are able to use geomagnetism for their spatial orientation.

It is assumed that this fact can be widespread at nocturnal active moths, because our results came from the catch data of more than 500 Macrolepidoptera species.

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ПРОМЕНЕ БРОЈА ЈЕДИНКИ И ВРСТА MACROLEPIDOPTERA УХВАЋЕНИХ СВЕТЛОСНИМ КЛОПКАМА У ВЕЗИ СА ГЕОМАГНЕТНИМ М-ИНДЕКСОМ

ЛАСЛО НОВИНСКИ и ЈАНОШ ПУШКАШ

Извод

Деценијама је познато да инсекти детектују геомагнетно поље и да га користе у оријентацији. Урађен је велики број лабораторијских експеримената и свеобухватних студија посвећених физиолошкој перцепцији и парвцима оријентације (Wehner & Lobhart, 1970; Kirschvink, 1983; Wehner, 1984, 1992; Jahn, 1986). Srygley & Oliveira (2001), Gillet & Gardner (2009) и Samia *et al*. (2010) утврдили су да на оријентацију мољаца ноћу не утичу само Месец или свтлост других небеских тела већ и многе друге појаве као што је геомагнетизам.

Подаци објављени у овом раду добијени су коришћењем светлосних клопки - JERMY-type у Камон Ботаничкој башти (Kámon Botanic Garden, Szombathely, Hungary 47°25'66"N 16°60'36"E) у периоду од 1962. до 1970. године.

Сабиране су четири просечне вредности М-индекса за сваку ноћ. Приказане су и просечне вредности броја ухваћених примерака сваке ноћи. Добијени резултати су приказани на гарфиконима.

Резултати наших истраживања показују ниске вредности геомагнетног М-индекса и по броју врста и примерака у току лета. Насупрот томе, веће вредности могу расти са бројем ухваћених врста и јединки. Пораст јачине геомагнетног поља утиче на интензивирање активности летења као и последица коришћења светлосних клопки. Наши резултати потврђују тврдње ранијих истраживања да инсекти користе геомагнетизам за оријентацију у простору. Сматрамо да је ова чињеница широко распрострањена код ноћних активности мољаца што поткрепљују наши резултати урађени на више од 500 врста Macrolepidoptera.

Received October 29th, 2016
Accepted March 4th, 2016

Research Article

iMedPub Journals
http://www.imedpub.com

Global Journal of Research and Review
ISSN 2393-8854

2016
Vol. 3 No. 1: 4

DOI: 10.21767/2393-8854.10004

Light-Trap Catch of Heart and Dart (*Agrotis exclamationis Linnaeus*) in Connection with the Hourly Values of Geomagnetic H-Index

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Abstract

We deal in this paper with light trapping results of the Heart and Dart (*Agrotis exclamationis* Linnaeus, 1758 Lepidoptera: Noctuidae), depending on the horizontal component of the geomagnetic field (H-index). We calculated relative catch vales from the hourly collecting individuals of examined species by generation. These hourly relative catch values were classified to the hourly values of H-index. These hourly catch results were correlated to the hourly values of H-index. We calculated correlations to demonstrate the supposed relationship between the two data.

Our results suggest that more effective light trap catch belongs to higher H-index values.

Keywords: Light-trap; Geomagnetic; Horizontal component; Heart and Dart

Received: December 09, 2016; **Accepted:** December 27, 2016; **Published:** December 30, 2016

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Citation: Nowinszky L, Puskás J. Light-Trap Catch of Heart and Dart (*Agrotis exclamationis Linnaeus*) in Connection with the Hourly Values of Geomagnetic H-Index. Glob J Res Rev. 2016, 3:1.

Introduction and Literature Background

It is well known for a long time that different species of insects are sensitive to geomagnetism and they use it in the spatial orientation.

Tshernyshev [1,2] suggest, the caught of some light trapped Coleoptera and Lepidoptera species increase during magnetic field perturbations that of other Lepidoptera and Diptera species to fall off by the phenomenon.

Pristavko and Karasov found correlation between the C and ΣK values and the number of collected individuals of the Spotted Ermel (*Hyponomeuta rorellus* Hbn) [3].

In a later paper Pristavko and Karasov suggest that ΣK had a greater impact on the flying activity of the same species at the time of geomagnetic storms [4].

Iso-Iivari and Koponen examined the influence of geomagnetism on light trapped insects in the far north of Finland [5]. They used the K-index values measured in every three hour, and the ΣK and δH values. They found a weak, but significant relationship between the geomagnetic parameters and the amount of trapped insects.

Becker and Gerisch examined the activity of a termite species (*Heterotermes indicola* Wasmann) found a stronger relationship between the vertical component of geomagnetism (Z) than with K-index [6].

Our recent results ascertained that in surroundings of New Moon when there is no visible moonlight, the higher values of the vertical component decreased the light-trap catch [7]. In the First Quarter, Full Moon and the Last Quarter, increasing values of the vertical component increased the catch in both the moonlit and moonless hours.

The examinations of Baker and Mather and Baker certified that the Large Yellow Underwing (*Noctua pronuba* L.) and Heart and Dart (*Agrotis exclamationis* L.) use both the Moon and the geomagnetism for their orientation [8]. If the nights are cloudy, the Large Yellow Underwing (*Noctua pronuba* L.) moths orientated with the help of geomagnetism. Kiss et al. and Nowinszky and Tóth was found that both the Moon and the geomagnetism are suitable for the orientation of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) and the Fall Webworm (*Hyphantria cunea* Drury) [9-14].

Srygley and Oliveira and Samia et al. found, that the navigation of moths at night cannot be helped by the Moon, but by geomagnetism [12,13].

Material

We downloaded the earth's magnetic x and y data of Tihany Geophysical Observatory, Hungary (46º54’57”N and 17º53’42”E) from the World Data Centre for geomagnetism, Kyoto's website (http://wdc.kugi.kyoto-u.ac.jp/hyplt/). We calculated on the horizontal component values of H-index over 2,150 nanoTesla of the formula, according to the instruction of Mr. László Szabados's Tihany Geophysical Observatory):

$$H = \sqrt{x2 + y2}$$

We used the light-trap catching data of Heart and Dart (*Agrotis exclamationis* Linnaeus, 1758.) from the fractioning light-trap operated by Prof. Járfás in Kecskemét-Katonatelep (46º50’17”N and 19º41’57”E) in years between 1967 and 1969. This light-trap collected the insects every night and hour different container between 6 p.m. and 4 a.m. (UT). There were caught in 764 nights (observing data) and 2,436 specimens.

The fractioning light-trap had as its light source three F-33 type fluorescent tubes; one installed above the other, 120 cm long each, with colour temperature of 4300 ºK. This light-trap was in operation during every day between 6 p.m. and 4 a.m. (UT). The storing bottles were changed every hour by a changing device. We not separated the moths neither they coming from first and second generation nor ones caught on different trapping levels.

Methods

The number of specimen of a given species in variant years and catching locale is not the same. Therefore we computed relative catch (RC) values. This is for a given sampling time unit (one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals [15]. The relative catch values were put on the H-index values of the given day and hour, and we summed up and averaged they. We arranged the catching geomagnetic H-index data pairs

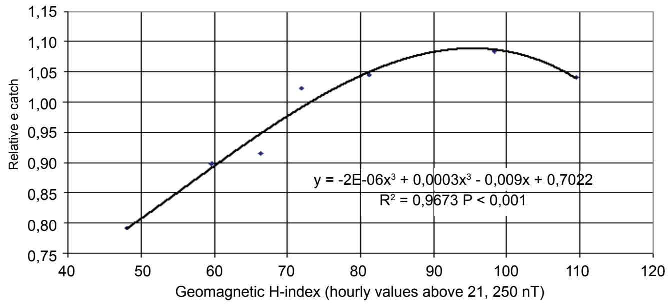

Figure 1 Light-trap catch of the Light-trap catch of Heart and Dart (Agrotis exclamationis Linnaeus) in connection with the hourly values of geomagnetic H-index.

of in classes, and then averaged them. Regression equation was calculated H-index values and relative catch values of examined species data pairs. We determined the significance level which was shown in the **Figure 1**.

Results and Discussion

Very few studies deal with the connection between the results of light trapping geomagnetic components, as the Kp, Cp, C, Ap and H-indices.

We examined therefore the connection of hourly light-trap catch of Heart and Dart (*Agrotis exclamationis* L.), spread in the whole Palearctic region, in nexus with the horizontal component of geomagnetic field (H-index).

According to all indications the light trap catch of Heart and Dart rises to the rising values of the H-index. We suggest that the higher geomagnetic intensity provides more trouble-free spatial orientation and therefore increases the catch.

Accordingly the higher geomagnetic horizontal component (H-index) and the increasing catch values probably can be expounded the fact, that in such cases the spatial orientation of the insects the geomagnetic field comes in great importance.

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Journal of Biology and Nature
4(4): 206-216, 2015
ISSN: 2395-5376 (P), ISSN: 2395-5384 (O)

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LIGHT-TRAP CATCH OF THE FLUVIAL TRICHOPTERA SPECIES IN CONNECTION WITH THE GEOMAGNETIC H-INDEX

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AUTHORS' CONTRIBUTIONS
This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Received: 1st October 2015
Accepted: 4th November 2015
Published: 24th November 2015

Original Research Article

ABSTRACT

The study deals with the change of light-trap catch of twelve caddisfly (Trichoptera) species of Danube and Tisza rivers in connection with the geomagnetic horizontal component (H-index). The numbers of specimens caught of all species were calculated relative catch values. These daily relative catch data were assigned to the daily values of geomagnetic field above 21,250 nT (H-index). We correlated the daily catch results pertaining to the daily values of geometric H-index values.
The catch of nine species increased in parallel with increasing values of the H-index, but the catch of two species declined. There was one species which has decreasing catch at River Danube, but it was increasing at River Tisza.

Keywords: Trichoptera; light-trap; geomagnetic horizontal component.

1. INTRODUCTION

Studying some species of termites (Isoptera), beetles (Coleoptera), flies (Diptera), orthopteroids (Orthoptera), and hymenopterans (Hymenoptera), Becker [1] found that they orient according the natural magnetic field. Way of their mobility is North-South, rarely East-West. Their original way of movement could be modified by artificial magnetic field.

Iso-Ivari and Koponen [2] studied the impact of geomagnetism on light trapping in the northernmost part of Finland. In their experiments they used the K index values measured in every three hours, as well as the ΣK and the δH values. A weak but significant correlation was found between the geomagnetic parameters and the number of specimens of the various orders of insects caught. Studying the few Willow Ermine (*Yponomeuta rorella* Hbn.), Pristavko and Karasov [3] revealed a correlation between the C and ΣK values and the number of individuals caught. In a later study [4] they also established that at the time of magnetic storms ΣK has a greater influence on the flying activity of the above species. The influence is also significant in years when ΣK is not higher than 16-26. Equally interesting is the observation that if ΣK < 26, flying activity intensifies the same day, if ΣK = 27-30, this happens the following day and if ΣK = 33-41, intensification follows only on the second or third day. Studying the termite species *Heterotermes indicola* Wasmann, Becker and Gerisch [5] found a stronger correlation between this activity and the

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vertical component of geomagnetism (z) than with the values of the K index. Tshernyshev and his colleagues have discussed in a series of studies the results of their laboratory and light trapping experiments with species of different orders of insects to reveal a connection between geomagnetism and certain life phenomena. Tshernyshev [6] found that the number of light-trapped beetles and bugs rose many times over at the time of geomagnetic storms in Turkmen. He found a high positive correlation between the horizontal component and the number of trapped insects. It was also observed by him [7] that the number of light-trapped insects significantly raised at the time of magnetic perturbations. Later, however, he reported that while light-trap catches of some Coleoptera and Lepidoptera species increased, that of other Lepidoptera and Diptera species fell back during magnetic perturbations [8,9]. Based on international literature and his own results, published a comprehensive study to give a summary of the latest state of knowledge on the relation between geomagnetism and the activity of insects [10].

Examinations over the last decades have also confirmed that some Lepidoptera species, such as Large Yellow Underwing (*Noctua pronuba* L.) [11] and Heart & Dart (*Agrotis exclamationis* L.) [12] are guided by both the Moon and geomagnetism in their orientation, and they are even capable of integrating these two sources of information. On cloudy nights, the imagos of *Noctua pronuba* L. orientated with the help of geomagnetism. In this case, too, their preference lay with the direction they had chosen when getting their orientation by the Moon and the stars. Using hourly data from the material of the Kecskemét fractionating light-trap, we have examined the light trapping of Turnip Moth (*Agrotis segetum* Den. et Schiff.), Heart & Dart (*Agrotis exclamationis* L.) and Fall Webworm Moth (*Hyphantria cunea* Drury) in relationship with the horizontal component of the geomagnetic field strength [13].

According to the authors of recent publications [14] and [15] the orientation/navigation of moths at night may becomes not by the Moon or other celestial light sources, but many other phenomena such as geomagnetism.

The results of our calculations have shown that in the period of the New Moon when there is no measurable moonlight, the higher values of the horizontal component are accompanied by a falling relative catch. In the other moon phases, i.e. in the First Quarter, Full Moon and the Last Quarter, growing values of the horizontal component are accompanied by an increasing catch in both the moonlit and moonless hours [16,17].

However, we did not find any studies, to investigate the relationship between the Earth's magnetism and light-trap catch of caddisflies.

2. MATERIALS AND METHODS

The average field strength of the Earth as a magnetic dipole is 33,000γ. (1γ = 10^{-5} Gauss = 10^{-9} Tesla = 1 nanotesla (nT)). Geophysical literature uses γ as a unit. Geomagnetic field strength can be divided into three components: H = horizontal, Z = vertical and D = declination components. With regard to the entomologic trials the extent of total field strength, on the one hand, and the value of horizontal component, on the other, are important because, insects fly rather horizontally than vertically.

The magnetic and geographic poles of the Earth do not coincide, therefore in addition of geographic; there are also geomagnetic coordinates of latitude and longitude. The latter characterize the geomagnetic conditions of a given geographical location. Geomagnetic parameters greatly differ in any given moment of time at the various points of the surface of the Earth. A distance of approximately 300 kilometres along the geomagnetic meridian may produce significantly different characteristics. These measurements are made at the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences at Nagycenk (Geographical latitude: 47°38′41″N, longitude: 16°43′81″E), near Sopron and the Observatory of the Hungarian Loránd Eötvös Geophysical Institute at Tihany (Geographical latitude: 46°90′57″N, longitude: 17°89′42″E).

The geomagnetic measuring data of a single observatory in the case of Hungary supply sufficient information for the whole country: i. e. the parameters measured along the magnetic meridian (direction: North-West to South-East) in function of time. The distance along the magnetic meridian never exceeds 300 km.

The geomagnetic data, measured in the whole Earth, were published by the Center for Data Analysis and Space Magnetism Graduate School of Science, Kyoto (http://wdc.kugi.kyoto-u.ac.jp/index.html). We downloaded the value of x and y index measured at Tihany by Hungarian Loránd Eötvös Geophysical Institute. We calculated the horizontal component (H index) values from these according to the advice of Mr. László Szabados using the following formula:

$$H = \sqrt{x2 + y2}$$

We withdrew 21,250 from the calculated values as we did it in our previous works. We used the H-index-21250 data in our calculation.

The selected caddisflies specimens used in our investigations are originated from previous light-trap collections.

There was the most important point of view at the selection of species and swarming the total number of male and female specimens exceeds 700. The collection sites, their geographical coordinates and the years of collection are as follow: River Danube: Göd (47°41′70″N; 19°08′23″E), (in year 1999) and Tisza River: Szolnok (47°10′76″N; 20°11′25″E), (in year 2000) [18]. Kiss and Zsuga [19] water quality tests have been performed.

Jermy-type light-traps were used in catch of caddisflies.

These light-traps consist of a 125 W mercury lamp and a saving lid with a diameter of 1 metre. There was a collecting funnel under the lamp. Its diameter was 40 cm and this collector drove into a container. We used clear chloroform as killing material. Our light-traps operated in all years and on all settlements between 1st April and 31st October on all nights.

We mean a generation's flying period by swarming.

Than the number of individuals of a given species in different places and different observation years is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago [20].

The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals. If the number of specimens taken from the average of the same, the relative value of catch: 1 [20].

From the collection data pertaining to examined species we calculated relative catch values (RC) by swarming of examined species. Following we arranged the data on the H-index in classes. Relative catch values were placed according to the features of the given day, and then RC were summed up and averaged. The data are plotted for each species and regression equations were calculated for relative catch of examined species and H-index data pairs. We determined the regression equations, the significance levels which were shown in the Figures.

3. RESULTS AND DISCUSSION

Our results are shown in the Table 1 and Figs. 1-12.

The light-trap catch of nine examined species increased in the higher values of the H-index. These

Table 1. The catching data (families, species, number of specimen and catching nights)

Families – species	River Danube (Göd, 1999)		River Tisza (Szolnok, 2000)	
	Number of		Number of	
	Specimen	Nights	Specimen	Nights
Hydroptilidae				
Agraylea sexmaculata Curtis, 1834			1,725	127
Ecnomidae				
Ecnomus tenellus Rambur, 1842			2,193	103
Polycentropodidae				
Neureclipsis bimaculata Linnaeus, 1758	4,619	167	1,593	95
Hydropsychidae				
Hydropsyche contubernalis Mc Lachlan, 1865	21,467	191	12,302	179
Hydropsyche bulgaromanorum Malicky, 1977	16,832	172	22,500	94
Brachycentridae				
Brachycentrus subnubilus Curtis, 1834	4,004	129		
Lepidostomatidae				
Lepidostoma hirtum Fabricius, 1775	2,434	107		
Limnephilidae				
Limnephilus affinis Curtis, 1834			723	104
Halesus digitatus Schrank, 1781			1,238	105
Leptoceridae				
Athripsodes albifrons Linnaeus, 1758			814	115
Ceraclea dissimilis Stephens, 1836			929	100
Setodes punctatus Fabricius, 1759	4,705	145	1,848	87

Notes: The taxonomic classification of the species was carried out according to Kiss ([21]
Most of the species, listed in the table, also were collected in Bükk Mountains by Kiss [22]

species are as follows: *Agraylea sexmaculata* Curtis *Ecnomus tenellus* Rambur, *Neureclipsis bimaculata* Linnaeus, *Hydropsyche contubernalis* Mc Lachlan, *Lepidostoma hirtum* Fabricius, *Limnephilus affinis* Curtis, *Athripsodes albifrons* Linnaeus, Ceraclea dissimilis Stephens and *Setodes punctatum* Fabricius.

The catch decreased of two species *Brachycentrus subnubilus* Curtis and *Halesus digitatus* Schrank when the value of H-index increased. Catching of the *Hydropsyche bulgaromanorum* Malicky declined at River Danube (area of village Göd, 1999), at River Tisza (area of city Szolnok, 2000) increased.

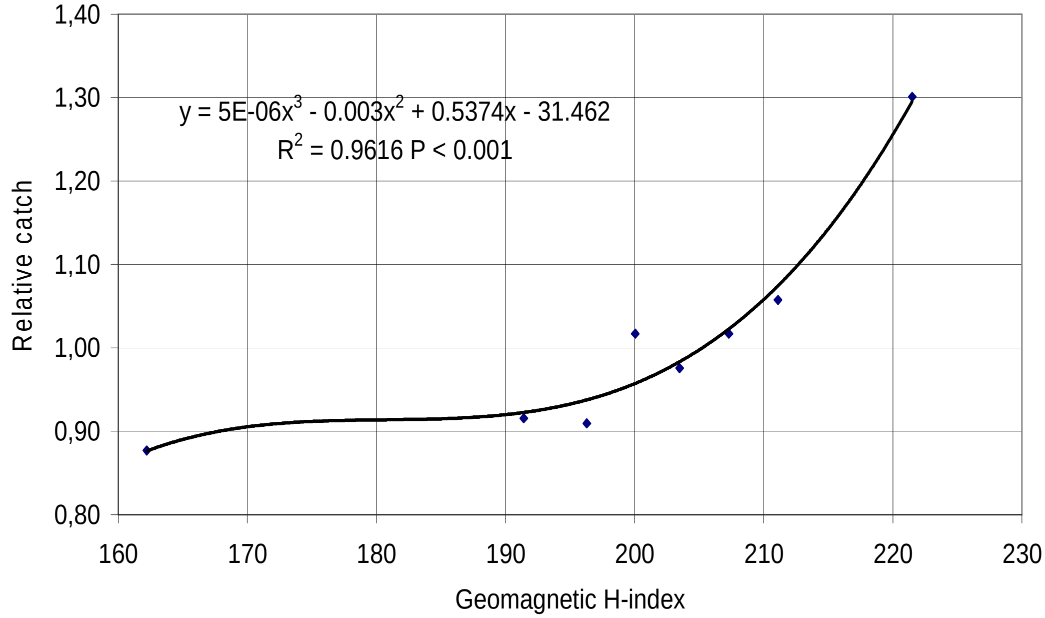

Fig. 1. Light-trap catch of the *Agraylea sexmaculata* Curtis in connection with the geomagnetic H-index (Szolnok, 2000)

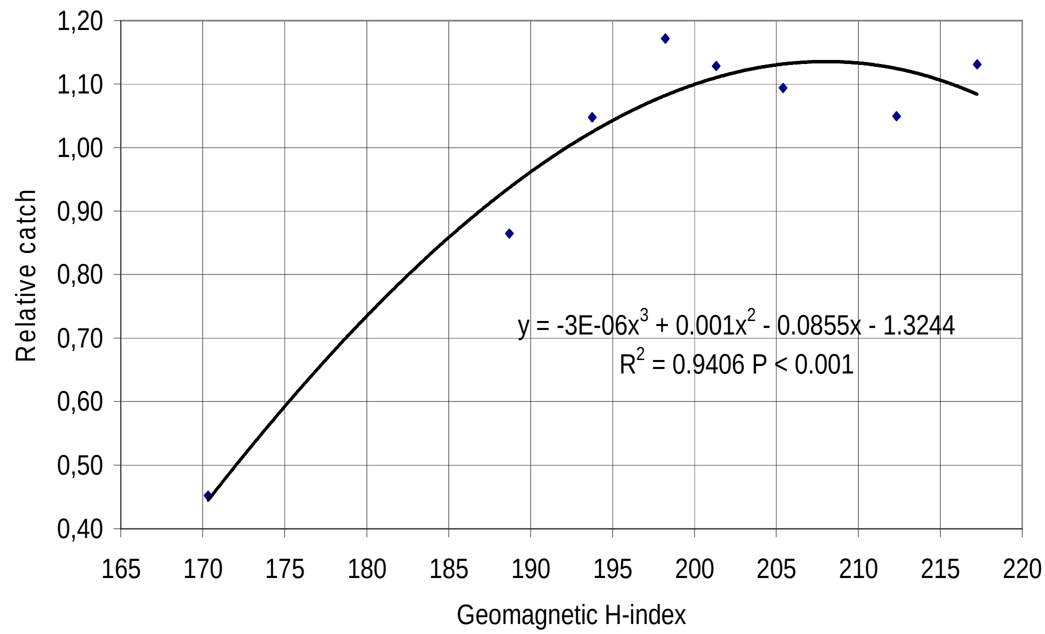

Fig. 2. Light-trap catch of the *Ecnomus tenellus* Rambur in connection with the geomagnetic H-index (Szolnok, 2000)

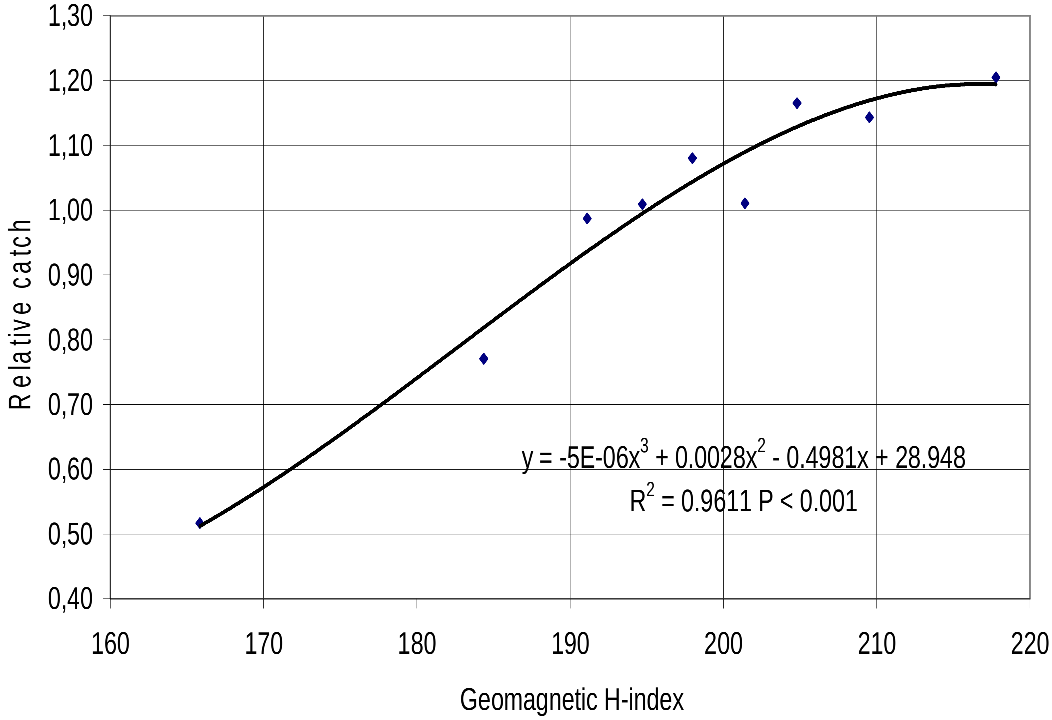

Fig. 3. Light-trap catch of *Neureclipsis bimaculata* Linnaeus in connection with the geomagnetic H-index (God, 1999 and Szolnok, 2000)

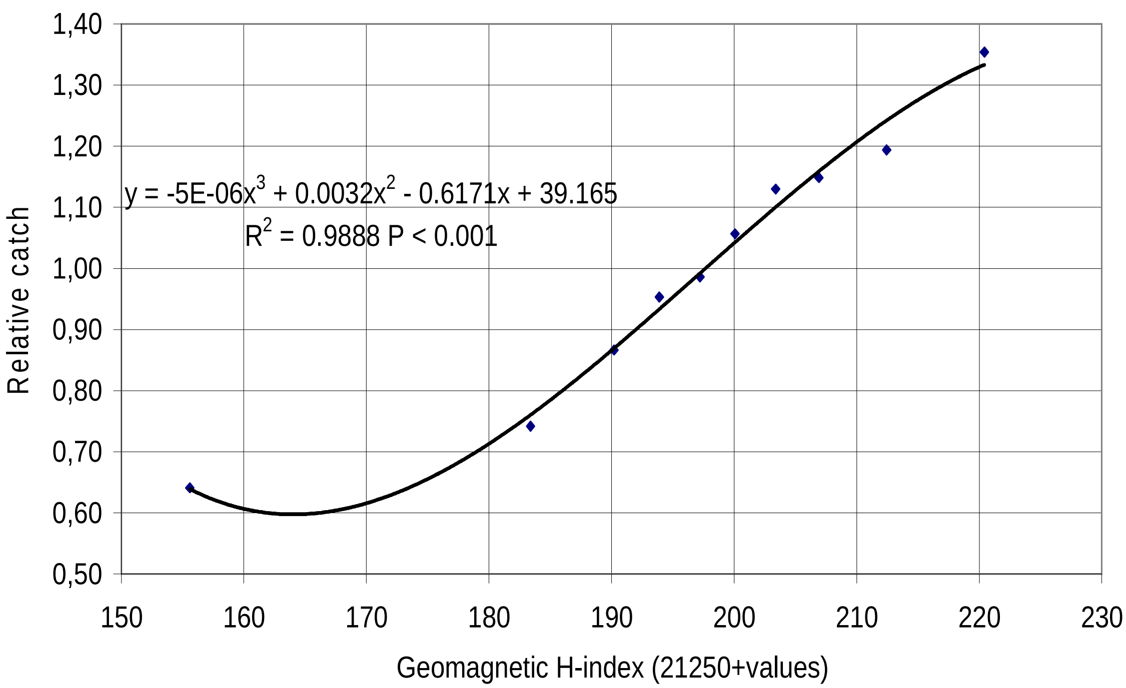

Fig. 4. Light-trap catch of the *Hydropsyche contubernalis* Mc Lachlan in connection with the geomagnetic H-index (God, 1999 and Szolnok, 2000)

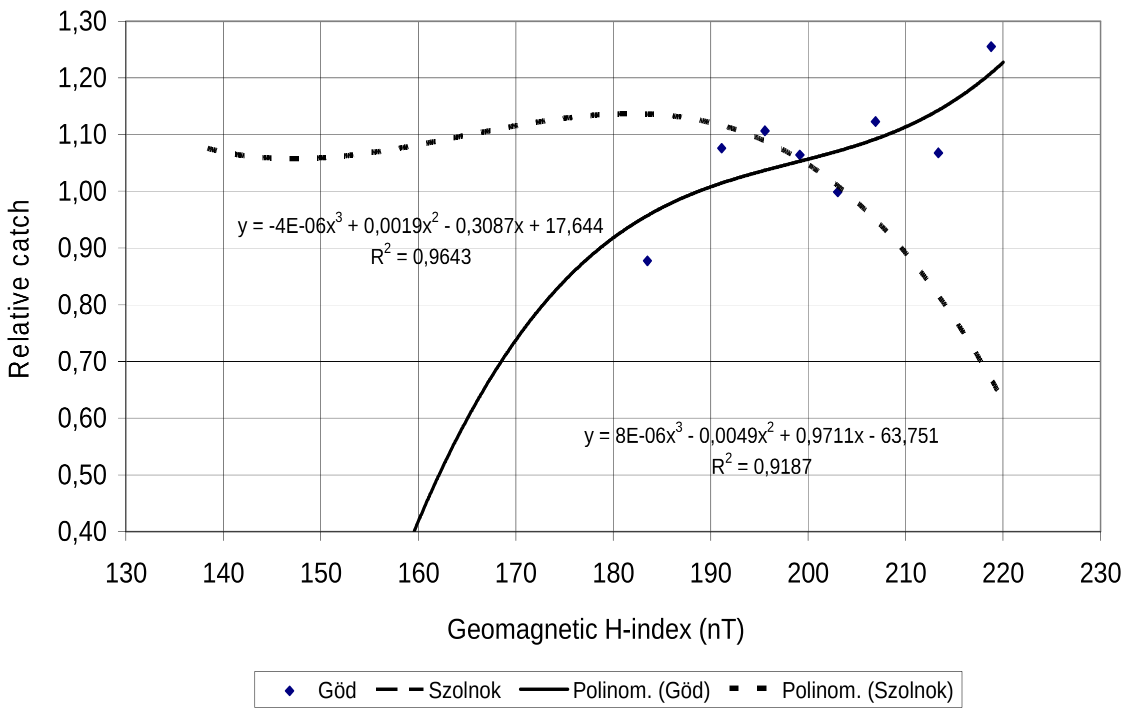

Fig. 5. Light-trap catch of *Hydropsyche bulgaromanorum* Malicky in connection with geomagnetic H-index (God, 1999 and Szolnok, 2000)

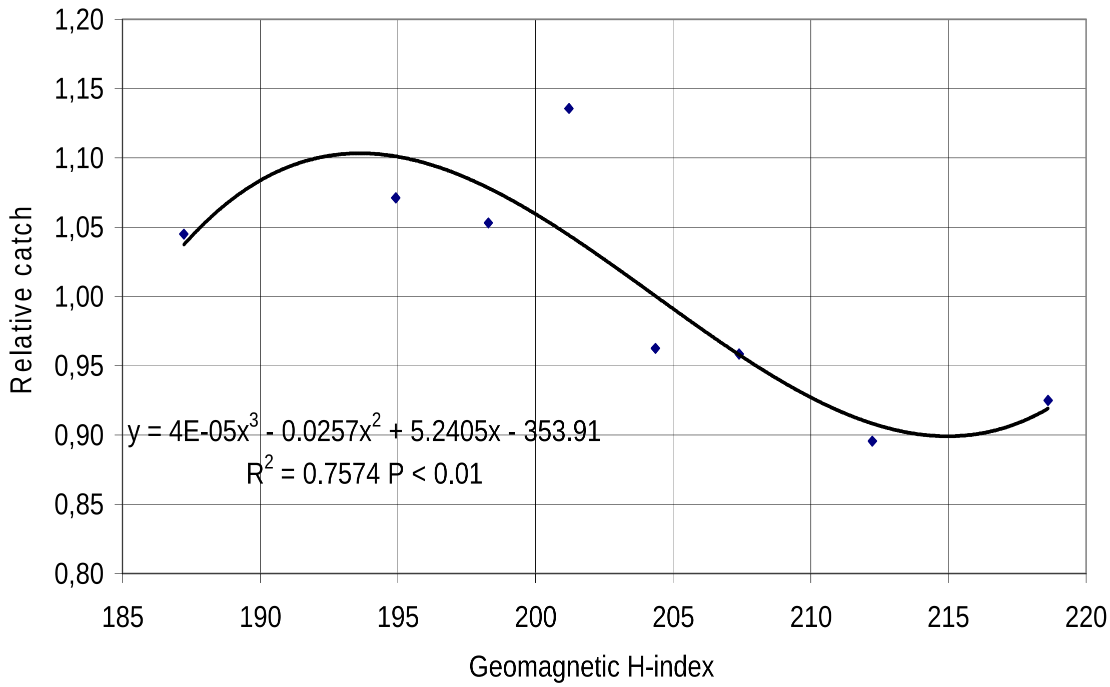

Fig. 6. Light-trap catch of the *Brachycentrus subnubilus* Curtis in connection with the geomagnetic H-index (God, 1999)

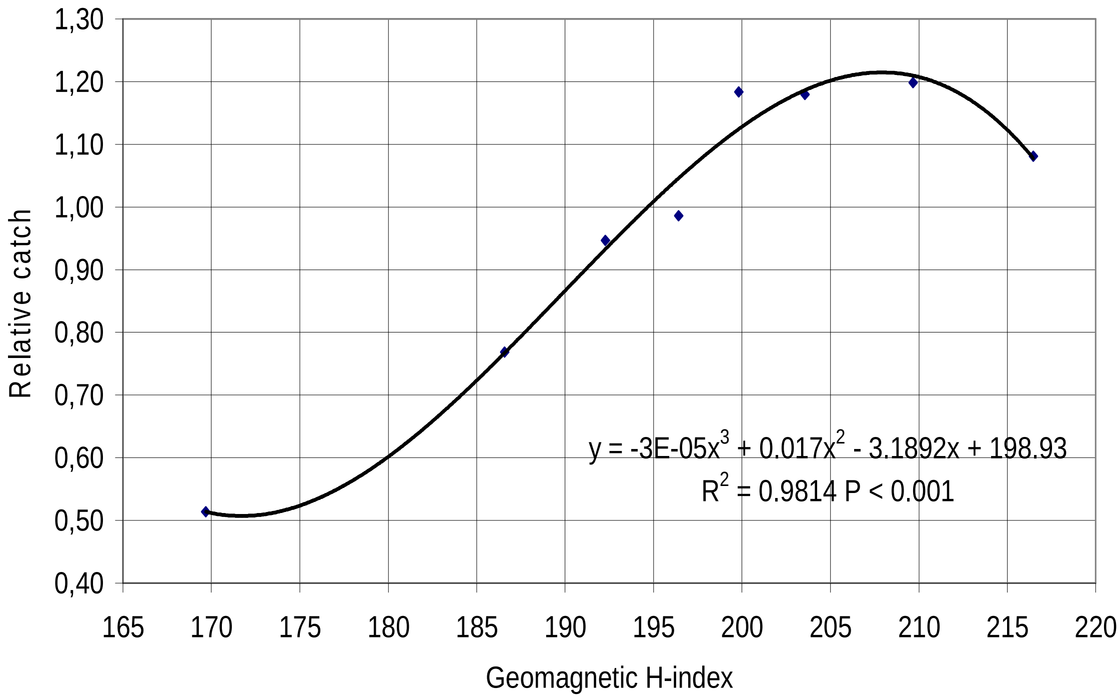

Fig. 7. Light-trap catch of the *Lepidostoma hirtum* Fabricius in connection with the geomagnetic H-index (God, 1999)

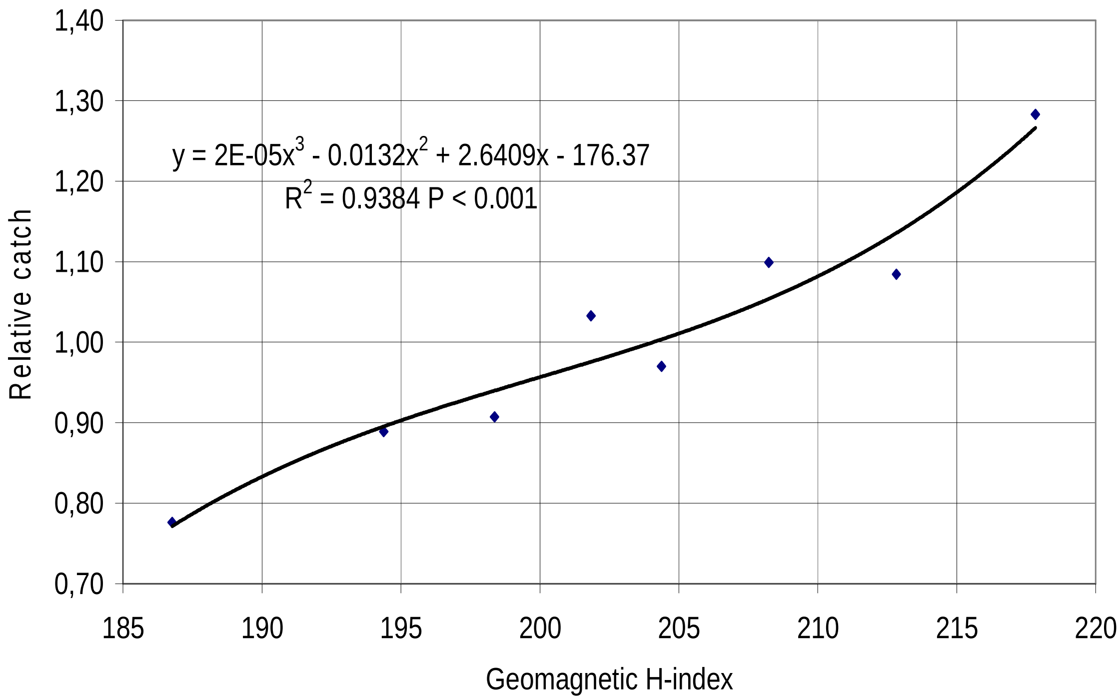

Fig. 8. Light-trap catch of the *Limnephilus affinis* Curtis in connection with the geomagnetic H-index (Szolnok, 2000)

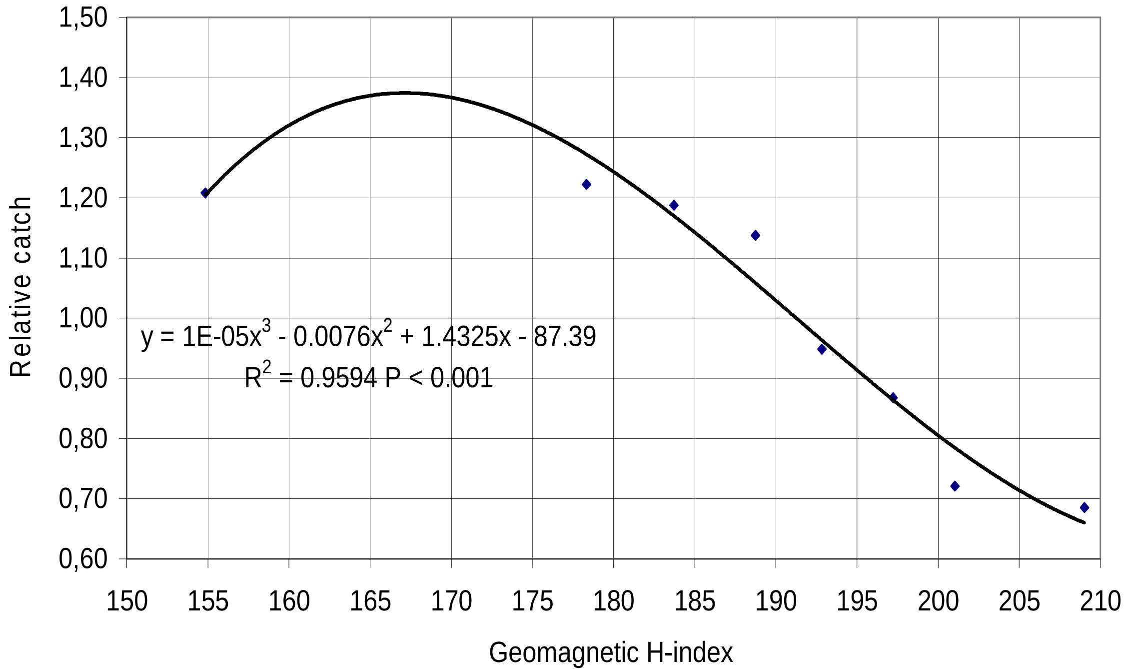

Fig. 9. Light-trap catch of the *Halesus digitatus* Schrank in connection with the geomagnetic H-index (Szolnok, 2000)

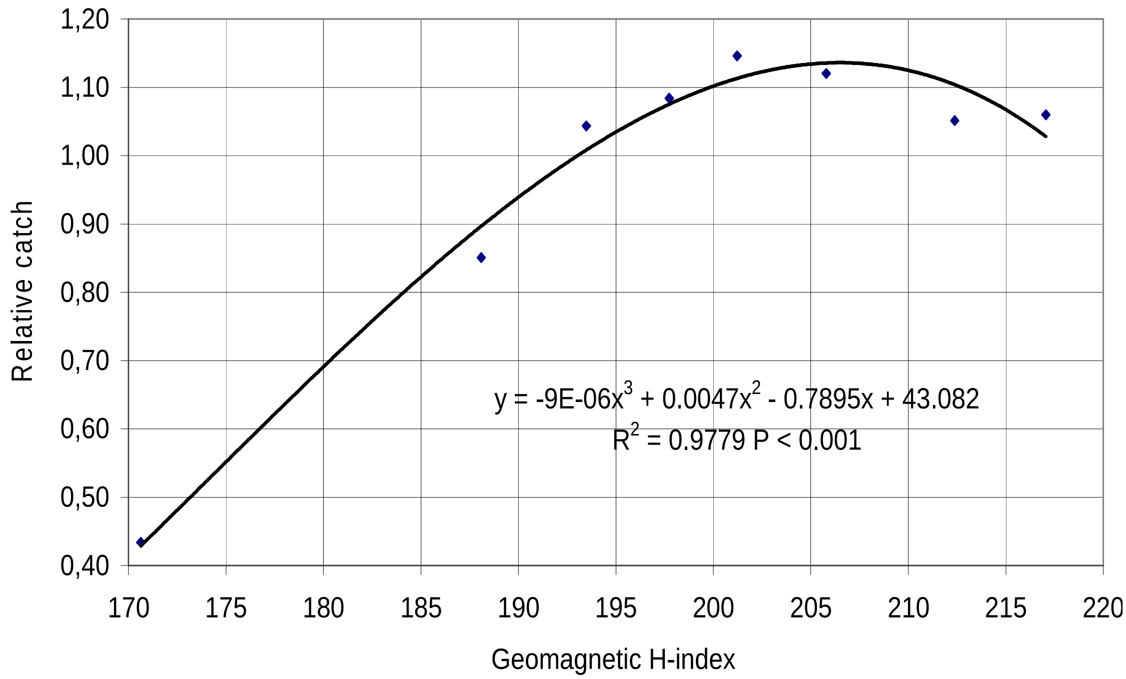

Fig. 10. Light-trap catch of the *Athripsodes albifrons* Linnaeus in connection with the geomagnetic H-index (Szolnok, 2000)

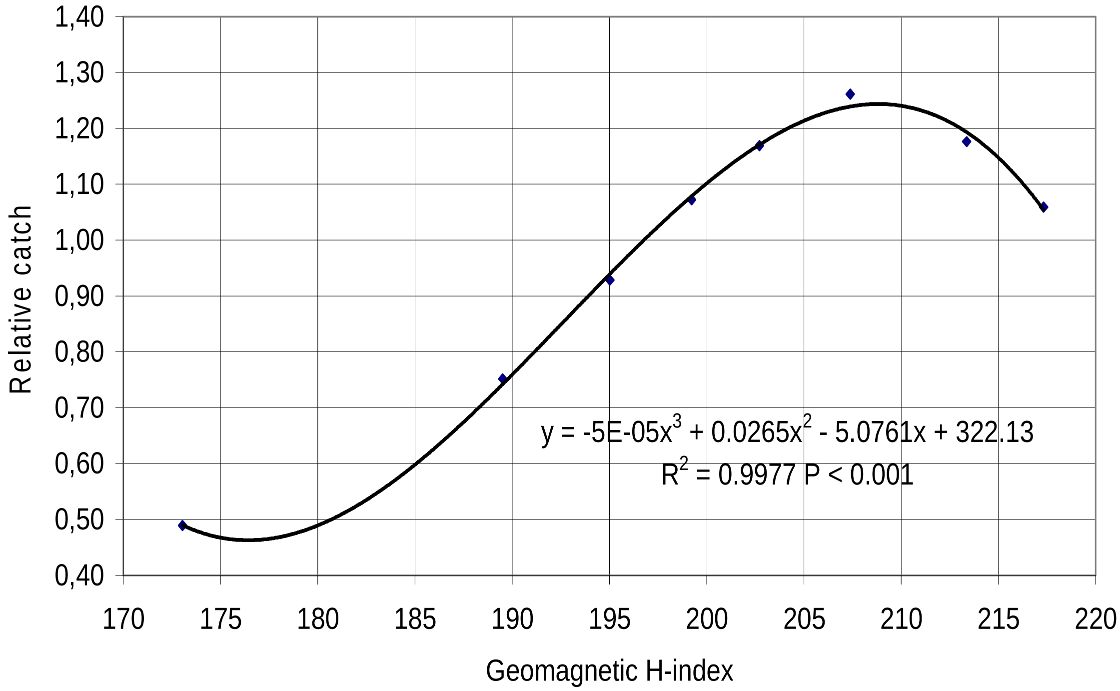

Fig. 11. Light-trap catch of the *Ceraclea dissimilis* Stephens in connection with the geomagnetic H-index (Szolnok, 2000)

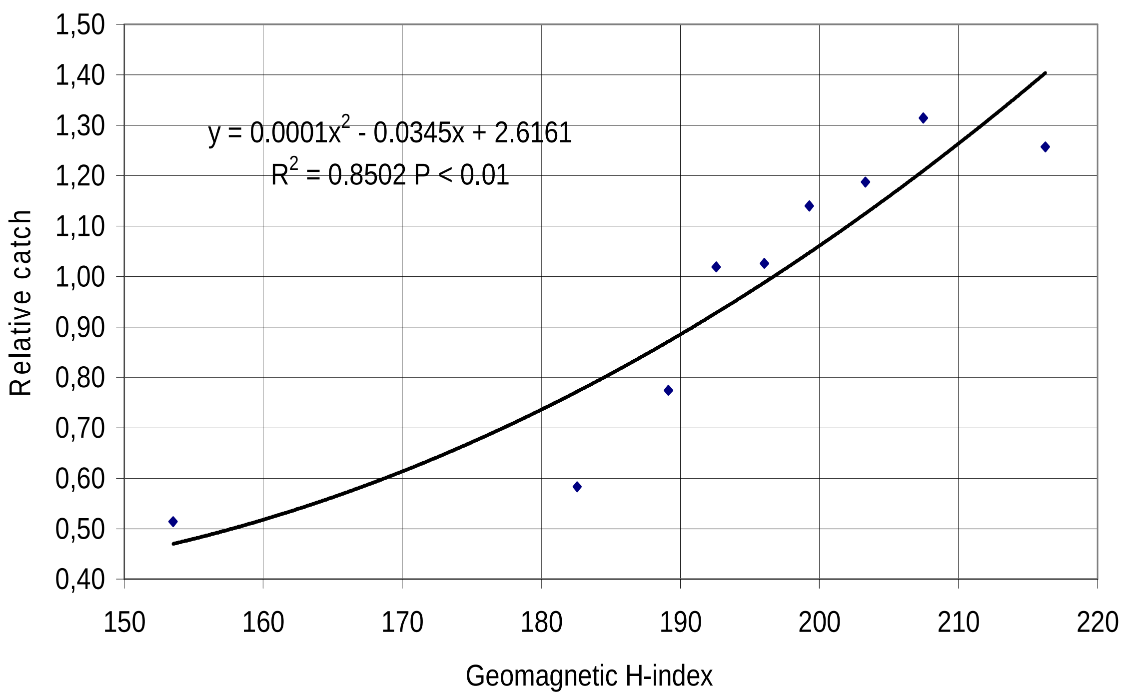

Fig. 12. Light-trap catch of *Setodes punctatum* Fabricius in connection with geomagnetic H-index (God, 1999 and Szolnok, 2000)

4. CONCLUSION

In parallel to the higher Earth's magnetic horizontal component (H-index) and the increasing catch values probably can be explained with the fact, that in such cases the spatial orientation of the insects the Earth's magnetic field comes into view.

The increase or decrease of the catch is explainable by our previous hypotheses [20]. This opposite form of behaviour may be the many reasons. The claim and tolerance to environmental factors of the species are different. Environmental factors interact with each other to exert their effects. Thus the same factor can be different effect. The species have different survival strategy. Adverse effects of two possible answers: passivity, or hiding or even increased activity, because you want to ensure the survival of the species. Therefore, the insect do "to carry out their duties in a hurry".

The fact that on the higher and increasing values of geomagnetic horizontal component the catches are not suddenly, but gradually decline, we deduce that the tolerance and response of insect specimens adverse effects to individually change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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LIGHT TRAPPING OF THE TURNIP MOTH (*AGROTIS SEGETUM* DEN. ET SCHIFF.) DEPENDING ON THE GEOMAGNETISM AND MOON PHASES

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(Received 17th April 2011; accepted 26th August 2011)

Abstract: The study deals with the change of light-trap catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.), in connection with the horizontal component of geomagnetic field and the moon phases. The numbers of specimens caught by generation relative catch values were calculated. These hourly relative catch data were assigned to the hourly values of horizontal component of geomagnetic field. They were separated by the moonlit and moonless hours of the four quarter of the Moon (New Moon, First Quarter, Full Moon and Last Quarter) were classified. We correlated the hourly catch results pertaining to the hourly values of both the horizontal component and moonlit or moonless hours of four moon quarters. After that we made correlation calculations to demonstrate the assumed connection. Our calculations have shown that in the period of the New Moon when there is no measurable moonlight, the higher values of the horizontal component are accompanied by a falling relative catch. In the other moon phases, i.e. in the First Quarter, Full Moon and the Last Quarter, growing values of the horizontal component are accompanied by an increasing catch in both the moonlit and moonless hours.
Keywords: *geomagnetic field, lunar month, insects*

Introduction

It has been known for decades that the insects detect the geomagnetic field, and even can use it as a three-dimensional orientation. It is also known for decades that the spatial orientation of the insect is able to use the Moon. We investigated, therefore, that the effectiveness of light-trap catch of insects changes to the combined effect of the horizontal component of the geomagnetic field strength and the moon phases?

A number of laboratory experiments and comprehensive studies are devoted to the physiological bases of perception and the ways of orientation (Wehner and Lobhart, 1970; Kirschvink, l983; Wehner, 1984 and 1992; Jahn, 1986). Becker (1964) has found that certain species of termites (Isotermes), beetles (Coleoptera), flies (Diptera), orthopteroids (Orthoptera) and membrane-winged insects (Hymenoptera) are guided in their orientation by the natural magnetic field. Mletzko (1969) carried out his experiments with specimens of ground beetles (*Broscus cephalotes* L., *Carabus nemoralis* Mull. and *Pterostichus vulgaris* L.) on a 100 square meter asphalt coated area in the Moscow botanical garden. He placed the insects in the middle of the area and followed their movement with a compass. After some uncertainty, the insects flew in a given direction with an accuracy of ±5° at daylight and ± 60° at night. The author assumes that orientation is guided by geomagnetism. Iso-Ivari and Koponen (1976) studied the impact of geomagnetism on light trapping in the northernmost part of Finland. In their experiments they used the K index values measured in every three hours, as well as the ΣK and the δH values. A weak but significant correlation was found between the geomagnetic parameters and the number of specimens of the various orders of insects caught. Studying the few Willow Ermine (Y*ponomeuta rorella* Hbn.), Pristavko and Karasov (1970) revealed a correlation between the C and ΣK values and the number of individuals caught. In a later study (Pristavko and Karasov, 1981) they also established that at the time of magnetic storms ΣK has a greater influence on the flying activity of the above species. The influence is also significant in years when ΣK is not higher than 16-26. Equally interesting is the observation that if $\Sigma K \leq 26$, flying activity intensifies the same day, if ΣK = 27-30, this happens the following day and if ΣK = 33-41, intensification follows only on the second or third day. Studying the termite species *Heterotermes indicola* Wasmann, Becker and Gerisch (1977) found a stronger correlation between this activity and the vertical component of geomagnetism (Z) than with the values of the K index. Tshernyshev and his colleagues have discussed in a series of studies the results of their laboratory and light trapping experiments with species of different orders of insects to reveal a connection between geomagnetism and certain life phenomena. Tshernyshev (1966) found that the number of light-trapped beetles and bugs rose many times over at the time of geomagnetic storms in Turkmenia. He found a high positive correlation between the horizontal component and the number of trapped insects. In laboratory conditions, Tshernyshev and Danilevsky (1966) could not reveal the influence of an alternating magnetic field on the activity of flies at low temperature (22°C), but observed a significant rise at 29°C. Tshernyshev (1968) studied the changes in the biological rhythm of the *Trogoderma glabrum* Herbst. as a function of the perturbations of the magnetic field. His assessment was based upon the K-index values over 4, i.e. over 40γ measures at 6 and 9 p.m. as well as at 3 a.m. It was proved that the biological rhythm of the species observed was influenced by factors that coincided with perturbations of the magnetic field. It was also observed by Tshernyshev (1965) that the number of light-trapped insects significantly rose at the time of magnetic perturbations. Later, however, he reported that while light-trap catches of some Coloptera and Lepidopera species increased, that of other Lepidoptera and Diptera species fell back during magnetic perturbations (Tshernyshev, 1971 and 1972). Tshernyshev and Afonina (1971) also observed that the activity of certain moths and beetles increased, but in some cases fell back under the influence of a weak and changing magnetic field induced in laboratory conditions. Based on international literature and his own results, Tshernyshev (1989) published a comprehensive study to give a summary of the latest state of knowledge on the relation between geomagnetism and the activity of insects. Tshernyshev and Dantharnarayana (1998) used an infrared actograph to study in laboratory conditions the activity of (*Helicoverpa armigera* Hbn.), Native Budworm (*Helicoverpa punctigera* Wallengren) and (*Heliothis rubescens* Walker). Examining the influence of the geomagnetic K index also in the context of the four typical lunar quarters (First Quarter, Full Moon, Last Quarter and new Moon), a significant negative correlation was found in the Last Quarter and a positive correlation in the other three. Moths are also disturbed by geomagnetic perturbations. 30 hours after perturbations the influence was still felt.

Examinations over the last decades have also confirmed that some Lepidoptera species, such as *Noctua pronuba* L. (Baker and Mather, 1982) and *Agrotis exclamationis* L (Baker, 1987) are guided by both the Moon and geomagnetism in their orientation, and they are even capable of integrating these two sources of information. On cloudy nights, the imagos of *Noctua pronuba* L. orientated with the help of geomagnetism. In this case, too, their preference lay with the direction they had chosen when getting their orientation by the Moon and the stars. Using hourly data from the material of the Kecskemét

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frationating light-trap, we have examined the light trapping of Turnip Moth (*Agrotis segetum* Den. et Schiff.), Heart-and-Dart (*Agrotis exclamationis* L.) and Fall Webworm Moth (*Hypantria cunea* Drury) in relationship with the horizontal component of the geomagnetic field strength (Kiss et al., 1981; Nowinszky and Tóth, 1983).

According to the authors of recent publications (Srygley and Oliveira, 2001; Gillet and Gardner, 2009; Samia et al., 2010) the orientation/navigation of moths at night may becomes not by the Moon or other celestial light sources, but many other phenomena such as geomagnetism.

The average field strength of the Earth as a magnetic dipole is 33,000γ. ($1\gamma = 10^{-5}$ Gauss = 10^{-9} Tesla = 1 nanotesla (nT)). Geophysical literature uses γ as a unit. Geomagnetic field strength can be divided into three components: H = horizontal, Z = vertical and D = declination components. The magnetic and geographic poles of the Earth do not coincide, therefore in addition of geographic; there are also geomagnetic co-ordinates of latitude and longitude. The latter characterize the geomagnetic conditions of a given geographical location. Geomagnetic parameters greatly differ in any given moment of time at the various points of the surface of the Earth. A distance of approximately 300 kms along the geomagnetic meridian may produce significantly different characteristics. So in Hungary, geomagnetic data registered at a single post of observation will provide sufficient information for the entire territory of the country. These measurements are made at the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences at Nagycenk, near Sopron and the Observatory of the Hungarian Loránd Eötvös Geophysical Institute at Tihany.

Material and methods

The yearbooks of the latter supplied us with the data we needed in our research, namely, those of the horizontal (H) component of the geomagnetic field strength. The yearbooks include values of the horizontal component over 21 500 nT over 41 800 nT. Since the values of the horizontal components of the geomagnetic field strength showed great differences in the years examined, we could work with values over 21 250 nT respectively, when processing our light trapping data.

For the purposes of our examination we had at our disposal three years of catch data pertaining to Turnip Moth (*Agrotis segetum* Den. et Schiff.) from the material of the Kecskemét fractionating light-trap. From the number of specimens caught we calculated relative catch values (RC) by generations. We had stated before in our earlier work (Kiss et al., 1981; Tóth and Nowinszky, 1994) that the impact of geomagnetism on light-trap catches should not be studied without consideration to the prevalent illumination conditions. Therefore we divided our relative catch data to those gained in or in the absence of moonlight and within these two classes established sub-categories according to the Moon phase angle around the four Moon quarters in the following way: In the swarming period of the various species, we calculated the value of the Moon phase angle for the 24th hour (UT) of each night. Then we formed 30 groups of phase angles of the 360 phase angle values of the complete lunar month. The group containing the phase angle values found in the vicinity of a Full Moon (0°, or 360°) $\pm$ 6° is marked: 0. Proceeding from here through the First Quarter in the direction of the new Moon, the groups are marked as: -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. From the Full Moon through the final quarter in the direction of the new Moon the groups are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The group of phases containing the new Moon is marked: ± 15. Each group contains 12-phase angle value. The four typical Moon quarters contain the following phase angle groups: Full Moon (-2 - +2), final quarter (3 -9), new Moon (10 - -10) and First Quarter (-9 - -3).

The numbers of specimens caught by generation relative catch values were calculated. These hourly relative catch data were assigned to the hourly values of horizontal component of geomagnetic field. They were separated by the moonlit and moonless hours of the four quarter of the Moon (New Moon, First Quarter, Full Moon and Last Quarter) were classified.

We correlated the hourly catch results pertaining to the hourly values of both the horizontal component and moonlit or moonless hours of four moon quarters. After that we made correlation calculations to demonstrate the assumed connection.

Results and discussion

The relative catch values of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) connected to the values of the horizontal component in moonlit and moonless hours of four quarters of the Moon can be seen in *Fig. 1*, *Fig. 2* and *Fig. 3*.

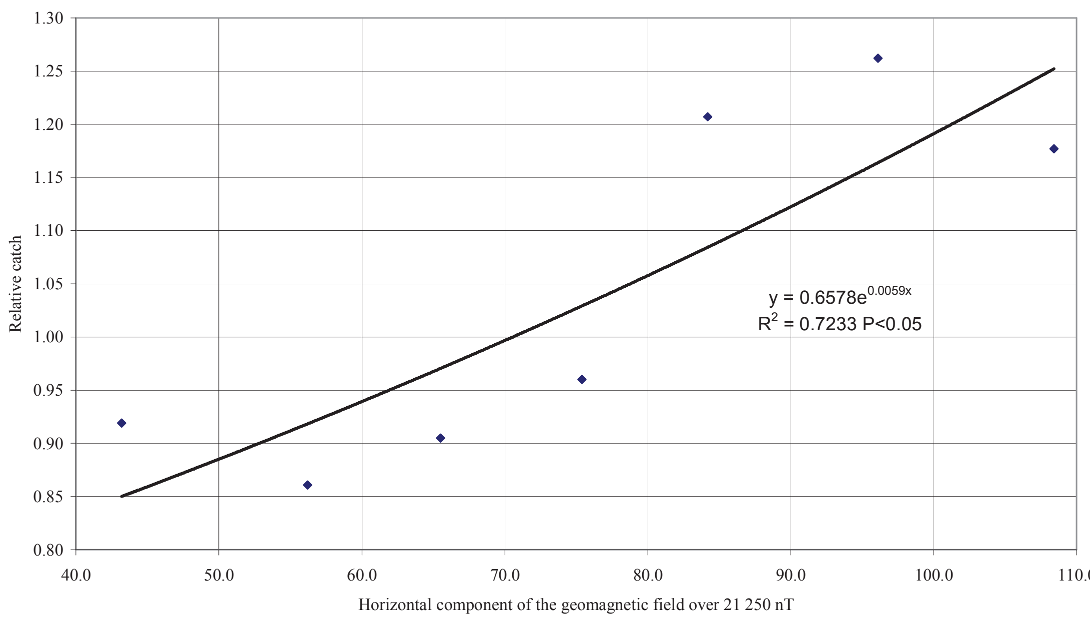

Figure 1. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) in moonlit hours of First- and Last Quarers and Full Moon in connection with the horizontal component of the geomagnetic field over 21 250 nT*

Our calculations with data of the horizontal component supplied by the material of the Kecskemét fractionating light-trap have shown that in the period of the new Moon when there is no measurable moonlight, the higher values of the horizontal component are accompanied by a falling relative catch. In the other Moon phases, i.e. in the First Quarter, Full Moon and the final quarter, growing values of the horizontal component are accompanied by an increasing catch in both the moonlit hour and those without moonlight. So it appears that in the period of lunation in which the presence of the Moon provides insects with orientation information at some time of the night, orientation is guided primarily by light stimulus even if the Moon is not over the horizon. Growth of the geomagnetic field strength may generate an intensification of the flying activity of insects, yet, with the role of the light stimulus being of prime importance in orientation, collecting is even more effective. On the other hand, in the vicinity of the new Moon when at no time of the night can insects base their orientation on the Moon, it is presumable that intensifying geomagnetic field strength that increases the security of the orientation of insects will, as against light stimuli, receive an increasingly important role in the process of orientation.

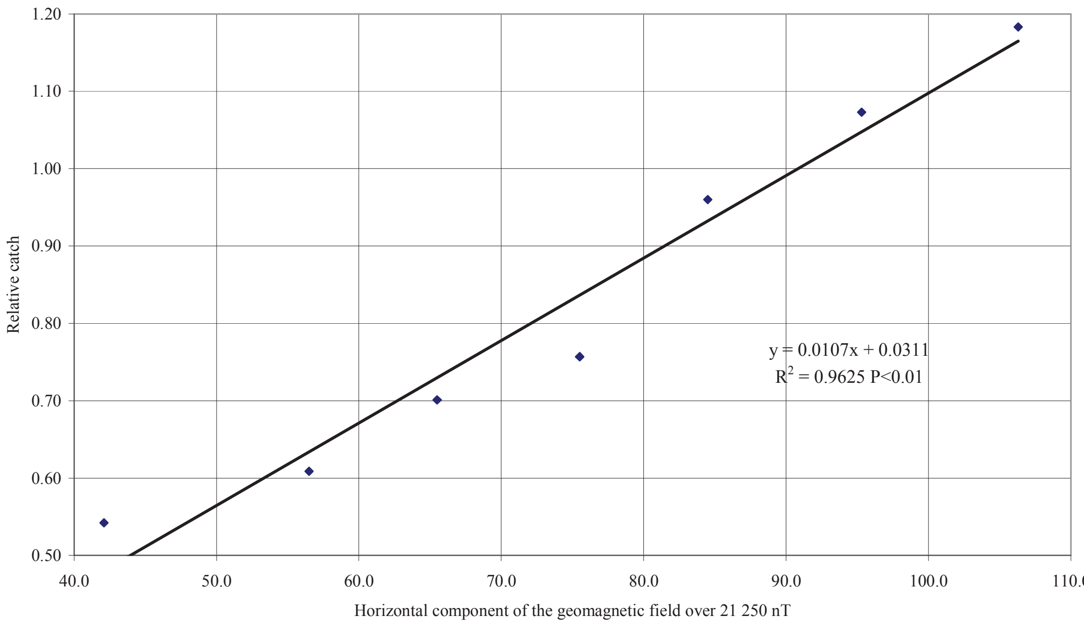

Figure 2. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) in moonless hours of First- and Last Quarers and Full Moon in connection with the horizontal component of the geomagnetic field over 21 250 nT*

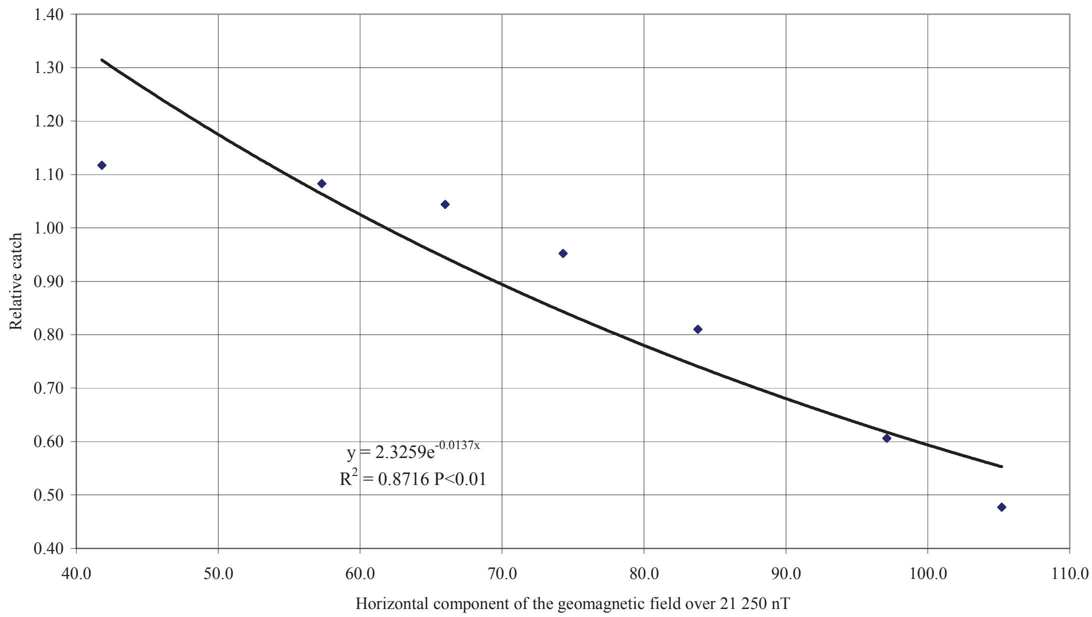

Figure 3. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) in moonless hours of the New Moon in connection with the horizontal component of the geomagnetic field over 21 250 nT*

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Research Article

iMedPub Journals
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Global Journal of Research and Review
ISSN 2393-8854

2017
Vol. 4 No. 2: 22

DOI: 10.21767/2393-8854.100022

Light-Trap Catch of Turnip Moth (*Agrotis segetum* Denis et Schiffermüller, 1775) in Connection with the Night Sky Polarization Phenomena

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Citation: Nowinszky L, Kiss M, Puskás J, Barta A (2017) Light-Trap Catch of Turnip Moth (Agrotis segetum Denis et Schiffermüller, 1775) in Connection with the Night Sky Polarization Phenomena. Glob J Res Rev. Vol. 4 No. 2: 22

Abstract

The study investigated the efficiency of the light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the polarization of the night sky. The hourly catch data of drawing during three years were assigned to the data of the 41 environmental variables. First we made cluster analysis with the data pairs. Based on this, further calculations were made between the most important influencing factors and the catch data. The results were depicted together with the confidence intervals. We can conclude that the catch at night is determined mainly by the Humidity, Sun-Sky-Pol, Moon-Sky-Pol, Moon-Pol and Clock variables, slightly influenced by Wind and H-index variables. The high relative humidity of the air has a decisive influence on the catch, because the insect can see only the distorted sky polarization pattern, and according to our assumption its orientation is hampered. The Sun stays in the first and last collection hours above the horizon at most. At this time the Sun's sky polarization is higher than the Moon's one. The catch is also influenced mainly in these hours. In the majority of the night, the sky polarization originated from the Moon is much higher. In these hours the Moon's modifying effect is decisive. The Moon modifies the catch when he does not stay above the horizon. The azimuth angle of the moon is also a determining factor for the effectiveness of the catch. The Moon phase angle is high when azimuth is smaller than 91.7. Meanwhile, the polarization of the sky and the polarized moonlight are high. This situation increases the effectiveness of the catch. The effect of polarized moonlight on the catch is less significant than the sky polarization.

Keywords: Light trapping; Turnip Moth; Night sky polarization

Received: June 14, 2017; **Accepted:** June 29, 2017; **Published:** June 30, 2017

Introduction and Literature Background

Verkhovskaya [1] described the first time that the arthropods (Arthropoda) are able to distinguish between the polarized light and not polarized light. She stated that many diurnal animals are able to perceive linearly polarized light.

The theory of polarization of skylight has a long history. The single scattering Rayleigh-method [2] describes the majority of the skylight polarization quite well, although there are areas (especially around the neutral points), where there are substantial differences between the Rayleigh-theory and the reality [3]. Berry [4] suggested a method to overcome the weaknesses of the Rayleigh-method which describes the polarization pattern of the whole clear sky quite accurately.

The polarization pattern of the sky in various sky conditions is nowadays well known thanks to the spread of full-sky imaging polarimeters. The degree of polarization is maximal along a great circle of the sky being 90 degree from the Sun, and minimal at the Sun and anti-Sun as well as at the Arago, Babinet and Brewster neutral points [5]. The degree of polarization also depends on the atmospheric conditions. In cloudy and foggy skies, as well as under canopies the degree of polarisation are much smaller compared to clear skies [6-8]. However, the direction of polarization pattern is very robust, even under forest canopies, where light scattering occur only in a very thin air layer under the foliage, the typical 8-shaped pattern as well as the axis of symmetry is well recognizable. The axis of symmetry of the direction of polarization pattern is the celestial great circle containing the Sun and anti-Sun during the daylight [5]. When the Sun is well below the Horizon and the Moon lights the atmosphere, then the axis of symmetry is the celestial great circle containing the Moon and anti-Moon [9]. Barta et al. [10] inspected the transition of characteristics of sky polarization between sunlit and moonlit skies during twilight.

According to Sotthibandhu and Baker [11] in case of a moonlit night the Moon azimuth is used as a signal as an information for orientation. In starlit night when the Moon is absence the stellar orientation about 95° from the pole star to strongly concerned [11].

Dacke et al. [12] wrote many animals are able to use the solar polarization pattern of the sky for their orientation, but the *Scarabeus zambesianus* Péringuey, 1901 is the first insect, who is able to use for this purpose in the moonlight million-fold less than the brightness of the solar polarization.

Dacke et al. [13] wrote the beetles remain more active in moonlit nights than the moonless nights, possibly using the Moon as a source for their guidance when it comes to polarized light patterns are no longer available.

These important new findings are confirmed in subsequent studies. They show the relative role of the Moon in orientation. They conclude that the Moon is not a primary tool for orientation. The effective cue polarization pattern around the Moon is more reliable for orientation [14].

Dacke and Horváth [15] and Dacke et al. [16] found that the Bogong Moths (*Agrotis infusa* Boisduval, 1832) can use several types of celestial compasses that run along straight tracks. These are the Sun, the Moon, the Polarized Light Pattern, and even the Milky Way, which is far more prominent than a single star.

Dacke et al. [16] suggest that manure bugs are the only animal species that are known to be using a lot of faint polarization patterns around the Moon as compasses to maintain the road.

However, the Moon is not visible every night and the intensity of the sky polarization pattern taper off as the Moon disappears. It is extremely important to state of Dacke et al. [16] that celestial orientation is as precise during First and Last Quarters of Moon as it is during Full Moon. Moreover, this orientation precision is equal to that measured for diurnal species that orient under the 100 million times brighter polarization pattern formed around the Sun. This indicates that, in nocturnal species, the sensitivity of the optical polarization compass can be greatly increased without any loss of precision [16].

Kyba et al. [17] found that in the bright moonlit nights in a highly polarized light bands stretching from the sky at 90 degrees to the Moon, and has recently shown that the nocturnal organisms are able to navigate it.

Several authors found that the polarized light-traps collect more insects than the unpolarized ones [18-22].

Dacke et al. [16] found that the celestial orientation is as precise during First- and Last Quarters of Moon as it is during Full Moon.

This fact suggests that the insects are able to use polarized moonlight for spatial orientation. Therefore they fly in higher amount the First- and Last Quarter to light than other lunar phases.

Several authors reported about it:

Nowinszky et al. [21]: Coleoptera: *Serica brunnea* L., *Melolontha melolontha* L., Lepidoptera: *Operoptera brumata* L., *Hyphantria cunea* Drury, *Agrotis segetum* Den. et Schiff.),

Danthanarayana and Dashper [22] Certain mosquitoes and moths,

Nowinszky et al., [23,24] *Operophtera brumata* L. and eight Trichoptera species,

Nowinszky and Puskás [25-28] twenty-four Microlepidoptera species; Lygus sp.; *Ostrinia nubilalis* Hbn.

Nowinszky et al. [28] seven Microlepidoptera species caught by pheromone traps.

Material

Járfás [29] constructed and operated a fractionating light-trap (next hour collecting killing jar) in Hungary (Kecskemét-Katonatelep, geographical coordinates are: 46°54′53″N and 19°41′57″E) between 1967 and 1969, during three years. This light-trap gave a priceless substance with a scientific value for the entomology researches.

This light-trap worked from 1st April to 31st October, from 7 p.m. to 5 a.m. every night of the year, regardless of weather, or the time of sunrise and sunset.

The light source of Járfás type fractionating light-trap composed of 3 pieces of 120 cm long F-33 type 40W light tubes placed above each other.

We worked up the collecting data of Turnip Moth (*Agrotis segetum* Denis et Schiffermüller, 1775) in connection with the data of 41 environmental factors.

The data of weather elements as follow: air temperature (°C), precipitation (mm), wind speed (km/h), air pressure (hPa), relative humidity (%) and cloud cover (okta=eight part) values were got from the Year-Books of Hungarian National Weather Service.

The Q-index data, which were processed in this study, were calculated by T. Ataç and A. Özgüç from Bogazici University Kandilli Observatory, Istanbul, Turkey. Its calculation is made by the following formula: Q=(i x t) where i=flare intensity, t=the time length of its existence.

Geomagnetic field strength can be divided into three divisions: H=horizontal, Z=vertical and D=declination components. The distance of 300 km along the geomagnetic meridian does not yet have significantly different properties. Thus, geomagnetic data recorded in Hungary at a single observation site provides relevant information across the country. These measurements were made at the observatory of the Geophysical Institute of Eötvös Loránd University of Tihany. The H-index values were used above 2150 nT [30].

Methods

The astronomical data were calculated with a program based on the algorithms and routines of the VSOP87D planetary theory for Solar System ephemeris and written in C by J Kovács. The additional formatting of data tables and some further calculations were carried out using standard Unix and Linux math and text manipulating commands. For computing the tidal potential generated by the Sun and the Moon we used the expansion of the gravitational potential in Legendre polynomials and expressed the relevant terms as a function of horizontal coordinates of the celestial objects.

We calculated the degree of polarization of clear sky lit by the Sun and by the Moon separately at the Zenith for every half hour between 1st January 1967 and 31st December 1969. For this we first determined the celestial position of the Sun and the Moon for every point in time of the above interval for a geographic position of 46° 54' 26.64"N and 19° 41' 30.12"E (Kecskemét, Hungary) [31] with the atmospheric refraction taken into account. We then calculated the degree of polarization of the clear sky at the Zenith by using the Berry-method [4]. For this calculation we assumed a neutral point distance of 27.5° and for the sake of simplicity a maximum of degree of polarization of 100%. Note, that during this paper we did not use the absolute degree of polarization, instead only their relative ratios, so assuming 100% maximum degree of polarization does not influence our end results, despite being a non-real scenario.

Using our own computer program, we investigated the lighting data required for the tests. György Tóth, an astronomer, developed this program on the TI 59 computer we used in our joint research [31]. This program was adapted to a modern computer by Miklós Kiss, associate professor.

The program calculates the light for any geographic location, day and time day, or twilight and night, separately and altogether, from Sun, Moon and starlight. Clouds are also taken into account in its calculation [32]. The clouds data were provided by the Annals of the Hungarian Meteorological Service. In these books, the data are recorded every 3 hours in octa [33].

The values of ambient illumination (lux) and moonlight (lux) were calculated using this program.

The collection distance was calculated from the light intensity of the lamp (candle) and the ambient illumination (lux) using the following formula:

$$r_0 = \sqrt{\frac{I}{E}}$$

Where: r_0= the collecting distance, I=the intensity of illumination by the light-trap (candela), E=the intensity of environmental illumination (lux).

The values of colour temperature of moonlight were calculated by our own computer programme for a former study [34] by the following formula:

$$T_c = \frac{T_{eff}}{(B-V)+0.53}$$

Where T_c= Colour temperature of Moon, T_{eff}=Colour temperature of Sun=5850 °K, (B-V)=Colour index of Moon depending on the phase angle of Moon.

The connection with colour index and the absolute value of Moon' phase angle:

$(B-V)=0.8457496+0.001671\,\alpha|-0.0000049\,|\alpha|^2$

We have calculated the relative catch values of the number of caught moths by broods. Basic data were the number of individuals caught by one night. In order to compare the differing sampling data of species, relative catching values were calculated from the number of individuals. For the examined species the relative catch (RC) data were calculated for each sampling night per year. The RC was defined as the quotient of the number of specimen caught during a sampling time unit (1 night) per the average catch (number of specimen) within the same generation relating to the same time unit. For example when the actual catch was equal to the average individual number captured in the same generation/swarming, the RC value was 1 [33].

The relative catch data were classified into the appropriate phase angle groups. The phase angle groups and the corresponding catch data were organized into classes. Their number was determined according to Sturges' method [34] using the following formula:

k=1+3.3 * 1gn

Where: k=the number of divisions, n=the number of observation data.

The time of New Moon, First Quarter, Full Moon and Last Quarter were taken from homepage of U.S. Naval Observatory Astronomical Applications Department.

The other phase angle divisions were calculated from these.

We have divided the 360° phase angle of the full lunar month (lunation) into 30 divisions. All divisions include 12 phase angle values. The phase angle division in vicinity of a New Moon contains phase angles 354°-360° and 0°-6° and named 0. Starting from here, divisions in the direction of the First Quarter until the Full Moon were named: 1 (6°-18°), 2 (18°-30°), 3 (30°-42°, 4 (42°-54°), 5 (54°-66°), 6 (66°-78°, 7 (78°-90°, 8 (90°-102°), 9 (102°-114°), 10 (114°-126°), 11 (126°-138°), 12 (138°-150°), 13 (150°-162°), 14 (162°-174°). The division including the Full Moon was named: 15 (174°-186°). Also starting from the Full Moon, divisions in the direction of the Last Quarter until a New Moon were named: -1 (186°-198°), -2 (198°-210°), -3 (210°-222°), -4 (222°-234°), -5 (234°-246°), -6 (246°-258°), -7 (258°-270°), -8 (270°-282°), -9 (282°-294°), -10 (294°-306°), -11 (306°-318°), -12 (318°-330°), -13 (330°-342°), and -14 (342°-354°). We have arranged all nights of the observation period into one of these phase angle divisions.

The data thus obtained are tabulated. We determined that the expected value (1) in which Moon Quarter is significantly divergent from the relative catch value. Because in the First and Last Quarter was found high-value relative catch we were looking relationship with the polarized moonlight values.

Cluster and factor methods were used with the use of SPSS 19 software package.

Our goal was to explain the relative catch (RC) variance as best as possible by reducing the number of other 41 variables.

The first approach was taken together with all of the 41 variables. The data for the Sun and Moon were calculated with this program as list those (abbreviations in parentheses).

Azimuth angle of Sun (Sun-Az), Altitude of Sun above horizon (Sun-Alt), Zenith distance of Sun (Sun-ZD), Gravitational potential of Sun (Sun-Pot), Azimuth angle of Sun Arago point (Sun-Ar-Az), Altitude os Sun Arago point above horizon (Sun-Ar-Alt), Azimuth of Sun Babinet point (Sun-Ba-Az), Altitude of Sun Babinet point above horizon (Sun-Ba-Alt), Azimuth odf Sun Brewster point (Sun-Br-Az), Altitude of Sun Brewster point above horizon (Sun-Br-Alt), Sky polarization originated from Sun (Sun-Sky-Pol), Gravitational potential of Sun and Moon (Sun-Moon-Pot), Azimuth of Moon (Moon-Az), Altitude of Moon above horizon (Moon-Alt), Zenith distance of Moon (Moon-ZD), Apparent magnitude of Moon (Moon-Vmagn), Illuminated fraction of Moon (Moon-Phase), Gravitational potential of Moon (Moon-Pot), Moonlight (Moon-Lux), Azimuth of Moon Arago point (Moon-Ar-Az), Altitude of Moon Arago point above horizon (Moon-Ar-Alt), Azimuth of Moon Babinet point Moon-Ba-Az), Altitude of Moon Babinet point above horizon (Moon-Ba-Alt), Azimuth of Moon Brewster point (Moon-Br-Az), Altitude of Moon Brewster point above horizon (Moon-Br-Alt), Sky polarization originated from Moon (Moon-Sky-Pol). We calculated azimuth values from North to East-South-West direction.

Additional environmental factors were

Phase angle divisions of Moon (°), Polarized moonlight (%), Environmental illumination (lux), Collecting distance (metres), Air temperature (°C), Wind speed (km/h), Relative humidity of air (%), Clouds (okta), Air pressue (hPa), Colour temperature (°K), Hours of collecting nights, Q-index (Features of solar activity), Height of Tropopause (km) and H-index (Horizontal component of geomagnetic field).

By performing cluster analyzes, we continuously filtered out the most influential factors for catch. We have determined the factors which are the most important for the effectiveness of the catch. We depicted these and also the results coming from the different factors and the connection with catch. Since our catch data have Poisson distribution, the spreads are roughly the same as averages. Figures also show the confidence intervals.

Results and Discussion

The results of cluster test are shown in **Figure 1.** There can be seen in the tree structure the Humidity (on level 1), Sun-Sky-Pol, Moon-Az, Wind (on level 2) and H-index (on level 3). It can be stated that Humidity is one of the predominant variables (the factor weight is the largest), which lists the RC values into 4 intervals.

The most important factors were the sky polarization generated by the Moon and the Sun and the relative humidity of the air. If the relative humidity of the air was lower than 61.60 % the effect of Sun-Sky-Pol occurs. Presumably, smaller vapours have no influence on the degree of polarization of the sky and the structure of the polarization planes (arrangement of 8 or lemniscate), so the insect can use polarization and the structure of the polarization planes for orientation. Based on the Sun-Sky-Pol values, the RC values are divided into two groups. If Sun-Sky-Pol is >74.249, then RC=1.650, otherwise RC=1.059. That is, the Sun's sky polarization will result in a greater relative catch. The role of humidity can be explained by the fact that, in the case of high humidity, the polarization pattern in the sky is distorted.

If the humidity reaches the medium value (61.60-79.80 %) this is determining variable together with Moon-Sky-Pol, Moon-Pol and Clock factors. The additional analyses confirmed this fact. The Moon-Sky-Pol especially prevails if Moon-Az value is <=91.78341. From the collection hours (2 to 6), the Moon polarity from the Moon is greater than the Sun's polarity, so Moon's effect prevails. Here RC=1.490 in the collection hours is permanently bigger, than RC=1.

The results of the cluster analysis were confirmed and complemented by our individual calculations based on each factor.

Figures 2 and 3 illustrate the position of the neutral points above the horizon as a function of the distance between the Sun and the Moon.

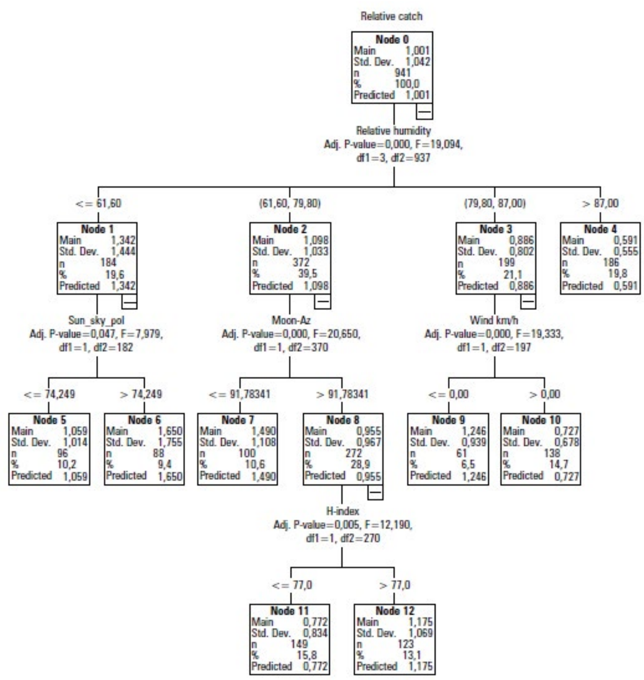

Figure 1 The result of the cluster test.

The catch decreases during the hours of the night collection and in addition to the circadian rhythm of species, the rising relative humidity from evening to dawn as well as decreasing air temperature affects it **(Figures 4 and 5).**

The Sun-Sky-Polarization and Moon-Sky-Polarization can be seen in connection with the catching hours of nights in **Figure 6**.

The catch of Turnip Moth was increase in the evening and dawn, when the Sun-Sky-Polarization is bigger than Moon-Sky-Polarization.

The catch of Turnip Moth was increase in the evening and dawn, when the Sun-Sky-Polarization is bigger than Moon-Sky-Polarization. The catch is reduced on the highest value, but this situation only can be seen when the Sun is just above the horizon, or it is directly below the horizon. The Sun Babinet point change together with the distance of the Sun above horizon, but the Sun Arago point changes in the opposite direction. The catch changes according to this fact **(Figures 7 and 8).**

The azimuth angle of the Moon also strongly influences the effectiveness of the catch. When the Azimuth is <91.7, the Moon is slightly above or below the horizon. In this case, the Moon phase is in the neighbourhood of the last quarter, the polarities of the moonlight are highest. The Moon polarization (Moon-Sky-Pol) generated by the Moon is high and the relative catch (RC) is also high. The RC values can be further divided into two groups according to the H-index values. If H index is>77.0 then RC=1.176, otherwise RC=0.772. The horizontal component of the Earth's magnetic field has a little effect on the relative catch **(Figure 9).**

The altitude of the Moon above horizon and the sky polarization generated by the Moon are in a strong connection with each other **(Figure 10).**

The catch is most effective when the Moon is in the vicinity of the horizon. At this time is the highest Moon-Sky-Pol, and at this time there is the highest catch belonging to Moon's Arago and Moon's Babinet points **(Figures 11-13).**

The Moon-Sky-Pol has the most important effect for catch, because the RC almost completely follows this influence. In contrast, both the Arago and the Babinet points may only play a

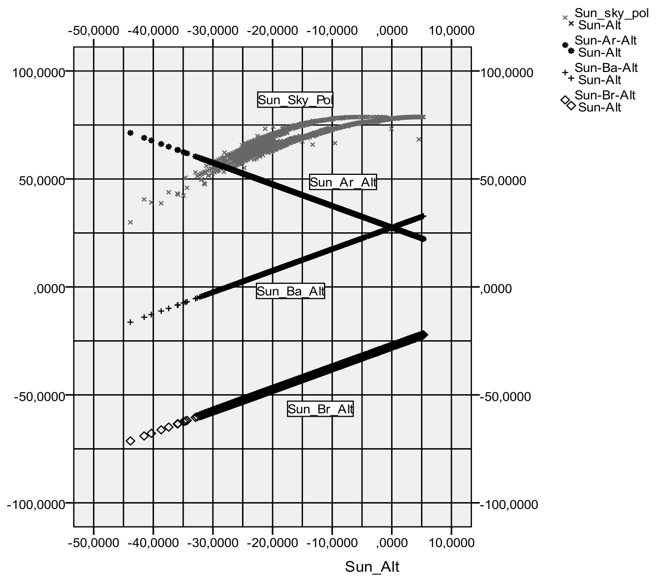

Figure 2 The result of the cluster test.

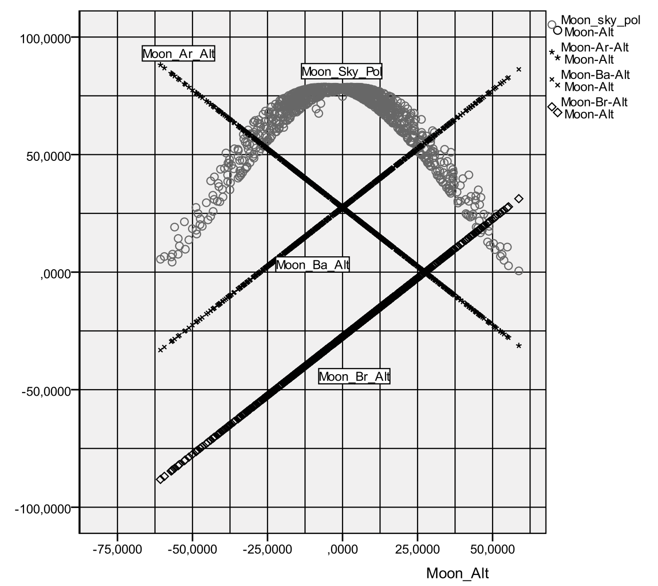

Figure 3 Moon Sky Polarization and Neutral Points in connection with Zenith Distance of Moon.

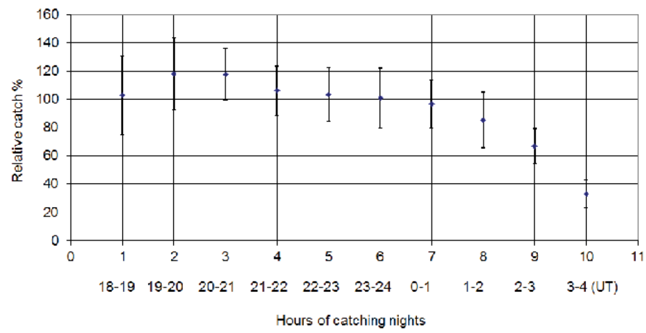

Figure 4 Light-trap catch of Turnip Moth (Agrotis segetum Den. et Schiff.) in connection with the catching hours of nights.

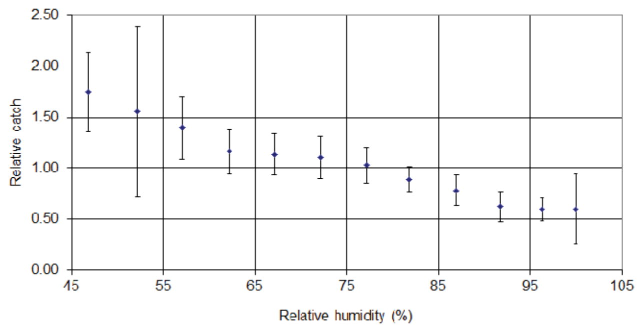

Figure 5 Light-trap catch of Turnip Moth (Agrotis segetum Den. et Schiff.) in connection with the relative humidity of air.

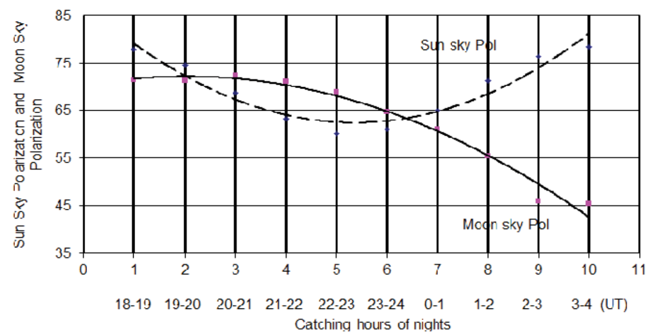

Figure 6 Sun Sky Polarization and Moon Sky Polarization in connection with the catching hours of nights.

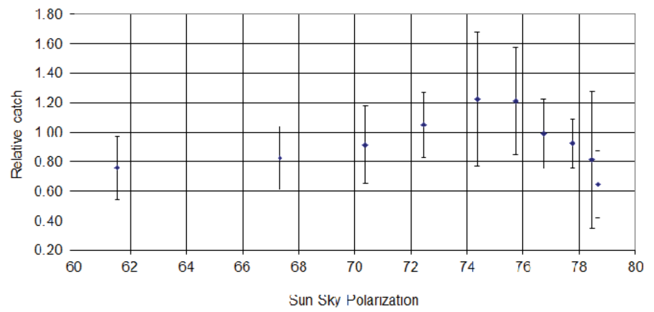

Figure 7 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the Sun Sky Polarization (in the evening and dawn, when the Sun Sky Polarization is bigger than Moon Sky Polarization).

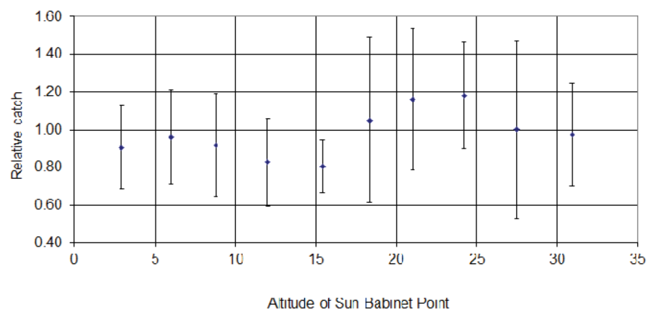

Figure 8 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the Altitude of Sun Babinet Point (in the evening and dawn, when the Sun Sky Polarization is bigger than Moon Sky Polarization).

role in the near Moon horizon, neither before nor after, there is not a clear correlation between the two neutral points' situation above the horizon and the RC.

If Moon-Az is>91.78341, then the Moon-Pol, the polarity of the moonlight also influences the catch, which has its effects in the First and Last Quarter. There is a smaller effect in the first lunar quarter, but in the Last Quarter a bigger local maximum can be experienced. These peaks are caused by the polarized moonlight, which is higher in the last quarter.

Moon-Pol can be depicted as a function of the phase angle; the Moon-Az is in a contact with the phase angle. If the structure of 8 of the polarisation planes is created then its slow rotation may indicate the passing of time for the insect around the zenith **(Figures 14-16).**

In the case of higher humidity (79.80-87.00), the degree and order of the polarity does not prevail, or it is less prevalent. Otherwise, at dawn there is more humidity, less catch, and the role of the H-index and/or wind variables may increase. When the wind is calm the RC is bigger, because RC=1.246, anyway RC=0.727 **(Figure 17).**

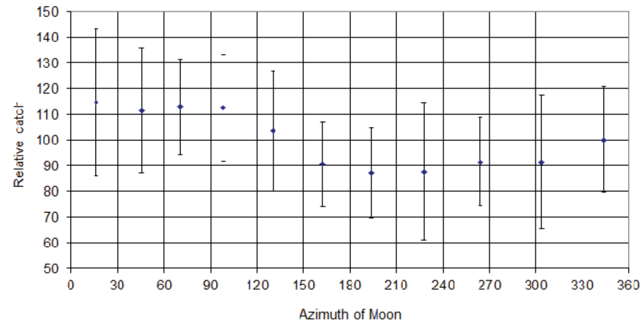

Figure 9 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with Azimuth of Moon.

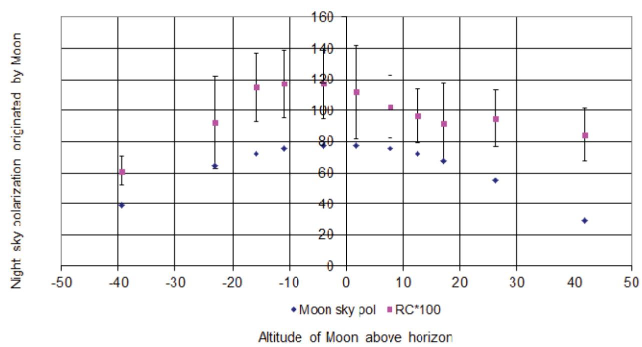

Figure 10 Night sky polarization originated by Moon and reative catch in connection with altitude of Moon above horizon.

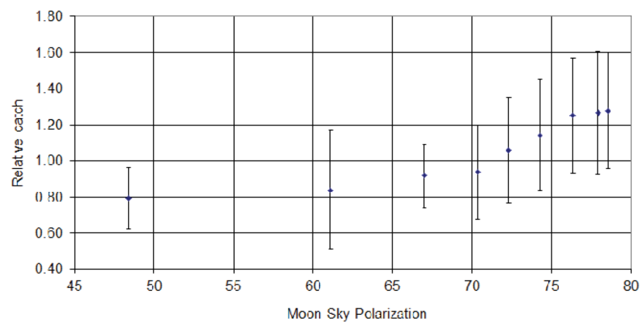

Figure 11 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the Moon Sky Polarization (in night when the Moon Sky Polarization is bigger than Sun Sky Polarization).

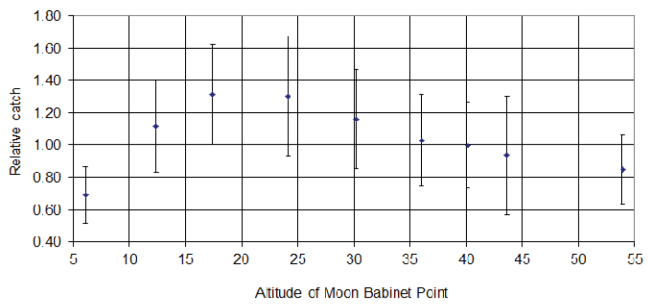

Figure 12 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the Altitude of Moon Babinet Point (in night when the Moon Sky Polarization is bigger than Sun Sky Polarization)

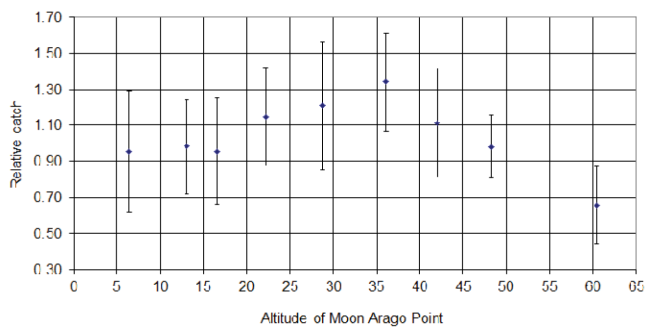

Figure 13 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the Altitude of Moon Arago Point (in night when the Moon Sky Polarization is bigger than Sun Sky Polarization).

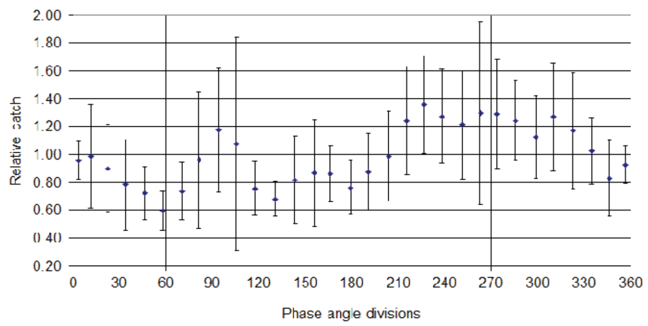

Figure 14 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the phase angle divisions of Moon (0° and 360° = New Moon, 180° = Full Moon).

In case of very high humidity (above 87%), the sky polarization pattern may be less presumably used by the insect. That is why the catch increases with the increase in the value of the H-index.

The effect of the factors that we did not detail only modifies the catch to a little bit, so we don't deal with these in this study. We could not demonstrate a significant relationship with the colour temperature of the moonlight, and we will report the gravitation of the Sun and the Moon in a separate study though with the significant influence **(Figure 18)**.

Naturally, our results refer only to the Turnip Moth (*Agrotis segetum* Denis et Schiffermüller), but it is assumed that other insect species have similar effects.

For this reason, it would be important to use fractionated traps as many collections as possible for further research (light traps, pheromone traps, suction traps, etc.).

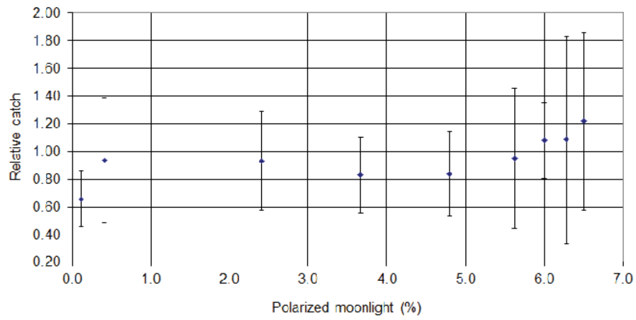

Figure 15 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the polarized moonlight in surroundings of First Quarter.

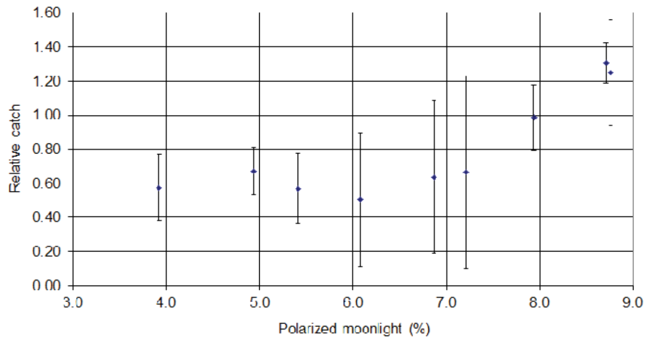

Figure 16 Light-trap catch of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the polarized moonlight in surrounding of Last Quarter

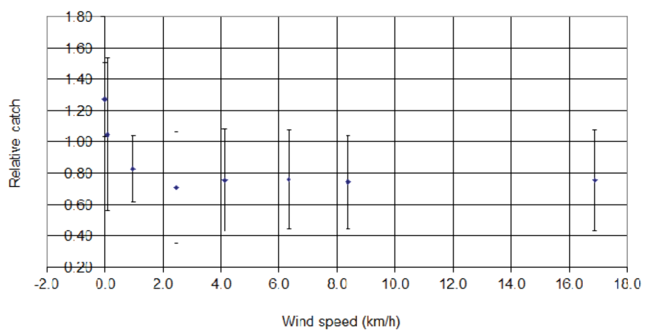

Figure 17 Light-trap catch of Turnip Moth (*Agrotis segetum Den. et Schiff.)* in connection with the Wind Speed (The relative humidity of air is between 79.8% and 87%).

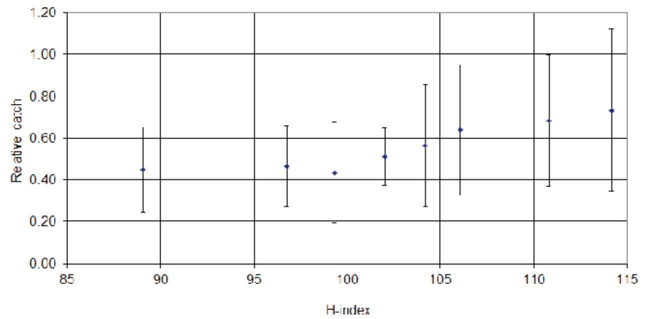

Figure 18 Light-trap catch of Turnip Moth *(Agrotis segetum* Den. et Schiff.) in connection with the geomagnetic H-index if the relative humidity of air is higher than 87%.

Acknowledgements

Flare Index Data used in this study were calculated by T. Ataç and A. Özgüç from Bogazici University Kandilli Observatory, Istanbul, Turkey. The Q-index daily data for the period 1967 and 1969 were provided by Dr. T Ataç. His help is here gratefully acknowledged.

We also would like to thank J Kovács (ELTE Astrophysical Observatory, Szombathely) for calculating the Moon and Sun data and describing the method of investigation.

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Research Article
Volume 2 Issue 4 - October 2017

Mod Appl Bioequiv Availab

Light Trapping of Caught Macrolepidoptera Individuals and Species in Connection with Night Sky Polarization and Gravitational Potential of Sun

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Submission: November 01, 2017; **Published:** November 21, 2017

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Abstract

The study investigated the light-trap catch of Macrolepidoptera individuals and species in connection with night sky polarization and gravitation of Sun. We calculated the degree of polarization of the clear sky at the Zenith by using the Berry-method. We used the whole Macrolepidoptera data for investigation the number of species and individuals caught in Kámon Botanic Garden between 1962 and 1970 in connection with night sky polarization of Sun and Moon. We established in the study, that the gravitational potential of the Sun and the sky polarization caused influence on the light trap catch.

Keywords: Light-trap; Moths; Sun's polarization and gravity

Introduction

The polarization pattern of the sky in various sky conditions is nowadays well known thanks to the spread of full-sky imaging polar meters. The degree of polarization is maximal along a great circle of the sky being 90 degree from the Sun, and minimal at the Sun and anti-Sun [1]. The degree of polarization also depends on the atmospheric conditions. In cloudy [2] and foggy [3] skies, as well as under canopies [4] the degree of polarisation are much smaller compared to clear skies. However the direction of polarization pattern is very robust, the typical 8-shaped pattern as well as the axis of symmetry is well recognizable. When The Sun is well below the horizon and the moonlights the atmosphere, then the axis of symmetry is the celestial great circle containing the Moon [5]. Barta et al. [6] inspected the transition of characteristics of sky polarization between sunlit and moonlit skies during twilight. Verkhovskaya [7] reported the first time that the arthropods (Arthropoda) are able to distinguish between the polarized light and not polarized one. Insects are able to utilize the sky polarization from the Sun and the Moon for their orientation. This question is dealt with by many researchers and mainly experiments with aquatic insects. It has been well known for almost for half a century that the polarized light of the sky plays an important role in the orientation of certain insects.

Researchers, however, has been as yet concentrated primarily on insects flying in daytime or at dusk and entomologists have paid less attention to species active at night. Horváth & Varjú [8] discovered that some insects are able to use the polarization pattern of the sky in daytime and at dusk. According to Dragonflies & mayflies [9] and *Ephemera danica*, are also deceived by dry asphalt surfaces as these reflect strong horizontally polarized light. Bernáth et al. [10] found oil barrels and sparkling black plastic foils luring dragonflies and insects as if they were traps. Robertson et al. [11] found that the solar panels also operate as ecological traps.

The attraction of night flying insects to the polarized light was primarily investigated by researchers in the context of polarized moonlight. Nowinszky et al. [12]: *Coleoptera: Serica brunnea L., Melolontha melolontha L.*, Lepidoptera: *Operoptera brumata L, Hyphantria cunea* Drury, *Agrotis segetum Den. et Schiff.*), Danthanarayana & Dashper [13]: Certain mosquitoes and moths. Nowinszky et al. [14,15]: *Operophtera brumata L.* and eight Trichoptera species. Nowinszky & Puskás [16]: twenty-four *Microlepidoptera* species. Nowinszky & Puskás [17]. *Lygus* sp. Nowinszky & Puskás [18]: *Ostrinia nubilalis* Hbn. Nowinszky et al. [19]: Pheromone trapping of seven *Microlepidoptera* species. Dacke [20] and Dacke et al. [21] found that the Bogong Moths

(*Agrotis infusa Boisduval*) can use several types of celestial compasses that run along straight tracks. These are the Sun, the Moon, the polarized light pattern, and even the Milky Way, which is far more prominent than a single star.

According to Sotthibandhu & Baker [22] in case of a moonlit night the Moon azimuth is used as a signal as an information for orientation. In starlit night when the Moon is absence the stellar orientation about 95° from the pole star to strongly concerned. Kyba et al. [23] found that in the bright moonlit nights in a highly polarized light bands stretching from the sky at 90 degrees to the Moon, and has recently shown that the nocturnal organisms are able to navigate it. We did not find any study, apart from our own one [24], in the literature which investigate the effectiveness of light trapping in the context of sky polarisation.

Material and Methods

The astronomical data were calculated with a program based on the algorithms and routines of the VSOP87D planetary theory for Solar System ephemeris and written in C by J. Kovács. The additional formatting of data tables and some further calculations were carried out using standard Unix and Linux math and text manipulating commands. For computing the tidal potential generated by the Sun and the Moon we used the expansion of the gravitational potential in Legendre polynomials and expressed the relevant terms as a function of horizontal coordinates of the celestial objects.

We calculated the degree of polarization of clear sky lit by the Sun and by the Moon separately at the Zenith for every half hour between 1st January 1967 and 31st December 1969. For this we first determined the celestial position of the Sun and the Moon for every point in time of the above interval for a geographic position of 46° 54' 26.64"N and 19° 41' 30.12"E in Kecskemét, Hungary with the atmospheric refraction taken into account [25]. We then calculated the degree of polarization of the clear sky at the Zenith by using the Berry-method [26]. For this calculation we assumed a neutral point distance of 27.5° and for the sake of simplicity a maximum of degree of polarization of 100%. Note, that during this paper we did not use the absolute degree of polarization, instead only their relative ratios, so assuming 100% maximum degree of polarization does not influence our end results, despite being a non real scenario. We had only one collection data from a whole night, so we worked with the gravity and polarization data calculated for 23 hours (UT).

The Forest Research Institute operated a Jermy-type light-trap in Kámon Botanic Garden (Szombathely, Hungary) between 1962 and 1970. The geographical coordinates of this Botanic Garden are 47°25′66″N and 16°60′36″E. The light-trap consists of a frame, a truss, a cover, a light source, a funnel and a killing device. All the components are painted black, except for the funnel, which is white. The frame is fixed to a pile dug into the ground. A metal ring holding the funnel and a flattened conical cover made of zinc-plated tin joins the steel frame. The cover is 100cm in diameter. The distance between the lower edge of the cover and the higher edge of the funnel is 20-30cm. The light source is a 100W normal electric bulb [27]. This light-trap operated continuously in all the years, except on snowy winter days and a few malfunctioning nights.

All Macrolepidoptera species and individuals were identified from the catch of this period. There were caught altogether the specimen of 549 different Macrolepidoptera species by light-trap during 9 years in following families: *Drepanidae, Lasiocampidae, Saturniidae, Sphingidae, Geometridae, Notodontidae, Arctiidae, Noctuidae, Nolidae*. We used the whole Macrolepidoptera data for investigation the number of species and individuals in connection with night sky polarization of Sun and Moon.

The caught individuals and species were investigated with combined data for 9 years. They were examined separately according to each aspect: spring, early- and late summer, autumn and winter [28]. We only processed the material of the early and late summer jointly because of the few details of the other aspects. The number of individuals of the respective species was not considered on a daily basis, it was only examined whether certain species was present on a particular day. Data on more-generation species were processed separately according to generations. On the other hand if between the swarming times of two generations vagabond or migrating individuals between the swarming periods of two generations could be easily observed, these were considered as independent generation. And if the two generations were not to be separated unambiguously from each other, the procedure used with one-generation species was followed [29].

We have calculated the relative catch values (RV) of the number of caught individuals and species by summer aspects. Basic data were the number of individuals and species caught by one night. In order to compare the differing sampling data, relative values were calculated from the number of individuals and species for each sampling night per year. The RV was defined as the quotient of the number of specimen caught during a sampling time unit (1 night) per the average catch of individuals and species within the same aspect relating to the same time unit. For example when the actual catch was equal to the average individual number captured in the same aspect, the RV was 1 [30]. Of course, each species appears and disappears naturally, so each aspect cannot be separated from each other with a sharp borderline. It is necessary to take natural periods as a starting point [31] when we determine an examination period. Therefore, the estimate of the boundary limits is as follows: We depicted the number of every day captured species separately in every year and we marked the points separating the borders of each aspect on the received curves. Our own program, necessary to depiction, printed the dates for the marked points.

We have examined the effectiveness of gravitational potential and night sky polarization of Sun and Moon for the catch of individuals and species. We did not receive significant

How to cite this article: László N, Miklós K, János P, András B. Light Trapping of Caught Macrolepidoptera Individuals and Species in Connection with Night Sky Polarization and Gravitational Potential of Sun. Mod Appl Bioequiv Availab. 2017; 2(4): 555594.

values neither the gravitational potential of Moon nor its sky polarization, so these results are not published. We depicted these and also the results coming from the different factors and the connection with catch. Since our catch data have Poisson distribution, the spreads are roughly the same as averages. Figures also show the confidence intervals.

Results and Discussion

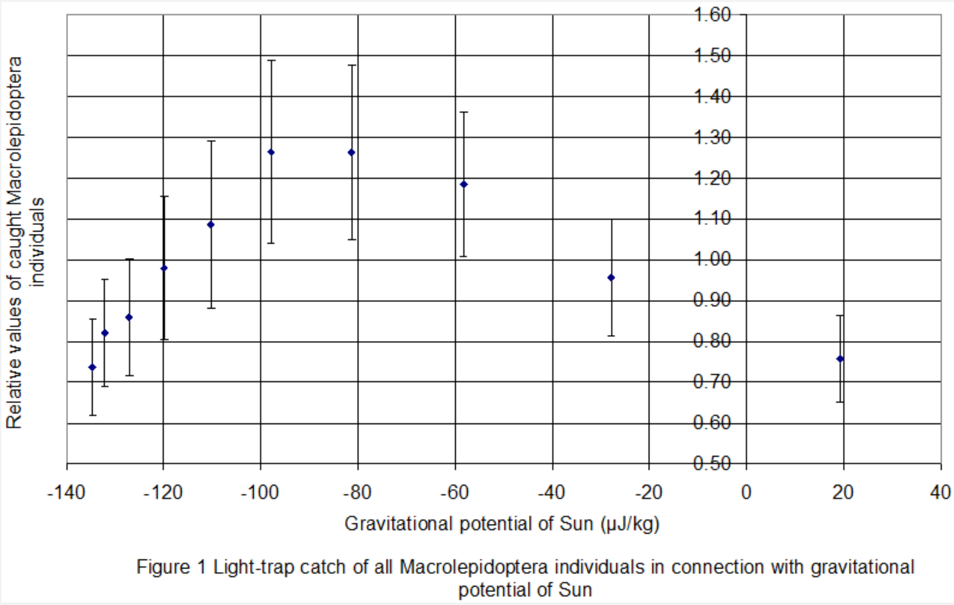

Figure 1: Light-trap catch of all macrolepidoptera individuals in connection with gravitational potential of sun.

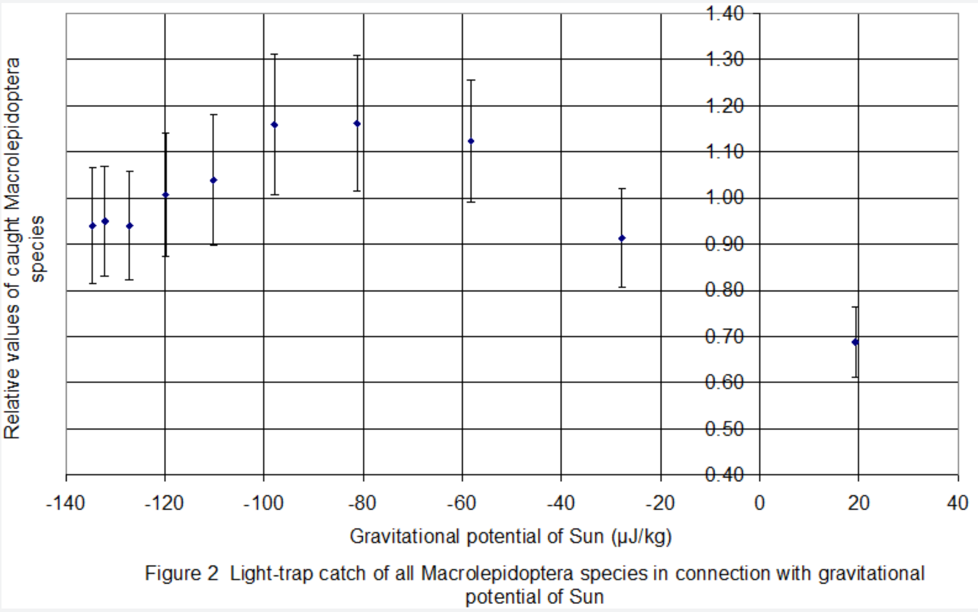

Figure 2: Light-trap catch of all macrolepidoptera pecies in connection with gravitational potential of sun.

The efficiency of gravitation potential of Sun for the catching results of caught individuals and species can be seen in Figure 1 & 2. The Sun is over the horizon only in the first and last collection hours, so it is there at dusk and dawn. Nevertheless, both its effects of the sky polarization and gravitation on the Macrolepidoptera individuals and species are larger than the Moon's influence. Our current result partially confirms and partially refutes our previous results. In our previous study [24], we processed the catch data of only one species (Turnip moth, *Agrotis segetum Denis et Schiffermüller*), but there we

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had only hourly catch data. We established in the study, that the gravitational potential of the Sun and the sky polarization caused by the Sun have an influence only in the period of dusk and dawn. The efficiency of night sky polarization originated by Sun for the catching results of caught individuals and species can be seen in Figure 3 & 4.

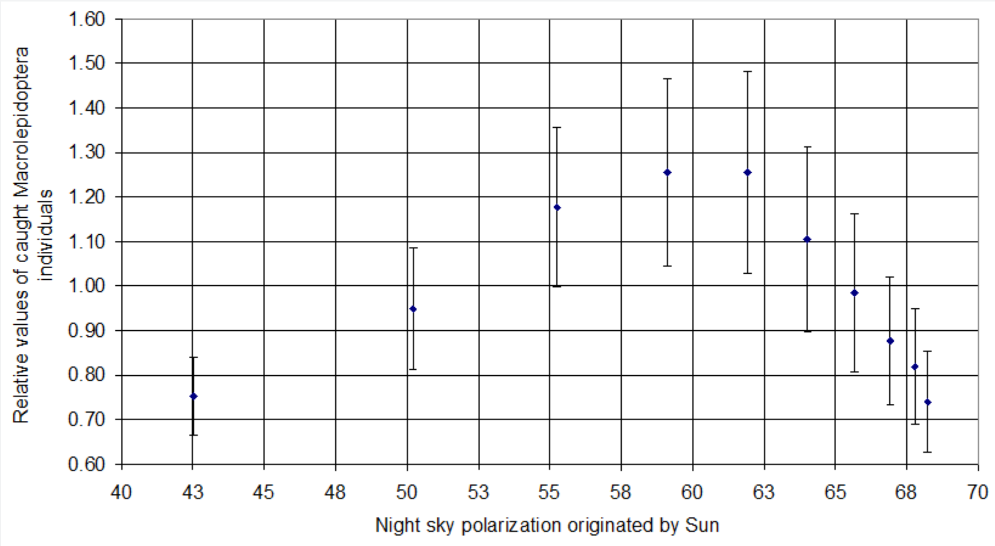

Figure 3 Light-trap catch of all Macrolepidoptera individuals in connection with night sky polarization originated by Sun

Figure 3: Light-trap catch of all macrolepidoptera individuals in connection with night sky polarization originated by sun.

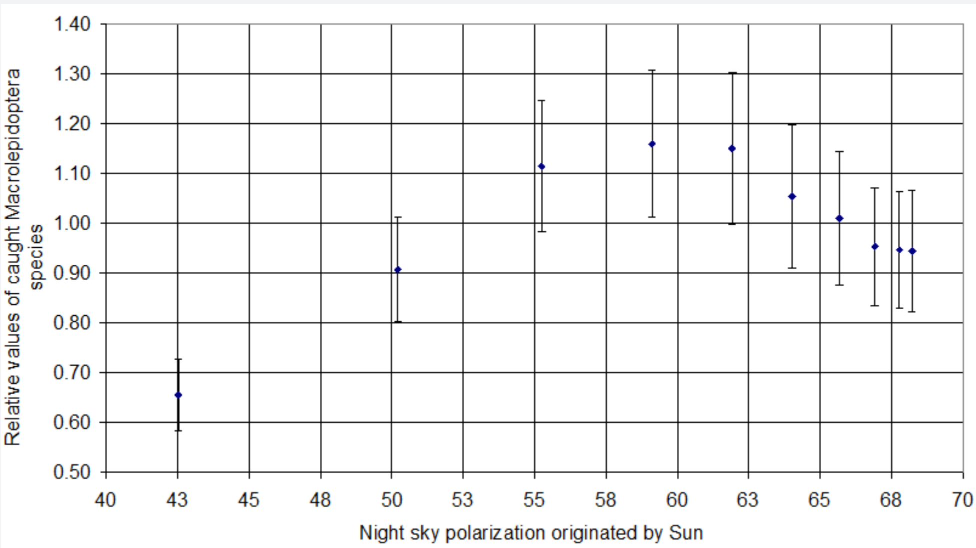

Figure 4 Light-trap catch of all Macrolepidoptera species in connection with night sky polarization originated by Sun

Figure 4: Light-trap catch of all macrolepidoptera pieces in connection with night sky polarization originated by sun.

In the largest part of the night the Moon has a greater influence on the light trap catch. However, our both studies proved that the gravitation of celestial bodies and the polarization of the sky have an influence on the collection. This is a new result and we did not find any precedent in the literature. Therefore, these should be taken into account when assessing the light trap catch results.

Conclusion

Our recent work calls attention of researchers to new and perhaps even more influential environmental factors. These are the gravitational potential of the Sun and the sky polarization originated by the Sun.

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Acknowledgement

We would like to thank J Kovács (ELTE Astrophysical Observatory, Szombathely) for calculating the Sun and Moon data and describing the method of investigation.

of the low rate of formation of the crystallohydrate of Darunavir and proves the high probability of the fact that the water contained in PRE¬ZISTA and KEMERUVIR tablets is hygroscopic.

Based on the evidence found, we may assert that as API the crystalline Darunavir Ethanolate and Darunavir Amorphous have no substantial advantages over each other.

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How to cite this article: László N, Miklós K, János P, András B. Light Trapping of Caught Macrolepidoptera Individuals and Species in Connection with Night Sky Polarization and Gravitational Potential of Sun. Mod Appl Bioequiv Availab. 2017; 2(4): 555594.

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Acta Phytopathologica et Entomologica Hungarica 34 (1–2), pp. 123–126 (1999)

Light Trapping of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in Connection with the Sun's Ultraviolet Radiation

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In present study the authors examined the light trapping success of European Corn Borer (*Ostrinia nubilalis* Hübner) adults in connection with the ultraviolet radiation of the Sun. According to their data the number of moths caught by the traps decreased on those nights when on the preceding day the ultraviolet radiation was lower than the monthly average; at the same time the catch increased when during the day before the radiation has exceeded the monthly average. If the low or high UV radiation prevails for more than one day, its influence on the trapping success becomes more pronounced.

Key words: European Corn Borer, Ostrinia, UV radiation, light-traps.

The most important knowledge on the Sun's UV radiation can be summarised in the following (Örményi, 1991):

One of the most important ranges of sunshine is the band of ultraviolet radiation. According to the international classification of Schulze (1970) radiation on the Earth's surface can be detected in two domains, i.e. UV "A" (315–390 nm) and UV "B" (290–315 nm). Radiation can be measured both by physical, chemical and biological methods. In his above-mentioned study Örményi (1971) has used physical ones.

The world-wide known instruments applying the physical methods are the following:

a) – Eppley UV radiation counter (Marchgraber and Drummonand, 1960) and

b) – the Robertson (1972) and Berger (1976) UV radiation counter (sunburnmeter) working mainly in UV "B" range.

Especially the UV "B" range is detrimental in large quantities to living organisms. The authors did not find either in Hungarian or in the international literature papers that dealt with the effect of the Sun's ultraviolet radiation. We studied therefore that on the nights following days with average, high or low radiation levels the number of corn borer (*Ostrinia nubilais* Hbn.) adults differed.

Materials and Methods

The global ultraviolet radiation was studied by Örményi (1991) from 1978 until 1993 in Budapest, at the site of St. Lucas Bath. These data were used in evaluating the catch results of European Corn Borer (*Ostrinia nubilalis* Hbn.).

The above-mentioned catch data were used for examining the data received from 39 stations of the National Agricultural light-trap network (1978–1993). These traps caught during 2183 nights among others 70,588 Corn Borer individuals; in our examination we used 23,032 observing data, i.e. the catch data of one night at one station independently of the number of moths caught.

Measuring the Sun's ultraviolet radiation

Measurements have been carried out by an Eppley UV radiometer mounted on a two and half meter high iron frame on the sun-bathing terrace of the National Institute for Reumatism and Physiotherapy (St. Lucas Bath). The measuring took place 148 in high above sea level. The device is qualified to measure the ultraviolet radiation of the Sun and sky. On the device two measuring heads were applied: in the first five-year period the head of No. 13 738, in the second period that of No. 13 737 was used (Eppley, 1974a,b). After these periods the heads were newly calibrated by the manufacturer; besides these, the devices were checked several times during these periods at the Bratislava Institute of Meteorology and Hydrology.

The segment of the horizon for the measuring place was determined by an ATS Soviet theodolite and amounted to 2.5% on the average, due to the neighbouring Buda mountains.

The device itself consisted of a photometer, a Weston photo-cell and an UG 11 wide-band filter. The spectrum activity of the latter was in the range of 290 to 385 nm, with a maximum value of 335 nm. The measuring head was covered by a Quartz filter that needed regular cleaning (Eppley Labor Inc., 1975). The head was connected to the recording compensograph (Leeds and Northrup Speedomax S-type) by an erthed coaxial cable. The values were recorded on the band in mV units. The calibration of the device was made in regular intervals, which practically meant that a socket with a tungtan iodine lamp fitting to the detachable top of the measuring head was placed on the top. By switching on the lamp an artificial UV radiation was generated and the compensograph showed its maximum value. Should this not happen, the head of the device was considered defective.

The daily values of the ultraviolet radiation (W/m^2) were expressed in the percentage of monthly average, then ranged into categories. From the lower values 3 categories (the ones lower than 25% the ones between 26 and 50%) from the higher ones two categories (126–150% and higher than 150%) were composed, while 1 category was reserved for values not differing considerably from the average (between 76 and 125%).

Methods of processing the catching data of light-traps

The environmental factors are not the same in all places and at all times of trapping; if the same individual number have been caught at two different stations or in different periods, that would have indicated by all means numerically different populations. To solve the problem, we calculated from the catch data relative catch (RC) values for observation sites and generations. RC is the quotient of the number of individuals caught during the sampling interval (1 night) and the mean values of the number of individuals of one generation counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

The different relative catch data belonging to different stations were summarised for each night, then ranged into the UV radiation category belonging to the data given. Within the categories we also indicated for how long (how many days), the low or high values remained in existence. The relative catch data were averaged within each category, then the significance level of their difference relative to the average was calculated by *t*-test following an analysis of variance.

Results

Our results are shown in Table 1.

Table 1

Light-trap catch of European Corn Borer (*Ostrinia nubilalis* Hbn.) given on the values of monthly average percent of Sun's ultraviolet radiation, also given according to the existence length of time

Length of time in days	UV value in monthly average%	Average of relative catch	Number of observing data	Significance level (%)
1	2	3	4	5
		Less UV value than 25% of monthly average		
1	19.73	0.142	15	95.0
		UV value between 26–50% of monthly average		
1	40.04	0.606	712	99.9
2	38.47	0.336	125	99.9
		UV value between 51–75% of monthly average		
1	64.69	0.941	2035	–
2	63.44	0.689	206	99.0
3	63.15	0.212	44	99.0
		UV value between 76–125% monthly average		
1	102.28	0.924	4064	99.0
2	102.99	1.006	2762	–
3	104.50	1.176	2120	99.9
4	102.40	1.142	1712	99.9
		UV value between 126–150% monthly average		
1	133.17	0.888	2123	99.9
2	133.82	1.100	576	–
3	133.84	1.162	268	–
4	134.20	1.357	155	99.0
		UV value more than 150% of monthly average		
1	155.94	0.593	104	99.0
2	152.82	1.622	38	95.0
All	99.74	0.999	23032	

Notes: The significance level, given in column 5, was calculated compared to the average of all the other cases. Values of relative catch were shown with italic, if the significance levels of neighbouring days differ on the level of 95%.

Discussion

Our results prove that the low light-trap catch values of European Corn Borer (*Ostrinia nubilalis* Hbn.) belonged to low values of ultraviolet radiation, and conversely, at the time of high ultraviolet radiation values the number of caught individuals also increased. It is remarkable that the high light-trap catches could be found only from the second day of high ultraviolet radiation existence.

Our present examinations did not answer that question, how the dose of daily ultraviolet radiation could be connected to the number of Corn Borer individuals caught by the traps during the following night. We suppose that ionization produced by ultraviolet radiation, influenced in a positive way the success of catch.

The ultraviolet radiation of Sun increases (Saikó, 1963) after the increase of number of sunspots. This event influences mainly the high atmosphere, because of ionization caused (Saikó, 1979). Errors and ionospheric storms can be caused by changes in radiation force, causing ionization in the F level of atmosphere (Saikó, 1963). As it was shown already in earlier papers (Nowinszky and Tóth, 1994) the light-trap catch of four harmful Geometrid moths had increased at the time of positive ionosphere storms, but it decreased at negative storms.

Ionization was examined at the sun-bathing terrace in the St. Lucas Bath of the National Institute for Rheumatics and Physiotherapy in Budapest (Örményi, 1967). According to his conclusions the number of small to medium positive ions increases parallel to the force of Sun's radiation, but the number of negative and ultra-large ions decreases. His establishments be useful in medical meteorologyresearches.

After further studies and tests our results can be well used in plant protection prognostics.

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http://www.soeagra.com
ISSN 0976-4585

RESEARCH PAPER

Flying Activity of the Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) Influenced by Ozone Content of Air

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ABSTRACT
The study deals the efficiency of light trapping of the Scarce Bordered Straw (Helicoverpa armigera Hbn.) in connection with the ozone content of air. The collection data of which use was made the Hungarian national light trap network between years 1997 and 2006. We calculated relative catch values from the number of caught insects. We assigned these to the ozone values, we averaged them, and we depicted the results together with the regression equation though.
We established that the light trapping of this species most fruitful when the ozone content of the air exceeds it the 80 µg/m3 value. As opposed to this, the low ozone values reduce the successfulness of the catching on one moderated only. Our results will be exploitable in the plant protecting and environment conservation researches.
Key words: *Helicoverpa armigera Hbn., light-trap, ozone*

INTRODUCTION

The ozone content of the air influences the strength of UV-B radiation which in its turn, as proved by our previous studies [1], bears an impact on the effectiveness of collecting insects by light-trap. Therefore it seemed reasonable to try and find a connection also between the ozone content of the air and the number of insects trapped [2].

In Hungary, ozone monitoring is carried out at four stations of the Hungarian National Meteorological Service. Monitoring at K-puszta (The geographical coordinates are 46.58 N and 19.35E) has been done since 1990. Today 10 minute average concentration values are detected at every station with the help of the ozone monitors. Since 1998, MILOS has forwarded data and QLC, having been collected earlier by a local data collecting programme (SCANAIR) and stored in PCs. SCANAIR reduced 15-minute data into half-hour averages which were then entered in the data base. At the K-puszta the job is performed by an Environment type monitor. A Thermo Electron type monitor also makes parallel monitoring possible. The ozone monitors are UV photometric ozone analysers which establish ozone concentration by illuminating with a UV lamp an air sample drawn into an absorption cell, then measuring the decline of illumination at a wavelength of 254 nm. The extent of this is proportionate to the ozone content of the air. The instrument establishes the ozone concentration in a ppb unit, by taking samples in every 10 minutes. The data are in a 0-150 ppb–s range. Sometimes negative values are received after calibration: this is to be handled as 0. High ozone values (> 100 ppb) occur mainly in the summer season, sometimes in early spring. Values over 120 ppb were measured vary rarely (so far in 1 -2 cases). A Thermo Electron type ozone calibrator is being used. Every measuring instrument must be calibrated at least once a year, in fact, the ozone calibrator, too, must be regularly adjusted to the international standard (in Prague). Calibration and data control cannot be fully automated, as the daily curves must be checked separately and outstanding data must not be automatically discarded. Each data is earmarked with a mistake code, which characterizes the quality of the data. Every external circumstance, including the various meteorological features must be examined (wind direction, wind speed, temperature, etc.) to explain extreme and seemingly wrong ozone values. A final file of data stores the raw measurement data, the calibrated and controlled data and the mistake code referring to data quality. The database is copied to CDs annually.

Ozone content in the summer months - from May until August - is higher than in other months of the year. There are typical daily changes. The ozone content is high from noon to evening and goes down from evening to dawn. It hits its lowest point in the dawn hours and begins to rise again in the early morning. Ozone concentrations in the atmosphere depended on several meteorological factors, too [3]. Greek authors [4, 5, 6, 7, 8, 9] in Greece have been studying the monthly changes and those in the different periods of each day of the ozone content.

The high concentration of ozone is maleficent to insects. The study of Kells et al. [10] evaluated the efficacy of ozone as a fumigant to disinfest stored maize. Treatment of 8.9 tonnes of maize with 50 ppm ozone for 3 days resulted in 92–100% mortality of adult Red Flour Beetle, *Tribolium castaneum* (Herbst), adult Maize Weevil, *Sitophilus zeamais* (Motsch.), and larval Indian Meal Moth, *Plodia interpunctella* (Hübner).

Biological effects of ozone have been investigated by Qassem [11] as an alternative method for grain disinfestations. Ozone at concentration of $0.07 g/m^3$ killed adults of Grain Weevil (*Sitophilus granarius* L.), Rice Weevil (*Sitophilus oryzae* L.) and Lesser Grain Borer (*Rhyzopertha dominica* Fabr.) after 5-15 hours of exposure. Adult death of Rice Flour Beetle (*Tribolium confusum* Duv.) and Saw-toothed Grain Beetle (*Oryzaephilus surinamensis* L.) was about 50% after 15-20 hours of exposure. Total adult death of all insect species was made with $1.45 g/m^3$ ozone concentration after one hour of exposure. Valli and Callahan [12] examinations made with light traps indicated an inverse relationship between O_3 and insect activity.

We know altogether a study in literature, which examines by the ozone contents of the air, in connection with the efficiency of the light trap catch of the insects. We assessed in an earlier study [1] the number caught of European Corn Borer (*Ostrinia nubilalis* Hbn.) (Lepidoptra: Pyraustidae) increase if the ozone content of air high.

MATERIAL AND METHODS

In our study we used the data pertaining to the Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) from the material of the Hungarian national light-trap network in the years 1997-2006. For we had at our disposal the ozone data registered at K-puszta in the same years.

We have downloaded these data ($\mu g/m^3$) from the website of Norsk institutt for luftforskning (Norvegian Institute for Air Research (NILU) (http://tarantula.nilu.no/projects/ ccc/emepdata. hzml/). The geographical coordinates of K-puszta are the following: 46° 58’ N and 19° 35’ E

Because the Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) flies in whole night, we worked with the ozone data of the time 23 o’clock (GMT). The light-traps have caught 3882 moths on 533 nights. We have worked up the 1397 observing data.

Observing data means the catching of one trap in one night, regardless of the number of insects caught. The number of observing data exceeds the number of the nights because more light-traps have worked on a night.

From the catching data of the examined species, relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 night) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number, the RC value is 1. We correlated the ozone data to the relative catch values. We arranged the pairs of data in classes, and then averaged them. We made correlation calculations to prove the connection.

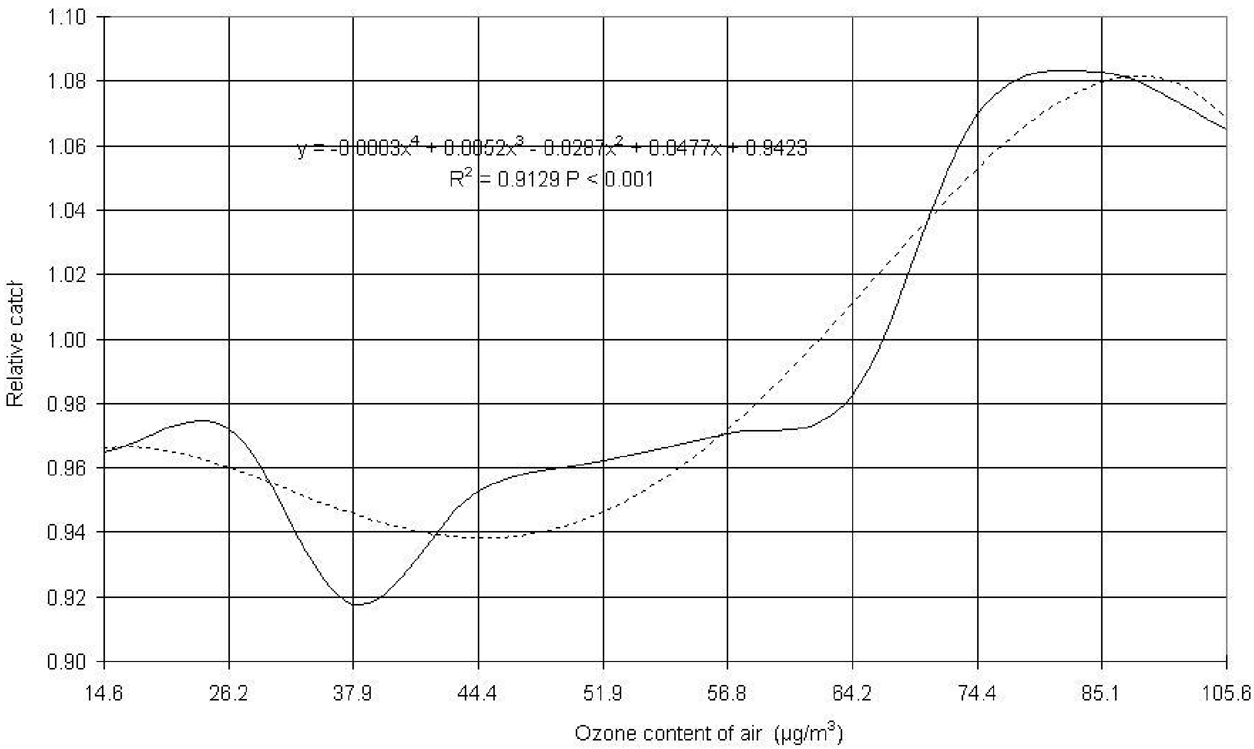
RESULTS AND DISCUSSION

Our results, including regression equations and significance levels, are displayed in Fig. 1.

Our earlier and present results suggest that the flying activity of the European Corn Borer *(Ostrinia nubilalis* Hbn.) and Common Cockchafer (*Melolontha melolontha* L.) increase when the ozone content is high. The light-trap catches verify this fact. We suggest similar examinations onto other harmful insect species relevantly with other sampling methods (for example pheromone-, suction-, Malaise-, bait traps). If it would be provable that the high ozone content of air increases the flying activity of other insect species, it would be necessary to take this fact into consideration when developing the plant protection prognoses. There could be more accurate plant protection prognosis hereby be prepared. Our result contradicts that of Valli and Callahan (1968), who experienced a decrease, in the activity of Corn Earworm (*Heliothis zea* Boddie) with the increase of the ozone content in parallel with.

It may be the reason of the contradiction that low relative catch values always refer to environmental factors in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism.

Fig. 1.
Light-trap catch of Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) in connected with the ozone content of air from the data of Hungarian national network (1997-2006)



The imago is short-lived; therefore unfavourable environmental endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to environmental factors an unfavourable situation. And so by the present state of our knowledge we might say that favourable and unfavourable environmental factors might equally be accompanied by a high catch.

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ISSN 0976-7614
RESEARCH ARTICLE

LIGHT-TRAP CATCH OF THE HARMFUL INSECTS IN CONNECTION WITH THE OZONE CONTENT OF THE AIR

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ABSTRACT

The study deals the efficiency of light trapping of the European Corn Borer (Ostrinia nubilalis Hbn.) and the Common Cockchafer (Melolontha melolontha L.) in connection with the ozone content of air. The collection data of which use was made the Hungarian national light trap network between years 1997 and 2006. We calculated relative catch values from the number of caught insects. We assigned these to the ozone values, we averaged them, and we depicted the results together with the regression equation though.

We established that the light trapping of this species most fruitful when the ozone content of the air is high. As opposed to this, the low ozone values reduce the successfulness of the catching on one moderated only. Our results will be exploitable in the plant protecting and environment conservation researches.

Keywords: Ostrinia nubilalis *Hb.*, Melolontha melolontha *L., light-trap, ozone.*

INTRODUCTION

The ozone content of the air influences the strength of UV-B radiation which in its turn, as proved by our previous studies (Puskás *et al*., 2001), bears an impact on the effectiveness of collecting insects by light-trap. Therefore, it seemed reasonable to try and find a connection also between the ozone content of the air and the number of insects trapped. In Hungary, ozone monitoring is carried out at four stations of the Hungarian National Meteorological Service (K-puszta, Hortobágy, Farkasfa and Nyírjes). Monitoring at K-puszta has been done since 1990 and in the other three villages since 1996. Today 10 minute average concentration values are detected at every station with the help of the ozone monitors. Since 1998, MILOS has forwarded data and QLC, having been collected earlier by a local data collecting programmed (SCANAIR) and stored in PCs. SCANAIR reduced 15-minute data into half-hour averages which were then entered in the data base. At three of the stations (K-puszta, Hortobágy, Farkasfa and Nyírjes), the job is performed by an Environment type monitor. A Thermo Electron type monitor at K-puszta also makes parallel monitoring possible. The ozone monitors are UV photometric ozone analyzers which establish ozone concentration by illuminating with a UV lamp an air sample drawn into an absorption cell, then measuring the decline of illumination at a wavelength of 254 nm. The extent of this is proportionate to the ozone content of the air. The instrument establishes the ozone concentration in a ppb unit, by taking samples in every 10 minutes. The data are in a 0-150 ppb–s range. Sometimes negative values are received after calibration: this is to be handled as 0. High ozone values (> 100 ppb) occur mainly in the summer season, sometimes in early spring. Values over 120 ppb were measured vary rarely (so far in 1 -2 cases). A Thermo Electron type ozone calibrator is being used. Every measuring instrument must be calibrated at least once a year, in fact, the ozone calibrator, too, must be regularly adjusted to the international standard (in Prague). Calibration and data control cannot be fully automated, as the daily curves must be checked separately and outstanding data must not be automatically discarded. Each data is earmarked with a mistake code, which characterizes the quality of the data. Every external circumstance, including the various meteorological features must be examined (wind direction, wind speed, temperature etc.) to explain extreme and seemingly wrong ozone values. A final file of data stores the raw measurement data, the calibrated and controlled data and the mistake code referring to data quality. The database is copied to CDs annually (Puskás *et al*., 2001).

Ozone content in the summer months - from May until August - is higher than in other months of the year. There are typical daily changes. The ozone content is high from noon to evening and goes down from evening to dawn. It hits its lowest point in the dawn hours and begins to rise again in the early morning. Ozone concentrations in the atmosphere depended on several meteorological factors, too (Tiwari *et al*., 2008).

Kalabokas and Bartzis (1998); Kalabokas *et al*., (2000); Kalabokas (2002); Papanastasiou *et al*., (2002 and 2003); Papanastasiou and Melas (2006) in Greece have been studying the monthly changes and those in the different periods of each day of the ozone content. Ozone content in the summer months – from May until August – is higher than in other months of the year. There are typical daily changes. The ozone content is high from noon to evening and goes down from evening to dawn. It hits its lowest point in the dawn hours and begins to rise again in the early morning.

The high concentration of ozone is maleficent to insects. The study of Kells *et al*., (2001) evaluated the efficacy of ozone as a fumigant to disinfest stored maize. Treatment of 8.9 tonnes of maize with 50 ppm ozone for 3 days resulted in 92–100% mortality of adult Red Flour Beetle, *Tribolium castaneum* (Herbst), adult Maize Weevil, *Sitophilus zeamais* (Motsch.), and larval Indian Meal Moth, *Plodia interpunctella* (Hübner). Biological effects of ozone have been investigated by Qassem (2006) as an alternative method for grain disinfestations. Ozone at concentration of 0.07g/m^3 killed adults of Grain Weevil (*Sitophilus granarius* L.), Rice Weevil (*Sitophilus oryzae* L.) and Lesser Grain Borer (*Rhyzopertha dominica* Fabr.) after 5-15 hours of exposure. Adult death of Rice Flour Beetle (*Tribolium confusum* Duv.) and Saw-toothed Grain Beetle (*Oryzaephilus surinamensis* L.) was about 50% after 15-20 hours of exposure. Total adult death of all insect species was made with 1.45 g/m^3 ozone concentration after one hour of exposure. Valli and Callahan (1968) examinations made with light traps indicated an inverse relationship between O_3 and insect activity.

MATERIALS

For we had at our disposal the ozone data registered at K-puszta between 1997-2006 years. We have downloaded these data (µg/m^3) from the website of Norsk institutt for luftforskning (Norvegian Institute for Air

Research (NILU) (http://tarantula.nilu.no/projects/ccc/emepdata. hzml/). The geographical coordinates of K-puszta are the following: 46° 58' N and 19° 35' E.

In our study we used the data pertaining to the European Corn Borer (*Ostrinia nubilalis* Hbn.) from the material of the Hungarian national light-trap network in the years 1997-2001. For we had at our disposal the ozone data registered at K-puszta in the same years. As we could not tell in what distance from the monitoring site the assumed impact of the ozone content could be detected, we processed data supplied first by the light-traps within 50 kilometres, then 100 kilometres and finally those provided by all the light-traps in the country. We used the same methods in all three examinations.

The ozone content of the air was monitored once in every hour, while the light-traps supplied a single data of the whole night of collecting. However, the European corn borer (*Ostrinia nubilalis* Hbn.) flies to light throughout the night (Járfás, 1979), and its activity reaches its maximum between 9h p.m. and 2h a.m. Therefore we correlated the collecting data to the ozone data monitored at 11h p.m. (UT). However, with the detected ozone values showing essential differences by years and even months, we could not work with the original data. Therefore we calculated relative ozone values by dividing the ozone values of the given calendar dates by the average of the period of the preceding and following three nights, a total of seven nights that is, and used these relative values in further calculations.

In our study, we used the data pertaining to the Common Cockchafer (*Melolontha melolontha* L.) (Coleoptera: Melolonthidae) from the material of the material of those light-traps which operated up to 100 km away from the K-puszta in the years 1997-2006.

Because the Common Cockchafer (*Melolontha Melolontha* L.) fly only in mid April to mid May and in the twilight hours only, the ozone data is only slightly changed during this period, there was no ozone data measured by the relative values are expected.

Accordingly we worked with the ozone data of the time 20 o'clock (GMT).

The data used are seen in table 1.

Number of	Within 50 km	Within 100 km	All light-traps
European Corn Borer (Ostrinia nubilalis Hbn.)			
Light-traps	7	22	42
Observing data	1570	5712	13237
Specimens	354	13569	27882
Nights	555	650	653
Common Cockchafer (Melolontha melolontha L.)			
Light-traps	—	22	—
Observing data	—	2627	—
Specimens	—	12551	—
Nights	—	422	—

Table 1: Catching data of the European Corn Borer (*Ostrinia nubilalis* Hbn.) from years between 1997-2001 and the Common Cockchafer (*Melolontha melolontha* L.) from years between 1997-2006.

METHODS

From the catch data we calculated relative catch values by generations at all the observation posts. The relative catch (RC) is the dividend of the number of individuals trapped in one unit of sampling, in case, one night, and the average number of specimens of a generation in a time unit of sampling. Observing data means the catching of one trap in one night, regardless of the number of insects caught. The number of observing data exceeds the number of the nights because more light-traps have worked on a night.

We correlated the relative catch values to the relative ozone data belonging to the same date and prepared in the way described above. We arranged the pairs of data in classes, then averaged and depict them. We have calculated regression equations, the strength of correlation and significance levels.

RESULTS AND DISCUSSION

Our results, including regression equations and significance levels, are displayed in Fig.1-4.

Fig. 1

Light-trap catch of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in connection with the ozone content of air, less then 50 km away to K-puszta

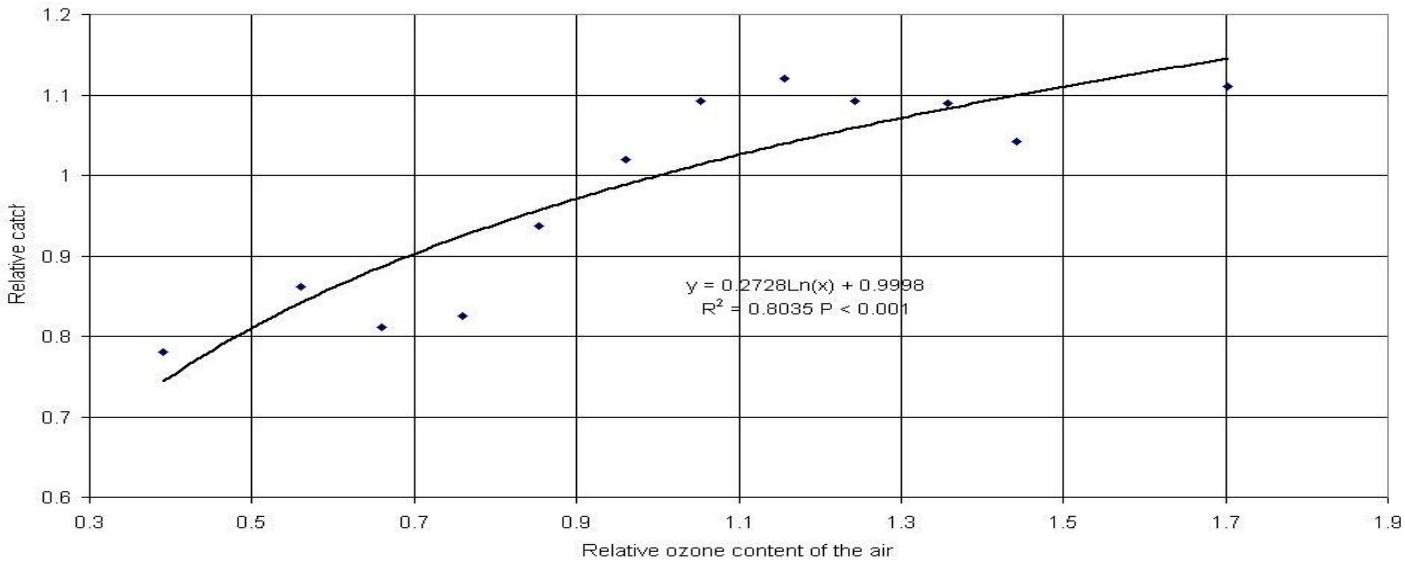


Fig. 2

Light-trap catch of the European Corn Borer (*Ostrinia nubilalis* Hbn.9 in connection with the ozone content of air, less than 100 km away to The K-puszta

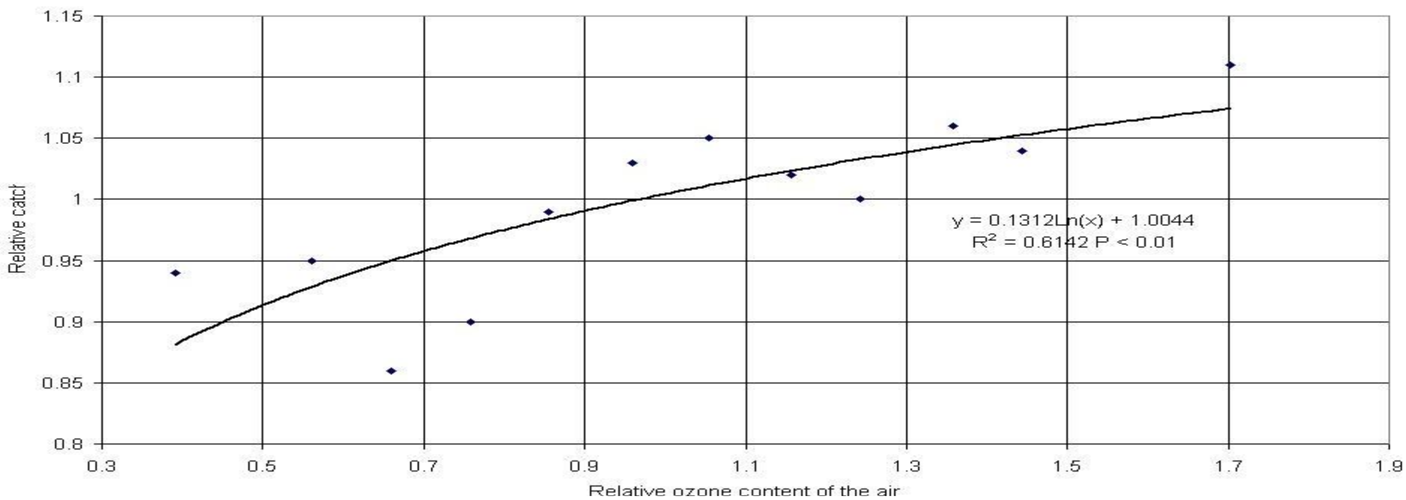


Fig. 3

Light-trap catch of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in connection with the ozone content of air, all the Hungary

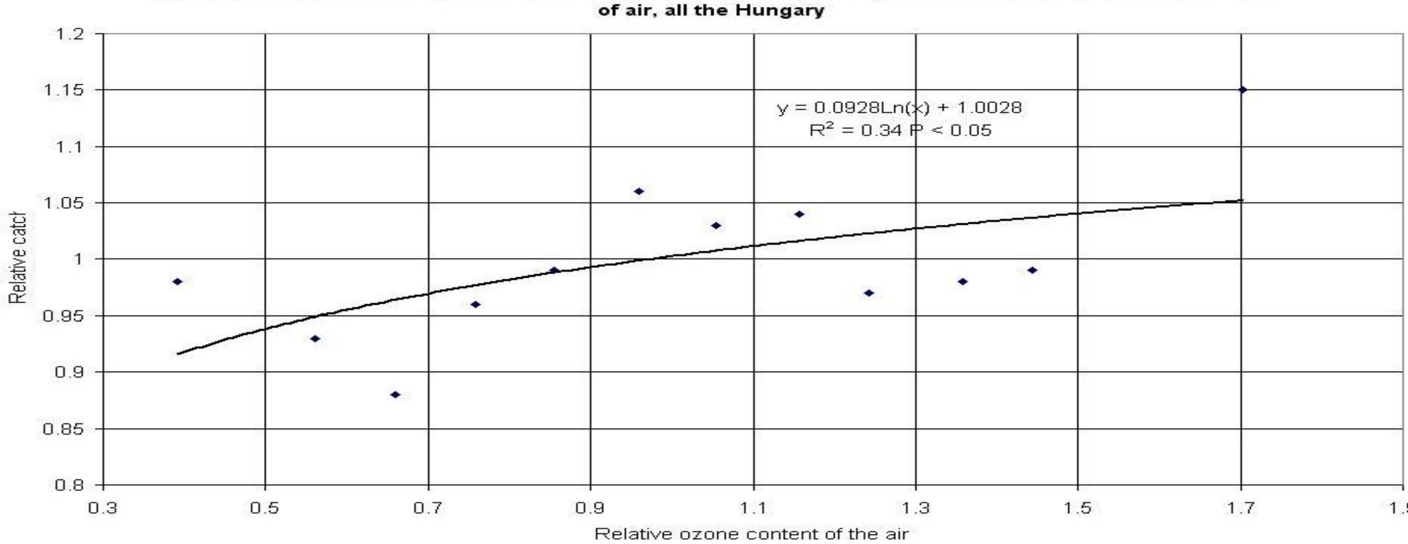
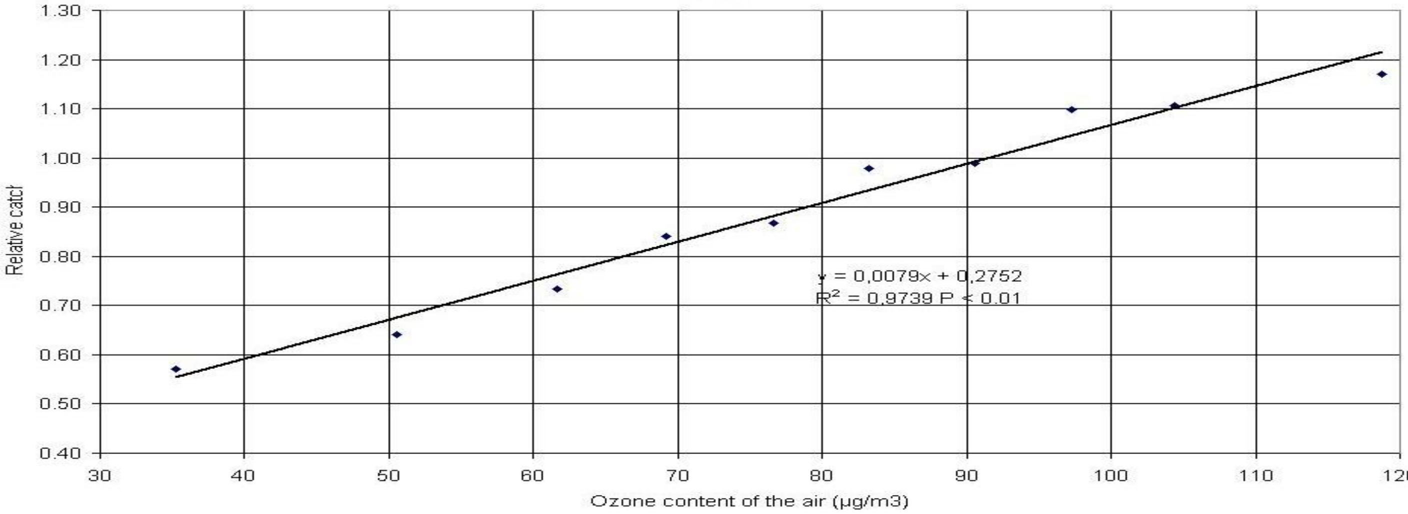


Fig. 4

Light-trap catch of the Common Cochcafer (*Melolontha melolontha* L.) depending on the ozone content of the air



Our present results suggest that the flying activity of the European Corn Borer *(Ostrinia nubilalis* Hbn.) and Common Cockchafer (*Melolontha melolontha* L.) increase when the ozone content is high. The light-trap catches verify this fact.

Our results have shown that high ozone content of the air is accompanied by a higher light-trap catch. The influence of the ozone content is detected in 100 kilometres from the monitoring site and is hardly weaker than within a 50 kilometre distance.

We suggest similar examinations onto other harmful insect species relevantly with other sampling methods (for example pheromone-, suction-, Malaise-, bait traps). If it would be provable that the high ozone content of air increases the flying activity of other insect species, it would be necessary to take this fact into consideration when developing the plant protection prognoses. There could be more accurate plant protection prognosis hereby be prepared. Our result contradicts that of Valli and Callahan (1968), who experienced a decrease, in the activity of Corn Earworm (*Heliothis zea* Boddie) with the increase of the ozone content in parallel with. It may be the reason of the contradiction that low relative catch values always refer to environmental factors in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism. The imago is short-lived; therefore unfavorable environmental endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to environmental factors an unfavorable situation. And so by the present state of our knowledge we might say that favorable and unfavorable environmental factors might equally be accompanied by a high catch (Nowinszky, 2003).

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MODELLING THE IMPACT OF TROPOSPHERIC OZONE CONTENT ON LIGHT- AND PHEROMONE-TRAPPED INSECTS

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(Received 3rd May 2012; accepted 17th October 2012)

Abstract. The study investigates the effect of the tropospheric ozone content on the relative catch of European Vine Moth (*Lobesia botrana* Den. et Schiff.), Spotted Tentiform Leafminer (*Phyllonoricter blancardella* Fabr.), Setaceous Hebrew Character (*Xestia c-nigrum* L.), Latticed Heath (*Chiasmia clathrata* L.), April Beetle (*Rhizotrogus aequinoctialis* Herbst) and *Ecnomus tenellus* Rambur trapped between 2004 and 2011 in Hungary. In order to describe the empirical connection between the ozone content of the air and the relative number of trapped insects, we introduce some nonlinear regression models of the same general model as origin. We show that elevated ozone content of air stimulates basically two different kinds of response in flying activity of insects.
Keywords: *ozone, insect, trap, Hungary, nonlinear regression models*

Introduction

According to the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC, 2007) tropospheric ozone (O_3) is the third most important anthropogenic contributor to greenhouse radiative forcing (3-7%) with a medium level of scientific understanding. Summer daytime ozone concentration correlates strongly with temperature. Tropospheric ozone is expected to increase at 40-60% up to the end of the 21st century which is linked to air quality and climate change (Meleux et al., 2007).

Tropospheric ozone was first determined to be phytotoxic to grapes in southern California in the 1950s (Karnosky et al., 2007). Ozone is a harmful agent causing oxidative stress on plants which may vary in their tolerances. Changes in agricultural productivity can be, in one hand, the result of direct effects of ozone at the plant level, or, in the other hand the consequence of indirect effects at the system level, for instance, through shifts in nutrient cycling, crop–weed interactions, insect pest occurrence, and plant diseases (Fuhrer, 2003).

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The tropospheric ozone (O_3) concentration has been monitored in Hungary at K-puszta (46°58'N 19°35') by the Hungarian Meteorological Service (HMS) since 1996, with 10 minutes averaged ozone concentration detected. Since 2004 the monitoring system was extended to 10 stations in Budapest and 37 ones in other locations throughout Hungary. The ozone content of the air is usually measured in ppm, ppb, µg or mg units (0.1 ppm O_3 by weight = 100 ppb O_3 by weight = 200 µg O_3/m^3 = 0.2 mg O_3/m^3).

The highest ozone levels occur typically in towns and cities, however, in some situations high ozone content have been measures in locations even hundreds of kilometres far away from the emission sources. Elevated ozone concentration is detected usually in summer months - from May until August – caused by bright sunshine and high temperature, or sometimes in early spring, mainly in March (Ferenczy, 2012).

Kalabokas and Bartzis (1998), Kalabokas (2002), Kalabokas et al. (2000) Papanastasiou et al. (2002, 2003) as well as Papanastasiou and Melas (2006) in Greece have studied the daily and monthly ozone content fluctuation. The ozone content is usually higher from noon to evening and decreasing from evening to dawn. It hits its lowest point in the dawn hours and begins to rise again in the early morning. However, according to Juhász et al. (2006) the ozone content of the atmosphere is occasionally still significantly high during the night.

Nevertheless, all external circumstances, including the various meteorological features (wind direction, wind speed, temperature, UV-radiation etc.) should also be considered in order to explain extreme ozone content values (Puskás et al., 2001).

In Hungary, according to the measurements of the Hungarian Meteorological Service (www.met.hu) the health protection threshold of ozone (according to the European Committee Directive, the highest 8-hour mean within one day is higher than 120 µg/m^3, http://www.eea.europa.eu/maps/ozone/legislation/eu-legislation-and-directives) are exceeded often in summer, the population information threshold (180 µg/m^3 for the mean value over one hour) are exceeded very rarely while the population warning threshold (240 µg/m^3 for the mean value over one hour) are extremely rarely.

Review of literature

Ozone in plant – insect relations

DeLucia et al. (2005) tested the hypothesis that changes in tropospheric chemistry affect the relationship between plants and insect herbivores by changing leaf quality. Their data suggest that global change in the form of elevated levels of CO and O_3 may exacerbate pest problems and, moreover, changes in tropospheric chemistry can alter the key aspects of leaf chemistry which affect the feeding and demographic performance of insects, thereby modulate the risk of crop damage by insect herbivores (Ashmore and Bell, 1991).

Through changes in metabolic processes, ozone has an impact on the quality of host plants of the phytophagous insects which indirectly can influence both the phytophagous insects and their predators and parasites (Holton et al., 2003). Agrell et al. (2005) introduced a phytophagous forest pest insect (*Malacosomadisstria*) whose food preferences changed as a result of ozone concentration change.

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Holopainen et al.(1997), Peltonen et al. (2006) and Percy et al.(2002) give further examples on the phytotoxic effects of plant-mediated O_3 on the behavior and functional activity of insects.

Ozone in pest-predator relations

Pinto et al. (2007, 2008) formulated their conjecture that, during an oxidative reaction, ozone degrades herbal fragrances induced from the host plant by the herbivores. Since herbal fragrances serve as an important signal for the natural enemies (predators or parasitoids) of herbivores, elevated ozone can weaken their orientation efficiency to find their prey or host (Butler et al, 2009; Gate et al., 1995; Holton et al., 2003; Dahlsten et al., 1997). Percy et al. (2002) detected significantly lower number of parasitoids under elevated ozone circumstances.

Though several publications consider the effect of tropospheric ozone concentration on plants or on the plant-insect communities, very few papers has its object on the relationship of ozone content of the air and insect activity. In an earlier study (Puskás et al., 2001), the authors detected the increase of the number of European Corn Borer (*Ostrinia nubilalis* Hbn.; Lepidoptra: Pyraustidae) caught when the ozone content in air was high. Puskás and Nowinszky (2010) established the same in case of the Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) and other harmful insects (Nowinszky and Puskás, 2011). Valli and Callahan (1968) indicated an inverse relationship between O_3 and insect activity, applying light traps.

Jones et al. (2004) have shown that elevated ozone concentration increase the susceptibility of the trees to bark beetles. Dahlstein et al. (1997) agree with Stark et al. (1968) and Grodzki et al., (2004) as they all have found that the number of *Dendroctonus brevicornis* and *Dendroctonus ponderosae* species increased while the number of their predators and parasitoids decreased on trees injured by ozone.

Ozonone as disinfectant

Extremely high concentration of ozone is harmful to insects. The study of Kells et al. (2001) evaluated the efficacy of ozone as a fumigant to disinfest stored maize. Treatment of 8.9 tonnes of maize with 50 ppm ozone for 3 days resulted in 92-100% mortality of adult Red Flour Beetle, *Tribolium castaneum* (Herbst), adult Maize Weevil, *Sitophilus zeamais* (Motsch.), and larval Indian Meal Moth, *Plodia interpunctella* (Hübner).

Biological effects of ozone have been investigated by Qassem (2006) as an alternative method for grain disinfestations. Ozone at concentration of 0.07 g/m^3 killed adults of Grain Weevil (*Sitophilus granarius* L.), Rice Weevil (*Sitophilus oryzae* L.) and Lesser Grain Borer (*Rhyzopertha dominica* Fabr.) after 5-15 hours of exposure. Adult death of Rice Flour Beetle (*Tribolium confusum* Duv.) and Saw-toothed Grain Beetle (*Oryzaephilus surinamensis* L.) was about 50% after 15-20 hours of exposure. Total adult death of all insect species was made with 1.45 g/m^3 ozone concentration after one hour of exposure. According to Bonjour et al. (2011), ozone fumigation has potential for the control of some stored grain insect pests on wheat.

Ozone effect experiments in laboratories

Direct effects of ozone on insects can be investigated mainly in laboratories while observations can supply information on complex (both direct and indirect) interactions,

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though exploring the relationship need high level caution (Alstad et al., 1982; Freedman, 1994; Butler et al., 2009).

Beard (1965) and Levy et al. (1972) executed long-term experiments on *Musca domestica* and *Drosophila* and *Stomoxys calcitrans.* They observed that ozone stimulated the ovipositional activity of female flies and the number of laid eggs was five times higher at elevated ozone concentration than at control circumstances.

Mondor et al. (2004) observed that in case ozone concentration was high, the intensity of escape reaction of *Chaitophorus stevensis* species has changed, the dispersity of the community increased sinificantly.

Observed ozone effect on ecosystems

Human-induced climate changes threaten the health of forest ecosystems. In particular, carbon dioxide (CO_2) and tropospheric ozone (O_3) will likely have significant but opposing impacts on forests and their associated insect communities. Hillstrom and Lindroth (2008) claim that, compared with other animal groups, insect communities are expected to be especially sensitive to changes in global climate. According to their observations between 2000 and 2003, elevated CO_2, and O_3, or both significantly affected insect community compositions in all years.

Since insects play key roles in forest ecosystems, changes in insect abundance, diversity or community composition have the potential to alter forest ecosystems. Regular monitoring and research on their response to global change is critically important to forest management and conservation.

Ozone and UV radiation

In previous studies of the authors (Puskás et al., 2001), it was proved that the ozone content of the air influences the strength of UV-B radiation which in its turn, bears an impact on the effectiveness of collecting insects by light-trap. Therefore, it seemed reasonable to find a direct empirical connection between the ozone content of the air and the number of trapped insects.

Materials and methods

The trapped species

European Vine Moth (Lobesia botrana Den. et Schiff.)

European Vine Moth is native to Southern Italy. It can be found throughout Europe in the Mediterranean, southern Russia, the Middle East, Near East, and northern and western Africa and Asia north of the Himalayas to Japan. Grape (*Vitis vinifera*) is its preferred hosts, but it has also been reported on several fruits (e.g. olive, blackberry, cherry, nectarine, persimmons and pomegranate) and a number of wild hosts (Briere and Pracros, 1998).

European grapevine moth has two generations in northern Europe, three generations in southern Europe including Hungary (Milonas et al., 2001). In May and June, first-generation larvae web and feed on the flower clusters. Second-generation larvae (July-August) feed on green berries. Third-generation larvae (August-September) cause the greatest damage by feeding inside berries. Additionally, feeding damage to berries after veraison exposes them to infection by *Botrytis* and other secondary fungi and pests

(Sáenz-de-Cabezón et al., 2005). European Vine Moth appears in all the wine-growing regions of Hungary, in very different frequency.

Spotted Tentiform Leafminer (Phyllonorycter blancardella Fabr.)

Tentiform leafminer was introduced from Europe in the 1930s. Populations in commercial orchards increased dramatically in the 1970s and 80s as the insect became resistant to organophosphate insecticides. The species is now distributed throughout Europe, the Baltic States, Byelorussia, Ukraine and Moldova as well as the European part of Russia, Transcaucasia, Urals, Asia Minor, Iran, Mongolia, and Northern America (Pfeiffer et al., 1995).

There are usually 2-5, mostly three generations of tentiform leafminer a year in Hungary. The insect overwinters as a pupa in leaves on the orchard floor. Adult moths begin to emerge when apple buds begin to break in late April and continue to emerge throughout May. The spotted tentiform leafminer infests apple. The larvae mine between layers of apple leaves, reducing photosynthetic area. Heavy infestations of leafminer affect fruit sizing, reduce vegetative growth and/or cause premature fruit drop.

Setaceous Hebrew Character (Xestia c-nigrum L.)

It is found in the Palearctic ecozone woodland. It is a common species throughout Europe, Britain and also can be found in North America, from coast to coast across Canada and the northern United States to western Alaska.

In the southern half of its range, including Hungary, there are two broods, flying in small numbers in May and June, but far more commonly in August and September. In the north there is just one generation, flying in July and August (Thompson and Nelson, 2003).

It is polyphagous, the larvae feed on a variety of herbaceous (agricultural and horticultural) plants, but especially nettle (*Urtic*a). include plants.

Latticed Heath (Chiasmia clathrata L.).

This species can be found throughout Europe from the Iberian Peninsula north to Scandinavia and east to Greece and Turkey and extends to eastern Siberia, China and Japan, North Africa, Central Asia, Siberia and the Far East.

The larvae feed on lucerne (*Medicago sativa*) and clover (*Trifolium*), however, it occurs in a range of open habitats, including moorland, grassland and waste ground.

There are usually two generations, especially in the south, flying in May and June, and August and September, and the species flies by day as well as at night.

April Beetle (Rhizotrogus aequinoctialis Herbst.).

It is distributed in Europe and in the Northern Mediterranean basin. It has a three-year development cycle. The adult does not feed; the larvae eat humus and different kinds of root. The larvae feed especially on herbaceous plants in moorland, grassland and waste ground but they can be found in orchards, vineyards and forest nurseries, too. Swarming is usually between end of March and beginning of June, mainly from noon to night (Janik et al., 2008).

Ecnomus tenellus Rambur

This caddishfly is one of most abundant insect which can be found in Hungary highland as well as in various natural and artificial lakes, backwaters, salt ponds, ditches

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and slow water rivers. Their presence often indicates degraded, low oxygen content water and plays an important role in aquatic ecosystems as fish food. The larvae have predatory lifestyle. The adults have cyclic pattern of flight activity from May till September with several peaks and without diapauses or parapauses (Nógrádi and Uherkovich, 2002; Kiss et al., 2006; Graf et al.,2008).

The examined sites and years

The data of investigated species and years, the number of observation stations and average value of ozone concentration in the examined period can be found in Table 1.

We worked with the ozone data measured at 23 o'clock (UT). Regardless of the number of insects caught, it was recorded whether or not the traps were successful in catching at a night (successful observation). The number of successful observations exceeds the number of the nights because not a single light-trap worked at a night.

Table 1. *Observed data of the examined species caught*

Pheromone trap catch					
			Number of		
Species	**Mean Ozone content ($\mu g/m^3$)**	**Years**	**Trap sites**	**Individuals caught**	**Successful Observations**
European Vine Moth *Lobesia botrana* Den. et Schiff. Lepidoptera Tortricidae	48.9	2004-2011	1	8 053	1 961
Spotted Tentiform Leafminer *Phyllonoricter blancardella* Fabr. Lepidoptera: Lithocolletidae	47.9	2004-2011	1	58 248	2 387
Light-trap catch					
			Number of		
Species	**Mean Ozone content ($\mu g/m^3$)**	**Years**	**Trap sites**	**Individuals caught**	**Successful Observations**
European Vine Moth *Lobesia botrana* Den. et Schiff. Lepidoptera Tortricidae	52.5	2004, 2005, 2007, 2008	1	3 820	342
	24.6	2006	1	1 628	120
Setaceous Hebrew Character *Xestia c-nigrum* L. Lepidoptera: Noctuidae	64.3	2004-2008	10	10 729	921
	47.7	2009-2011	10	3 913	694
Latticed Heath *Chiasmia clathrata L.* Lepidoptera: Geometridae	67.1	2007, 2008, 2011	10	3 564	851
	31.6	2005-2006	21	6 789	1 078
April Beetle *Rhizotrogus aequinoctialis* Herbst Coleoptera: Melolonthidae	79.3	2004-2007, 2009-2011	2	1 924	272
Ecnomus tenellus Rambur Trichoptera: Ecnomidae	25.6	2001-2005	5	21 717	848

It is clear that the sizes of the populations are very different at different sites and time intervals. Therefore we calculated the dimension-free relative catch (RC) data for each observation site and day. The RC is the quotient of the number of individuals caught by a trap during a sampling time unit (1 night) and the average number of individuals of the same generation caught in the same time unit calculated over the whole experimental area (Nowinszky, 2003).

The relationship of the ozone content of the air (μg/m^3) and the relative catch values was investigated.

The general model

We defined a general model of the form:

$$Y = \chi[X < p_0]*[p_1 + (p_2 - p_1)/(1+\exp(-p_3*(X-p_4)))]+ \\ \chi[X \geq p_0]*[p_2 + (p_5 - p_2)/(1+\exp(-p_6*(X-p_7)))]+\varepsilon \quad \text{(Eq.1)}$$

where Y denotes the relative catch (RC) while X is for the ozone content of the air [μg/m^3] and ε is a normally distributed error term with expected value of zero;

$\chi[X < p_0]$, $\chi[X \geq p_0]$ are characteristics functions which take 1 if the condition given in brackets $[X < p_0]$ or $[X \geq p_0]$ holds and zero if it is false;

p_1 is the parameter the fitting curve approaches as $X \to -\infty$;

p_2 is the parameter the fitting curve approaches as $X \to p_0$;

p_5 is the parameter the fitting curve approaches as $X \to +\infty$;

p_3 and p_6 are velocity factors of the exponential terms;

p_4 and p_7 are parameters which represent the inflexion points of the models.

The general model has the shape of *Fig. 1*. The curve can be split into four sections. The different sections can be expressed in different forms of exponential or saturation models. Section 1 and 2 or Section 3 and 4 together can be called as logistic (S-shape) models. Thus Section 1,2, 3 and 4 together can be regarded as a "bi-logistic model".

We have chosen different special nonlinear regression models to fit the distinct type of data of different sites and time scales. All the models can be originated as a part of the general model of (*Eq.1*). We applied saturation models (Models 1, 4, 5, 8 and 9), exponential model of two different forms (Model 3 and 10), transformed saturation model (Model 11), logistic model (Model 2) and bi-logistic models (Models 6 and 7) in the forms given in the Tables 1-6. In the models Y denotes the relative catch (RC) while X is for the ozone content of the air [μg/m^3] and ε is a normally distributed error term with expected value of zero. Normality was tested by Shapiro-Wilk test (p>0.05).

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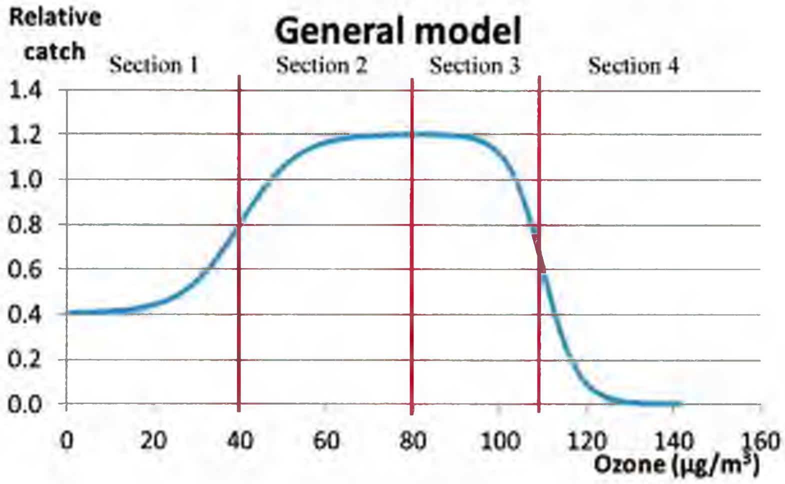

Figure 1. *General model of relative catch depending on the ozone content of the air [µg/m³] expressed in form (Eq. 1) with parameters* $p_0 = 80$; $p_1 = 0.4$; $p_2 = 1.2$; $p_3 = 0.15$; $p_4 = 40$; $p_5 = 0$; $p_6 = 0.25$ *and* $p_7 = 110$.

The parameter estimations were calculated together with their *t*-values and significance levels. The models were tested by the *F*-value and its significance level. Finally the explained variance (R^2) was evaluated.

Results

Model 1, Model 4, Model 5, Model 8 and Model 9 are saturation models where

p_1 is the parameter the fitting curve takes at point X=0;

p_2 is the parameter which represents the change of the fitting curve values on the whole range of ozone content in the experiment;

p_3 is a velocity factor of the exponential term.

In Model 2 (logistic model)

p_1 is the parameter the fitting curve approaches as $X \to -\infty$;

p_2 is the parameter the fitting curve approaches as $X \to +\infty$;

p_3 is a velocity factor of the exponential term;

p_4 is the parameter which represents the inflexion point of the model.

In Model 3 (exponential model) p_1 is a coefficient of the exponential term;

p_2 is a velocity factor of the exponential term.

In Models 6 and 7 we applied the general model in form of Eq(1).

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Table 2. *Nonlinear regression models of the relative catch of Lobesia botrana Den. et Schiff.(depending on the ozone content of the air [µg/m³] at different sites and time intervals with their parameter estimates, together with the regression diagnostics(F values of the models, t values of the parameters and the explained variance R^2)*

Species	Site	Time	Model 1		
Lobesia botrana Den. et Schiff.	Bodrog-kisfalud	2004-2011	$Y = p_1 + p_2 * (1 - \exp(- p_3 * X)) + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.21	2.39*	2804.36***	0.96***
	p_2	0.90	11.88***		
	p_3	0.05	6.18***		
	Site	Time	Model 2		
	Cserke-szőlő	2004 2005 2007 2008	$Y = p_1 + (p_2 - p_1)/(1 + \exp(- p_3 * (X - p_4))) + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.82	20.84***	1506.91***	0.92***
	p_2	1.10	40.57***		
	p_3	0.19	1.97+		
	p_4	43.51	15.28***		
	Site	Time	Model 3		
	Cserke-szőlő	2006	$Y = p_1 * \exp(p_2 X) + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.46	8.33***	43.63**	0.90**
	p_2	0.30	6.60**		
	Site	Time	Joint model 4		
	Bodrog-kisfalud	2004-2011	$Y = p_1 + p_2 * (1 - \exp(- p_3 * X)) + \varepsilon$		
	Cserke-szőlő	2004 2005 2007 2008			
	Estimated parameters		*t*	*F*	R^2
	p_1	0.30	3.59**	3357.6***	0.911***
	p_2	0.84	12.82***		
	p_3	0.040	5.45***		

+significant at $p<0.1$; * significant at $p<0.05$; ** significant at $p<0.01$; *** significant at $p<0.001$

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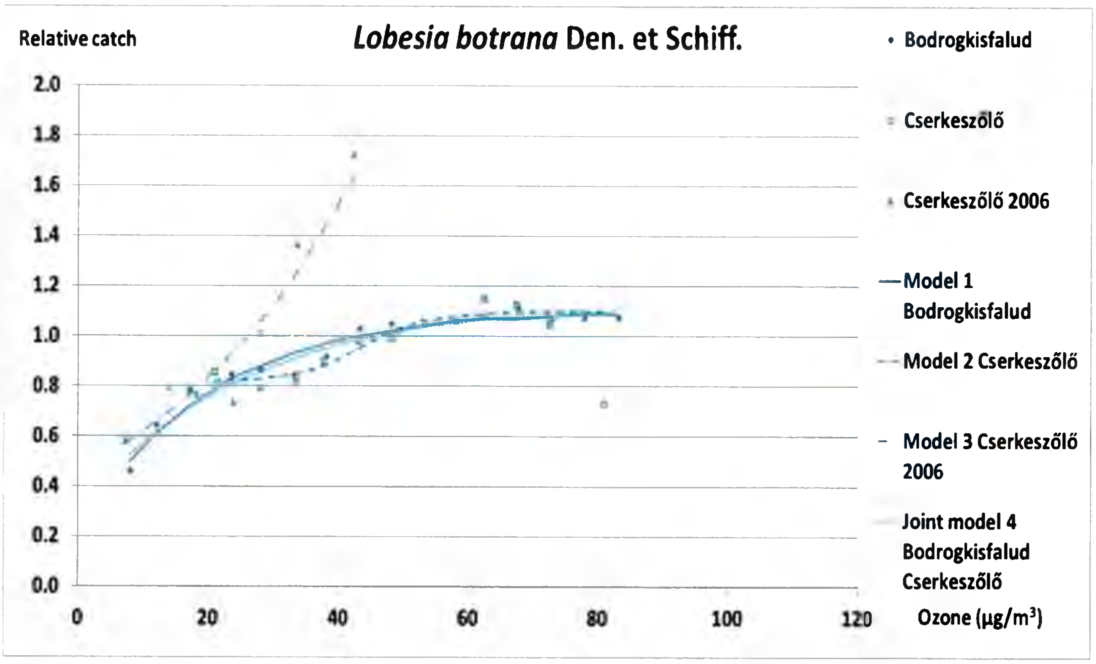

Figure 2. *Observed relative catch values and the fitted curves of nonlinear regression models relative to Lobesia botrana Den. et Schiff. depending on the ozone content of the air [μg/m³] at different sites and time intervals*

Relative catch data of *Lobesia botrana* Den. et Schiff., Bodrogkisfalud showed saturation growth (*Model 1, Fig. 2, Table 2*). In 2006 we measured significantly lower ozone content in the air in Cserkeszőlő and detected different character of relative catch responses of *Lobesia botrana* Den. et Schiff. Therefore, we fitted a quickly growing exponential model to the relative catch data of 2006 (*Model 3, Fig. 2, Table 2*) and a slowly growing logistic model to the data in other years in Cserkeszőlő (*Model 2, Fig. 2, Table 2*). Nevertheless, considering the growing speed, Model 1 and Model 2 can be regarded similar, thus we fitted a joint (saturation) model (Model 4) which can substitute Model 1 and 2, i.e. it can represent the data a Bodrogkisfalud and also Cserkeszőlő but the year 2006 (*Fig. 1, Table 2*).

Table 3. *Nonlinear regression models of the relative catch of Lobesia botrana Den. et Schiff. depending on the ozone content of the air [μg/m³] at different sites and time intervals with their parameter estimates, together with the regression diagnostics(F values of the models, t values of the parameters and the explained variance R^2)*

Species	Site	Time	Model 5		
Phyllonoricter blancardella Fabr.	Bodrog-kisfalud	2004-2011	$Y = p_1 + p_2 * (1 - \exp(-p_3 * X)) + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.20	2.41*	1979.64***	0.96***
	p_2	1.03	16.85***		
	p_3	0.03	5.19***		

* significant at p<0.05; ** significant at p<0.01; *** significant at p<0.001

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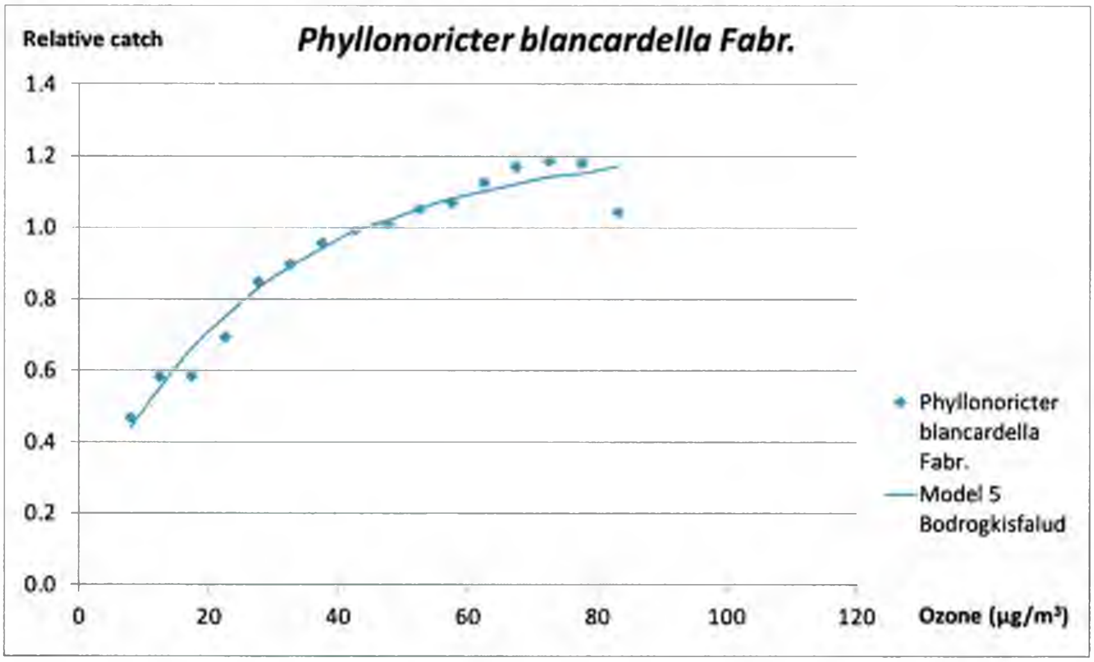

Figure 3. *Observed relative catch values and the fitted curve of nonlinear regression model relative to Phyllonoricter blancardella Fabr. depending on the ozone content of the air [µg/m^3] at Bodrogkisfalud (2004-2011)*

In case of *Phyllonoricter blancardella* Fabr., we fitted a slowly growing saturation model (*Fig. 3*) that is very similar to the Model 1 and joint Model 4 of *Lobesia botrana* Den. et Schiff. which indicates a presumably similar response strategy of the two species when the ozone content of the air is below 90 µg/m^3.

According to the calculated determination coefficients, all the Models 1-5 explain more than 90% of the variance of the observed data and have highly significant *F* values as well. By the significant (in most cases highly significant) *t* values all the parameter estimates can be judged as reliable (*Table 2* and *Table 3).*

Xestia c-nigrum L. was trapped at 10 sites between 2004 and 2011. In the years 2009-2012, during the observation period, lower mean ozone content of the air was measured than in years 2004-2008 and the relative catch data followed distinguishably different curves *(Fig. 4).* Therefore, we split the data into two (2004-2008 and 2009-2011) and fitted two different models with the same form *(Eq.1)* of the general model *(Model 6 and Model 7, Table 4, Fig. 4).*

After an increase of relative catch with increasing ozone content of air, we noticed a definite fall of the number of relative catches when the ozone content exceeded a critical value, and this was detectable in both time scales but at different critical values of ozone content (i.e. 80 µg/m^3 in earlier years with higher ozone content and 44 µg/m^3 in the later years with lower mean ozone content of the air).

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Table 4. *Nonlinear regression models of the relative catch of Xestia c-nigrum L. depending on the ozone content of the air [µg/m³] at different sites and time intervals with their parameter estimates, together with the regression diagnostics(F values of the models, t values of the parameters and the explained variance R^2)*

Species	Number of observation sites	Time with higher ozone content	Model 6 at higher mean ozone content		
Xestia c-nigrum L.	10	2004-2008	$Y = \chi[X < 80]*[p_1 + (p_2 - p_1)/(1+\exp(-p_3*(X - p_4)))] + \chi[X \ge 80]*[p_2 + (p_5 - p_2)/(1+\exp(-p_6*(X - p_7)))] + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.46	6.07***	769.49***	0.96***
	p_2	1.16	37.50***		
	p_3	0.16	3.46**		
	p_4	40.36	19.32***		
	p_5	0.73	7.30***		
	p_6	0.01	0.2ns		
	p_7	80	0.11ns		
	Number of observation sites	Time with lower ozone content	Model 7 at lower mean ozone content		
	10	2009-2011	$Y = \chi[X < 44]*[p_1 + (p_2 - p_1)/(1+\exp(-p_3*(X - p_4)))] + \chi[X \ge 44]*[p_2 + (p_5 - p_2)/(1+\exp(-p_6*(X - p_7)))] + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.62	15.08***	1383.02***	0.99***
	p_2	1.25	19.06***		
	p_3	0.22	3.57**		
	p_4	29.32	21.49***		
	p_5	0.20	0.92ns		
	p_6	0.09	3.03*		
	p_7	72.66	15.92***		

+significant at $p<0.1$; * significant at $p<0.05$; ** significant at $p<0.01$; *** significant at $p<0.00$; ns not significant

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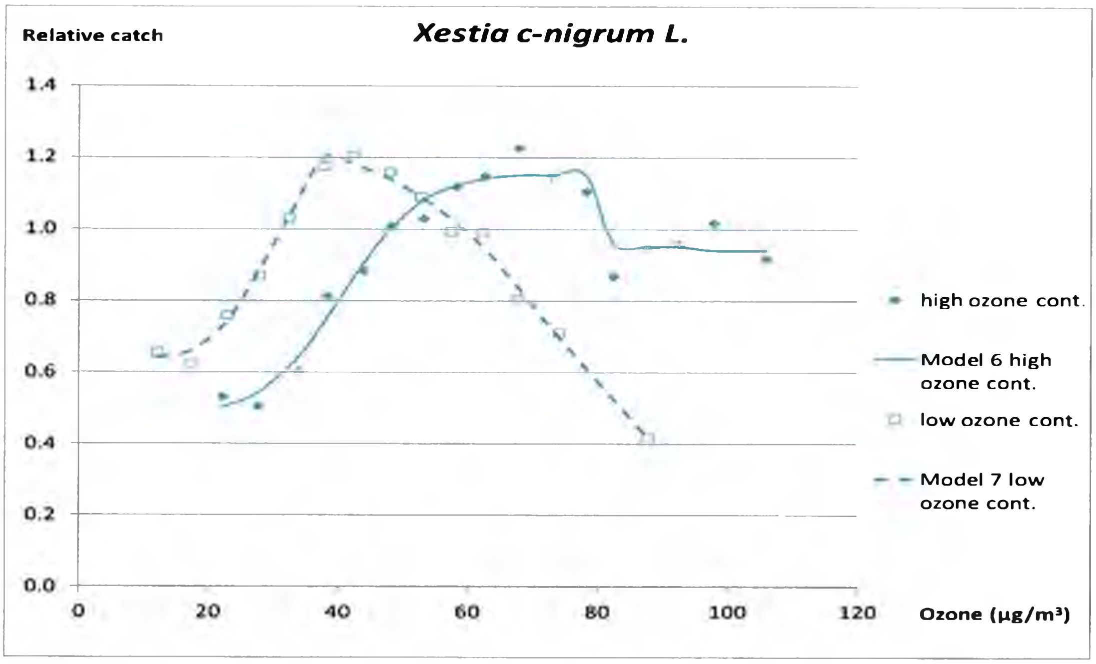

Figure 4. *Observed relative catch values and the fitted curves of nonlinear regression models relative to Xestia c-nigrum. L. depending on the ozone content of the air [µg/m³],2004-2011*

According to the calculated determination coefficients, both Models 6 and 7 explain 96% of the variance of the observed data and have highly significant F values as well *(Table 4)*. Most of the estimated parameters have significant t values except p_6 and p_7 of Model 6 (i.e. velocity term and inflexion point of Section 3 with 4 of General model, *Fig. 1*) and p_5 of Model 7 (the limit of the model as $X \rightarrow +\infty$). In case of Model 6 the second part of the model (Section 3 and 4 of the General model) does not fit very well, indeed. For Model 7 the reason of insignificant parameter estimation is that the there is no observation in the range of ozone content of the air which corresponds to Section 4 of the General model *(Fig. 1, Fig. 4)*.

Note that also in case of *Lobesia botrana* Den. et Schiff and *Phyllonoricter blancardella* Fabr. we observed significantly lower relative catch when the ozone content exceeded 80 µg/m³, however, we should not go far with consequences as there was not enough number of such events available to model.

Chiasmia clathrata L. was trapped altogether at 21 sites between 2005 and 2011 but in years 2009 and 2010. In the years 2005-2006, during the observation period, lower mean ozone content of the air was measured than in years 2007, 2008 and 2011, and, similarly to the case of *Xestia c-nigrum* L., the relative catch data followed distinguishably different curves (*Fig. 5*). Therefore, again we split the data into two (2004-2005 and later years) and fitted two different models with the same form (Model 8 and Model 9, *Table 5, Fig. 5*). Relative catch of *Chiasmia clathrata* L. in both time intervals followed saturation model as the ones of *Lobesia botrana* Den. et Schiff. and *Phyllonoricter blancardella* Fabr. The most important difference is that in case we detected high ozone content of the air (i.e. above 80 µg/m³), instead of a fall we observed a slight increase of relative catch values (*Fig. 5*).

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Table 5. *Nonlinear regression models of the relative catch of Chiasmia clathrata L. depending on the ozone content of the air [µg/m³] (2005-2011) with their parameter estimates, together with the regression diagnostics(F values of the models, t values of the parameters and the explained variance R^2)*

Species	**Number of observation sites**	**Time with higher ozone content**	**Model 8 at higher mean ozone content**		
Chiasmia clathrata L.	10	2007, 2008, 2011	$Y = p_1 + p_2 * (1 - \exp(-p_3 * X)) + \varepsilon$		
	Estimated parameters		t	F	R^2
	p_1	0.48	6.18***	1670.73***	0.89***
	p_2	0.64	9.50***		
	p_3	0.04	3.81**		
	Number of observation sites	Time with lower ozone content	Model 9 at lower mean ozone content		
	21	2005, 2006	$Y = p_1 + p_2 * (1 - \exp(-p_3 * X)) + \varepsilon$		
	Estimated parameters		t	F	R^2
	p_1	0.45	3.53**	870.03***	0.85***
	p_2	0.71	6.40***		
	p_3	0.60	2.92*		

* significant at p<0.05; ** significant at p<0.01; *** significant at p<0.001

According to the calculated determination coefficients, both Models 8 and 9 explain more than 85% of the variance of the observed data and have highly significant *F* values as well *(Table 5)*. By the significant (in most cases highly significant) *t* values all the parameter estimates can be judged as reliable.

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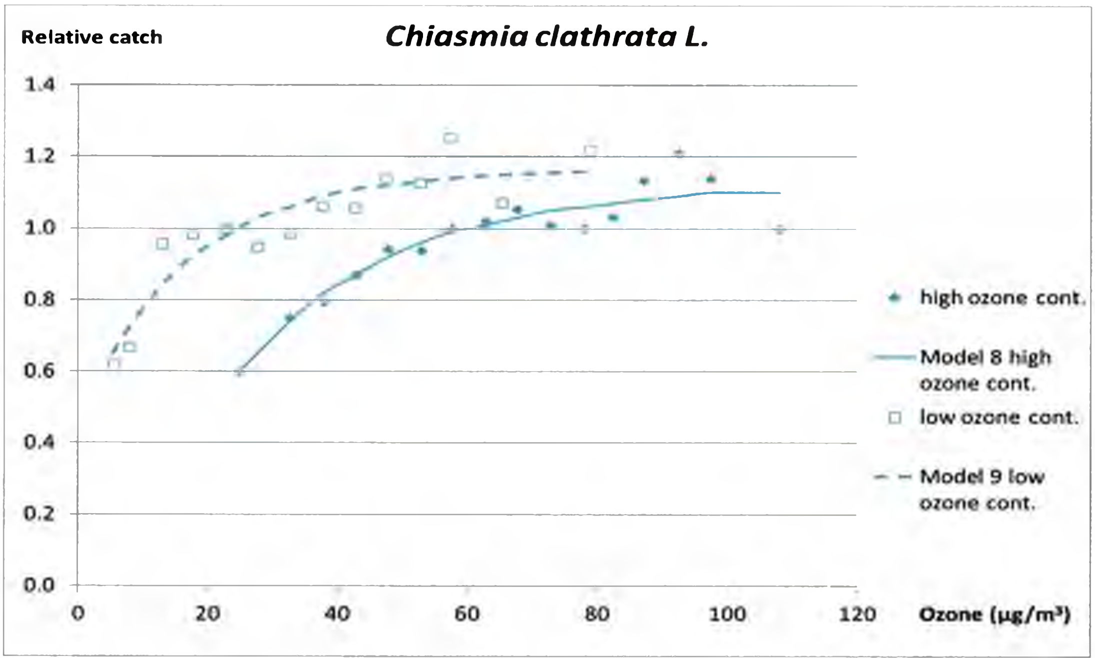

Figure 5. *Observed relative catch values and the fitted curves of nonlinear regression models relative to Chiasmia clathrata L. depending on the ozone content of the air [µg/m³ (2005-2011)*

Rhizotrogus aequinoctialis Herbst was trapped altogether at 21 sites between 2005 and 2011 but in 2008. In contrary to the cases of *Lobesia botrana* Den. et Schiff., *Phyllonoricter blancardella* Fabr. and *Xestia c-nigrum* L., relative catch data of *Rhizotrogus aequinoctialis* Herbst show a definite increase if the ozone content of the air exceeds 80 µg/m³ (Fig. 6). In its model (Model 10) the exponential term is multiplied by a linear term the coefficients of which are p_1 (slope) and p_2 (intersection) while p_3 is a velocity factor of the exponential term *(Table 6).*

Table 6. *Nonlinear regression models of the relative catch of Rhizotrogus aequinoctialis Herbst depending on the ozone content of the air [µg/m³](2004-2011) with their parameter estimates, together with the regression diagnostics(F values of the models, t values of the parameters and the explained variance R^2)*

Species	Number of observation sites	Time	Model 10		
Rhizotrogus aequinoctialis Herbst	2	2004-2007 2009-2011	$Y = (p_1 X + p_2) * (\exp(-p_3 * X)) + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	0.17	11.13***	44.56***	0.94***
	p_2	-0.10	-3.58**		
	p_3	-0.04	-7.31***		

* significant at p<0.05; ** significant at p<0.01; *** significant at p<0.001

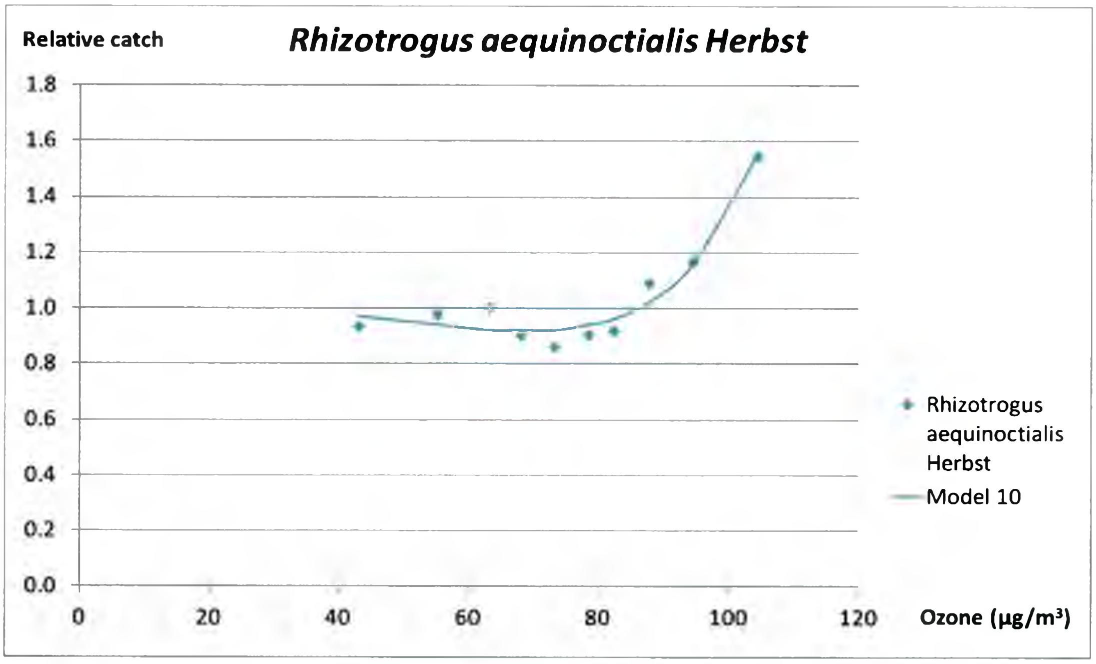

Figure 6. *Observed relative catch values and the fitted curve of nonlinear regression model relative to Rhizotrogus aequinoctialis Herbst depending on the ozone content of the air [µg/m³] (2004-2011)*

We observed the same intensive increase of relative catch values at high ozone content circumstances for *Economus tenellus* Rambur (*Fig. 7).* In its transformed saturation model (Model 11) p_1 is the parameter the fitting curve takes at the right end of the range of the observed ozone content (X=105 µg/m³), p_2 is the parameter which represents the change of the fitting curve values on the whole range of ozone content in the experiment while p_3 is a velocity factor of the exponential term *(Table 7).*

Table 7. *Nonlinear regression models of the relative catch of Economus tenellus Rambur depending on the ozone content of the air [µg/m³] (2001-2005) with their parameter estimates, together with the regression diagnostics(F values of the models, t values of the parameters and the explained variance R^2)*

Species	Number of observation sites	Time	Model 11		
Economus tenellus Rambur	5	2001-2005	$Y = p_1 + p_2 * (1 - \exp(-p_3 * (-X + 105))) + \varepsilon$		
	Estimated parameters		*t*	*F*	R^2
	p_1	2.68	29.85***	867.15***	0.98***
	p_2	-1.74	-18.87***		
	p_3	0.13	7.10***		

* significant at p<0.05; ** significant at p<0.01; *** significant at p<0.001

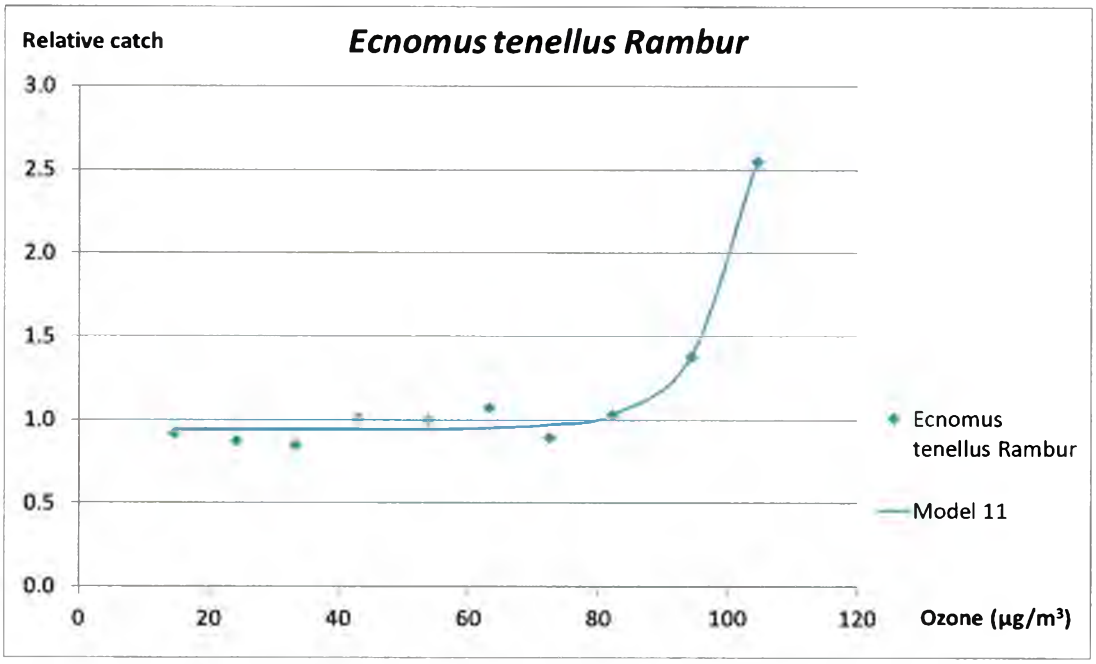

Figure 7. Observed relative catch values and the fitted curve of nonlinear regression model relative to Economus tenellus Rambur depending on the ozone content of the air [μg/m³] (2001-2005)

According to the calculated determination coefficients, both Model 10 and Model 11 explain more than 90% of the variance of the observed data and have highly significant *F* values as well (*Table 6, Table 7*). By the highly significant *t* values all the parameter estimates can be judged as reliable.

Discussion

Our earlier and present results suggest that the flying activity of the European Corn Borer (*Ostrinia nubilalis* Hbn.), Scarce Bordered Straw (*Helicoverpa armigera* Hbn), European Vine Moth (*Lobesia botrana* Den. et Schiff.), Spotted Tentiform Leafminer (*Phyllonoricter blancardella* Fabr.), Latticed Heath (*Chiasmia clathrata* L.), April Beetle (*Rhizotrogus aequinoctialis* Herbst) and *Ecnomus tenellus* Rambur. increase when the ozone content is high. In case of Hebrew Character (Xestia c-nigrum L.) we detected the increasing flying activity with increasing ozone concentration up to a certain level of ozone concentration which was followed by a decreasing flying activity.

Low relative catch values always refer to environmental factors in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism. The imago is short-lived; therefore unfavourable environmental endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to environmental factors of an unfavourable situation. By the present state of our

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knowledge we might say that unfavourable environmental factors might be accompanied by both high and low catch (Nowinszky, 2003; Puskás and Nowinszky, 2003).

Each case of the light trapping is unique and unrepeatable and the above results cannot be certificated with laboratory experiments. Therefore, the results of this kind of regularities are difficult to confirm. Laboratory experiments should always be supplemented by field observations because observation results throw new light upon the relation between the ozone in the air and ecosystem.

As the impact of the tropospheric ozone content on the relative catch of the insects is not widely researched field yet, our observations raise several unsolved problems. It need to be clarified whether the main reasons of the examined phenomenon should be searched in the rate of ozone sensitivity of the species, in the current phonological phase of the insects in which the high ozone content is observed, in the length of time of ozone stress or in other species-specific aspects. It is important to investigate the

Ozone content in the troposphere has increased markedly during the past century, mainly because of the release of nitric oxide, carbon monoxide and gaseous hydrocarbons from vehicles and industrial processes and from the burn of biomass in the tropics (Lelieveld et al., 1995). The elevated ozone content in troposphere can cause not only damage to crops and human health but, with interaction of other environmental effects, can also upset the balance of ecosystems. This fact indicates the importance of investigating the impact of elevated tropospheric ozone content on ecosystems, including on the flying activity of insects.

We suggest similar examinations onto other harmful insect species relevantly with other sampling methods (e.g. suction-, Malaise-, bait traps). If it were undoubtedly provable that elevated tropospheric ozone content increases the light-trap catch of certain insect species, it would be necessary to take this fact into consideration when developing the entomological researches and plant protection prognoses, too.

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http://www.ecology.uni-corvinus.hu • ISSN 1589 1623 (Print) • ISSN 1785 0037 (Online)

Journal of Advanced Laboratory Research in Biology **www.sospublication.co.in**

ISSN 0976-7614

Volume V, Issue III, July 2014 **Research Article**

Influence of ozone content on light trapped trichoptera Species in central Europe

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Abstract: The study deals with the connection between ozone content of air and light trap catch of ten Caddisflies (Trichoptera) species from a Jermy-type light-trap. Five species were collected in connection with the increasing the high values of the ozone content, but decrease were observed in case of four species. The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the ozone content of air, expressing the different lengths and intensities of the ozone content. The different form of behaviour, however, is not linked to the taxonomic position. Further testing will be required for fuller explanation of the results.

Keywords: Caddisflies, ozone, light-trap.

1. Introduction

Summer daytime ozone concentration correlates strongly with temperature. The tropospheric Ozone (O_3) concentration has been monitored in Hungary at K-puszta (46°58'N 19°35'E) by the Hungarian Meteorological Service since 1996, with 10 minutes averaged ozone concentration detected. Since, 2004 the monitoring system was extended to 10 stations in Budapest and 37 ones in other locations throughout Hungary. The ozone content of the air is usually measured in ppm, ppb, μg or mg units (0.1 ppm O_3 by weight = 100 ppb O_3 by weight = 200 μg O_3/m^3 = 0.2 mg O_3/m^3) (Ladányi *et al.*, 2012).

Ozone concentration in the summer months – from May until August – is higher than in other months of the year. There are typical daily changes. The ozone content is high from noon to evening and decreases from evening to dawn. It hit its lowest point in the dawn hours and begins to rise again in the early morning. Ozone concentrations in the atmosphere depend also on several meteorological factors (Tiwari *et al.*, 2008).

The highest ozone levels occur typically in towns and cities, however, in some situations high ozone content has been measured in locations even hundreds of kilometers far away from the emission sources. Elevated ozone concentration is detected usually in the summer months - from May until August - caused by bright sunshine and high temperature, or sometimes in early spring, mainly in March (Ferenczy, 2012).

Kalabokas and Bartzis (1998), Kalabokas (2002), Kalabokas *et al.*, (2000), Papanastasiou *et al.*, (2002, 2003) as well as Papanastasiou and Melas (2006) in Greece have studied the daily and monthly ozone content fluctuation. The ozone content is usually higher from noon to evening and decreasing from evening to dawn. It hit its lowest point in the dawn hours and begins to rise again in the early morning. However, according to Juhász *et al.*, (2006) the ozone content of the atmosphere is occasionally still significantly high during the night.

The highest concentration of ozone is maleficent to insects. The study of Kells *et al.*, (2001) evaluated the efficacy of ozone as a fumigant to disinfest stored maize. Treatment of 8.9 tonnes of maize with 50 ppm ozone for 3 days resulted in 92–100 % mortality of adult Red Flour Beetle, *Tribolium castaneum* (Herbst), adult Maize Weevil, *Sitophilus zeamais* (Motsch.), and larval Indian Meal Moth, *Plodia interpunctella* (Hübner).

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Biological effects of ozone have been investigated by Qassem (2006) as an alternative method for grain disinfestations. Ozone at a concentration of 0.07 g/m^3 killed adults of Grain Weevil (*Sitophilus granarius* L.), Rice Weevil (*Sitophilus oryzae* L.) and Lesser Grain Borer (*Rhyzopertha dominica* Fabr.) after 5-15 hours of exposure. Adult death of Rice Flour Beetle (*Tribolium confusum* Duv.) and Saw-toothed Grain Beetle (*Oryzaephilus surinamensis* L.) was about 50 % after 15-20 hours of exposure. Total adult death of all insect species was made with 1.45 g/m^3 ozone concentration after one hour of exposure. Valli and Callahan (1968) examinations made with light-traps indicated an inverse relationship between O_3 and insect activity. According to Bonjour *et al*., (2011), ozone fumigation has potential for the control of some stored grain insect pests of wheat.

Our earlier results suggest that the flying activity of the Common Cockchafer (*Melolontha melolontha* L.) (Puskás and Nowinszky, 2010), European Corn-borer (*Ostrinia nubilalis* Hbn.) (Nowinszky and Puskás, 2011), Scarce Bordered Straw (*Helicoverpa armigera* Hbn), (Puskás and Nowinszky, 2010), Latticed Heath (*Chiasmia clathrata* L.) and April Beetle (*Rhizotrogus aequinoctialis* Herbst) increase when the ozone content is high. In case of Hebrew Character (*Xestia c-nigrum* L.) we detected the increasing flying activity with increasing ozone concentration up to a certain level of ozone concentration which was followed by a decreasing flying activity (Ladányi *et al*., 2012).

In the our earlier study (Nowinszky *et al*., 2012) we established that the pheromone trapping of the seven Microlepidoptera species, Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius), Red Midget Moth (*Phyllonorycter corylifoliella* Hübner), Codling Moth (*Cydia pomonella* Linnaeus), Peach Twig Borer (*Anarsia lineatella* Zeller), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller), Oriental Fruit Moth (*Grapholita molesta* Busck) and Plum Fruit Moth (*Grapholita funebrana* Treitschke) are most fruitful when the ozone content of the air is high. By contrast, low ozone values, reduce the successfulness of the catching to a moderate level.

2. Materials

We had at our disposal the ozone data registered at K-puszta in the year 2000.

We have downloaded these data (µg/m^3) from the website of Norsk institutt for luftforskning (Norwegian Institute for Air Research (NILU) (http://tarantula.nilu.no/projects/ ccc/emepdata. hzml/). The geographical coordinates of K-puszta are the following: 46° 58’ N and 19° 35’ E. We worked with the ozone data of the time 23 o’clock (GMT).

We collected caddisflies (Trichoptera) species with a Jermy-type light-trap near the Tisza River at Szolnok (47°10'76"N, 25°11'25"E) in 2000 between 1st June and 30th September. Those species were chosen, which fly to the lamp en masse.

The catching data of Caddisflies species are presented in Table 1.

Light trapped species	Number of individuals	Number of nights
Ecnomidae		
Ecnomus tenellus Rambur, 1842	2193	103
Polycentropodidae		
Neureclipsis bimaculata Linnaeus, 1758	1502	93
Hydropsychidae		
Hydropsyche contubernalis Mc Lachlan, 1865	11711	176
Hydropsyche bulgaromanorum Malicky, 1977	22508	101
Limnephilidae		
Limnephilus affinis Curtis, 1834	707	100
Halesus digitatus Schrank, 1781	1009	55
Leptoceridae		
Athripsodes albifrons Linnaeus, 1758	810	112
Ceraclea dissimilis Stephens, 1836	947	102
Oecetis ochracea Curtis, 1825	282	81
Setodes punctatus Fabricius, 1793	1759	83

Table 1: Catching data of the Trichoptera species of Tisza River at Szolnok.

3. Methods

The light source of the applied Jermy-type light-traps was a 100W normal white light electric bulb hanged under a metal cover (Ø: 1m) at 200 cm height above the ground. The traps were operated through every night during the season from April until October (Jermy, 1961).

It is clear that the sizes of the species populations are very different at different sites and time intervals. Therefore, we calculated the dimension-free relative catch (RC) data for each observation site and day. The RC is the quotient of the number of individuals caught in a trap during a sampling time unit (1 night) and the average number of individuals of the same generation caught in the same time unit calculated over the whole experimental area. In case of the expected average individual number, the RC value is 1 (Nowinszky, 2003).

We paired the relative catch values of each species of the ozone data on every day during the collection periods. We arranged the values of the ozone data into classes using the method of Sturges (Odor and Iglói, 1987), and then calculated the average relative catch data related to them within both classes. We demonstrated our results and communicated the equations of the curves and significance levels too.

4. Results and Discussion

Our results, including regression equations and significance levels, are displayed in Figure 1-10.

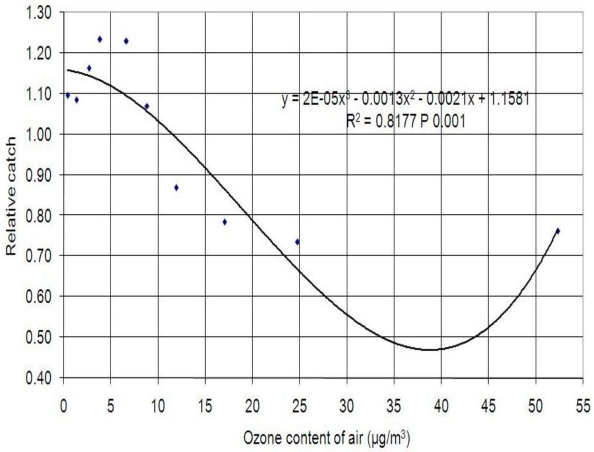

Figure 1: Light-trap catch of *Ecnomus tenellus* Rambur depending on the ozone content of the air (Szolnok, 2000).

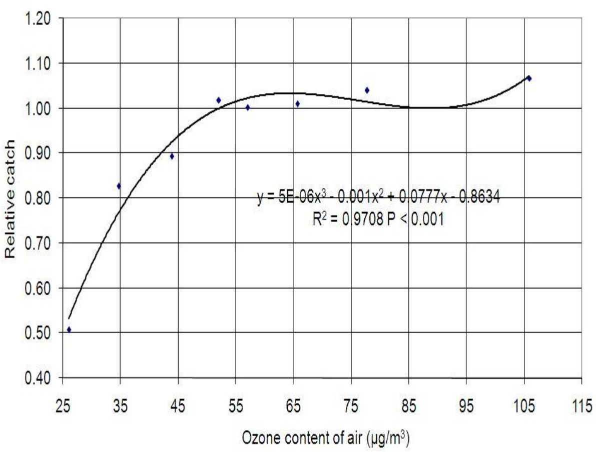

Figure 2: Light-trap catch of *Neuroclipsis bimaculata* L. depending on the ozone content of the air (Szolnok, 2000).

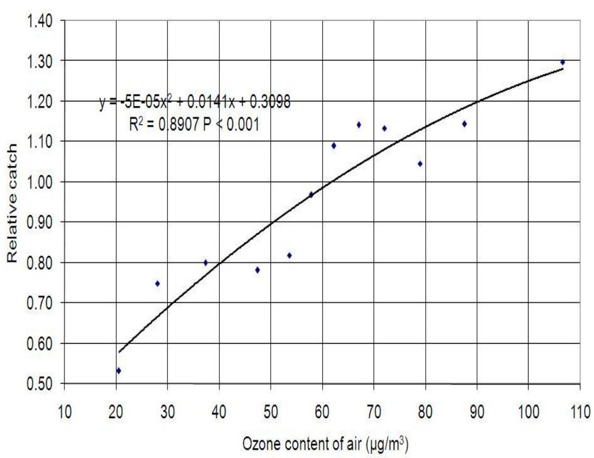

Figure 3: Light-trap catch of *Hydropsyche contubernalis* McLachlan depending on the ozone content of the air (Szolnok, 2000).

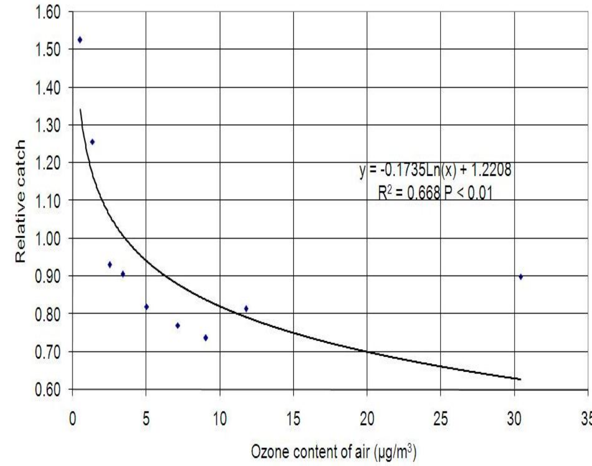

Figure 4: Light-trap catch of *Hydropsyche bulgaromanorum* Malicky depending on the ozone content of the air (Szolnok, 2000).

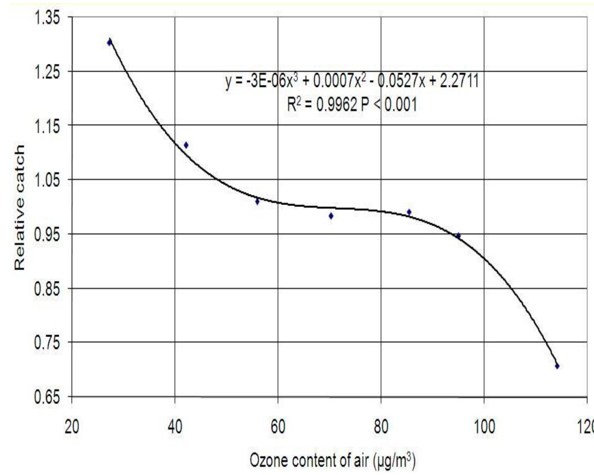

Figure 5: Light-trap catch of *Limnephilus affinis* Curtis depending on the ozone content of the air (Szolnok, 2000).

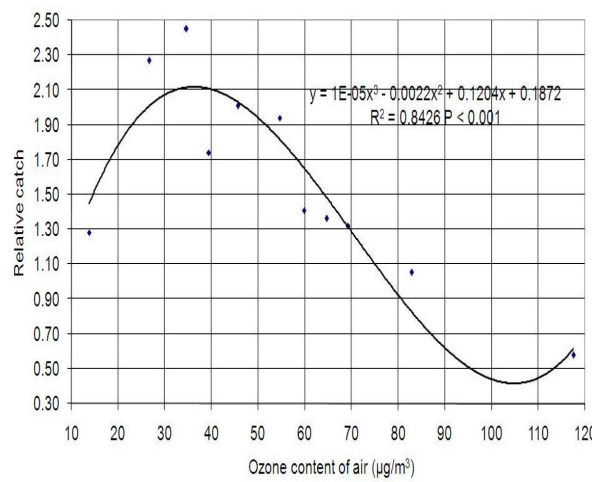

Figure 6: Light-trap catch of *Halesus digitatus* Schrank depending on the ozone content of the air (Szolnok, 2000).

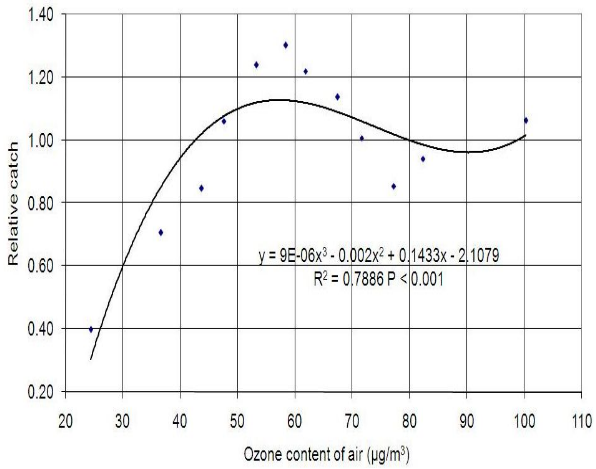

Figure 7: Light-trap catch of *Athripsodes albifrons* L. depending on the ozone content of the air (Szolnok, 2000).

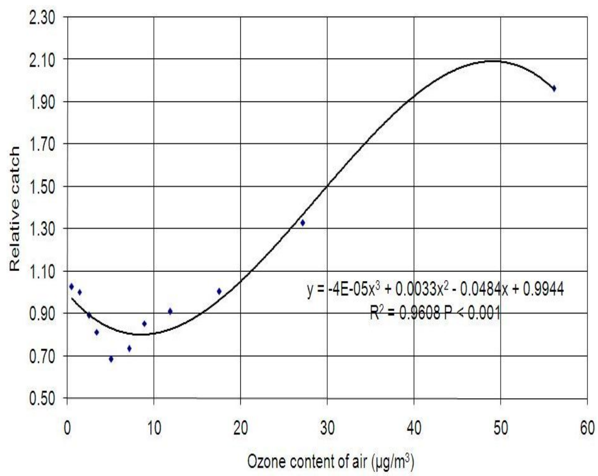

Figure 8: Light-trap catch of *Ceraclea dissimilis* Stephens depending on the ozone content of the air (Szolnok, 2000).

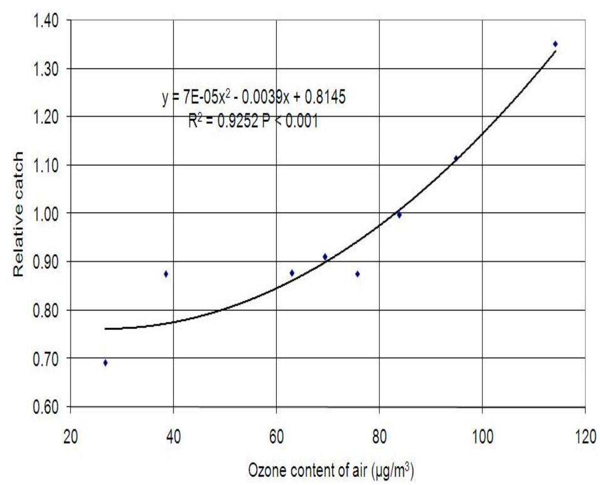

Figure 9: Light-trap catch of *Oecetis ochracea* Curtis depending on the ozone content of the air (Szolnok, 2000).

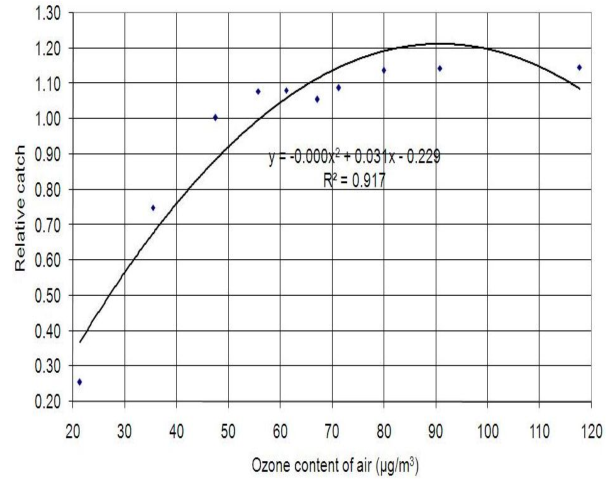

Figure 10: Light-trap catch of *Setodes punctatus* Fabricius depending on the ozone content of the air (Szolnok, 2000).

Our present results, suggest that the flying activity of the *Athripsodes albifrons* L., *Neuroclipsis bimaculata* L., *Oecetis ochracea* Curtis, *Setodes punctatus* Fabr., *Hydropsyche contubernalis* McLachlan and the *Ceraclea dissimilis* Stephens increase when the ozone content is high. Contrarily these flying activities of the *Ecnomus tenellus* Rambur, *Hydropsyche bulgaromanorum* Malicky, *Halesus digitatus* Schrank and the *Limnephilus affinis* Curtis decrease when the ozone content is high. The light-trap catches verify this fact. Low relative catch values always refer to weather situations in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental -lived, therefore unfavourable weather endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to weather an unfavourable situation. And so by the present state of our knowledge we might say that favourable and unfavourable weather situations might equally be accompanied by a high catch (Puskás and Nowinszky, 2003).

As the impact of the tropospheric ozone content on the relative catch of the insects is not widely researched field yet, our observations raise several unsolved problems. It need to be clarified whether the main reasons for the examined phenomenon should be searched in the rate of ozone sensitivity of the species, in the current phonological phase of the insects in which the high ozone content is observed, in the length of time of ozone stress or in other species-specific aspects (Ladányi *et al.*, 2012). It is important to investigate the ozone content in the troposphere has increased markedly during the past century, mainly because of the release of nitric oxide, carbon monoxide and gaseous hydrocarbons from vehicles and industrial processes and from the burn of biomass in the tropics (Lelieveld *et al*., 1995).

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G. AGRIC. 3 (1) 27-38 (1991)

Vertical Distribution Related with Migration and Moon Phases of Macrolepidoptera Species Collected by Light Traps

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ABSTRACT

In a Macrolepidoptera material caught at heigths of 2 and 10 m, respectively, by light traps working with 125 W mercury vapour lamps as light source in a forest environment the authors determined the number of species and individuals in connection with migration and moon phases. They found that the high trap besides showing the presence of several species captured larger numbers of migratory-, vertical migratory-, supposed internal migratory moths and even of non-migratory moths, though for the latter the differences were not significant.

For the migratory species in the low trap the flying activity was found to culminate at full moon. On the other hand, the ratio of catches in the high- and the low trap was the smallest at full moon, and was non-significant only at that time. The migratory species may be supposed to fly at that time at heights still greater than that, as proved by investigations carried out abroad. On the basis of their results the authors think it necessary to make observations of migratory moths in higher layers of air, since they have arrived at the conclusion that the larger number of insects caught by the high trap is due to the greater flying height rather than to the larger collecting area.

Key Words: Macrolepidoptera, nocturnal large moths, flying intensity, migration, moonlight gradation, prognosis.

INTRODUCTION

The vertical distribution of insects flying at night was already studied by Williams (1939) with light traps placed at ground level and at a height of 10 m. In the Hungarian literature few papers deal with the problem of flying height, because the light sources of the Jermy-type traps of the Hungarian agricultural and forestry light trap system are uniformly placed at a height of

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2 m. Studies of this kind have remained therefore isolated and have taken place at relatively low levels. Most of the Microlepidoptera species lighttrapped by VOJNITS and VOIGT (1971) flew to the lower (1.5 m) trap in larger numbers than to the higner (2.5 m) trap. JÁRFÁS (1977, 1978, 1982) with his collaborators (JÁRFÁS, SZABÓ and SOHAJDA, 1975; JÁRFÁS and SZABÓ, 1975; JÁRFÁS and VIOLA, 1984; JÁRFÁS and VIOLA, 1985) studied in series of experiments the flying height of moth pests at three levels, up to 360 cm above ground. His light trap collected the largest numbers of most species at the medium level (121-240 cm). According to Bürgés, Gál and Eke (1976) much more of the specimens of *Laspeyresia splendana* Hbn. were caught by light traps placed in the crown stratum (12 m) than by those placed low (2 m). In another experiment GÁL, BÜRGÉS and EKE (1976) studied the light attracted flight of *Curculio elephas* Gyll. and *Laspeyresia splendana* Hbn. at heights of 2, 5 and 10 m. The individual number of either species was smallest at the lowest, and largest at the highest level. From catches of 125 W mercury vapour lamps operated at heights of 2 and 10 m, respectively, HERCZIG and BÜRGÉS (1981) drew several important conclusions. Species of the families Arctiidae, Thaumetopoeidae, Thyatiridae and Noctuidae flew in larger numbers to the high trap. The individual number of migratory species was four-times larger in the high than in the low trap, irrespective of their taxonomic place. The high trap captured species not living in the environment.

In the foreign literature many works deal with the question of vertical distribution. In the course of light trap experiments in Kenya TAYLOR and BROWN (1972) compared the number of species and individuals caught at heights of 1 and 12 m, respectively. Species of the family Sphingidae flew to the high, while the Pyralidae species to the low trap in larger numbers. With the latter family the individual number was also larger in the low trap. CALLAHAN et al. 91972) in Georgia, USA, collected insects with 15 UV light traps at various levels of a TV tower up to 320 m. Most moths flew to traps placed at 7 and 25 m. From 83 to 320 m the distribution was nearly uniform, though remarkably more moths were caught over stretches between the red signal lights. More than half of the insects caught from 9 orders and 35 families belonged to the species *Heliothis zea* Boddie. The proportion of this species was strikingly high 82 per cent - at 320 m.

The distribution of insects can be studied at much greater heights with the help of tow nets carried by kites(FARROW and DOWSE, 1984; McDONALD and FARROW, 1988) and by the application of radar technics (RILEY and REYNOLDS, 1979; DRAKE, 1982, 1984; FARROW, 1986). Some authors use various methods simultaneously to study the vertical distribution in higher layers of air (FARROW, 1982; DRAKE and FARROW, 1985; RILEY, REYNOLDS and FARROW, 1987).

PREUSS and PREUSS (1972) elaborated a method for the telescopic observation of the flying height and number of insects flying before the moon.

For us those studies are the most important which deal with the vertical distribution of insects in connection with migration and moon phases. BROWN and TAYLOR (1971) using suction traps in Kenya found that the moths showed maximum density at new- and full moon, and minimum density with the prime and the wane of the moon, either at 1.5 or 9 or even 15 m. In the figure representing the suction trap observations of PERFECT and COOK (1982) it can be seen that the species examined gave preference to the 1.5 m trap before sunset, while after sunset the 12 m trap collected more specimens. Unfortunately, they did not compare their results to the moon phases. El-ZIADY (1957) thinks it likely that at full moon the insects fly higher, that is why the light traps capture fewer specimens at that time. He checked his theory using a suction trap placed at a height of about 10 m, and actually observed the activity peak at full moon.

DENTHANARAYANA (1986) used a vertical suction trap series over 9 lunar cycles on the ground surface and at heights of2,5 5, 10 and 20 m, respectively. According to the evidence of his findings the individual density of *Plutella xylostella* L. and *Culex pipiens australicus* DOBROWORSKY et DRUMMOND is significantly higher in the higher layers at around the prime and the wane of the moon than at full- and new moon, and even at full moon it is higher than at new moon. In an earlier paper DANTHANARAYANA (1976) threw up the idea that the three-peak lunar periodicity of the flight of insects observed at about the prime and wane of the moon and at full moon may have been related with migration. The author points out that in these periods the insects move in higher layers of air and reach the height where they are carried by horizontal air currents.

In our study from catches in light traps placed at heights of 2 and 10 m we tried to establish the connection of the flying height of insects with moon phases and migration. We wanted to get an answer to the question whether the ratio of species- and individual number of migratory and non-migratory moths in the low- and high trap was steady or varied with the lunar cycles. The results of our investigations of basic research nature may be of practical use in the forecasting service of plant protection.

MATERIALS AND METHODS

HERCZIG and BÜRGÉS (1981) operated two light traps in a closed Castaneo-Quercetum forest nearby the village Rezi in the Keszthely range of mountains, from 1 April to 30 September 1979, using 125 W mercury vapour lamps as light source. One of the traps was placed 2 m above ground, the other in the crown of a chestnut-tree, at a height of 10 m. The two traps worked at a distance of some 100 m from one another, with a building in between, so they influenced but slightly each other's action. Unfortunately, for operative defects in several cases the high trap only worked for three weeks or so altogether. From the catches the data of Macrolepidoptera species have been processed.

From the catches of either trap the species were placed in four types of migration. The groups were set up on the basis of studies by VOJNITS (1966, 1970), GYULAI (1978), UHERKOVICH (1978) and MÉSZÁROS (1966, 1987-88).

Among the "migratory moths" the "true", the "adventive" and the "inland" migrators were placed. A special type was formed by the species called "vertical migrators" by GYULAI (1978). Another group was composed again of the species whose flying height was found by HERCZIG and BÜRGÉS (1981) to be very similar to that of evidently migratory species; they are the "supposed inland migrators". Finally, the last type included the non-migratory species.

Out of the migratory moths the following were present in the traps, though some species were only represented by a few specimens:

Sphinx pinastri L.
Scotia segetum Schiff.
Scotia exclamationis L.
Scotia ipsilon Hfn.
Ochropleura plecta L.
Xestia C-nigrum L.
Mamestra brassicae L.
Mythimna albipuncta Den. et Schiff.
Mithimna vitellina Hbn.
Mythimna pallens L.
Mythimna l-album L.
Trachea atriplicis L.
Photedes fluxa Hbn.
Agrotis venustula Hbn.
Heliothis maritima Grsl
Axylia putris L.
Melicleptria scutosa Schiff.
Cucullia fraudatrix Ev.
Porphyrinia purpurina Schiff.
Acontia luctuosa Schiff.
Autographa gamma L.
Macdonnoughia confusa Steph.
Minucia lunaris Schiff.

Of the vertical migrators the following species were caught in the traps:

Opigena polygona Schiff.
Noctua pronuba L.
Noctua orbona Hfn.
Noctua interposita Hbn.
Noctua comes Hbn.
Noctua fimbriata Schrb.
Noctua janthina Schiff.

The supposed inland migratory species are:

Xestia triangulum Hfn.
Xestia xanthographa Schiff.
Haplodrina alsines Brahm.
Haplodrina blanda Schiff.
Haplodrina ambigua Schiff.

Owing to lack of space the non-migratory species are not listed here.

In the course of data processing all nights of the collecting period were placed in four groups according to the characteristic quarters of moon, the same way as it was done earlier (KISS et al., 1981; NOVINSZKY and TÓTH, 1983).

Full moon: 1st, 2nd, 3rd, 28th, 29th and 30th day of lunation
Last quarter: 4th, 5th, 6th, 7th, 8th, 9th and 10th day
New moon: 11th, 12th, 13th, 14th, 15th, 16th, 17th, 18th, 19thand 20th day
First quarter: 21st, 22nd, 23rd, 24th, 25th, 26th and 27th day.

Then from the data of both the high and the low trap we determined the daily average species- and indivudal numbers of moths belonging to the different migratory types for each quarter of moon.

The difference in average values between the high- and the low trap was checked by F-test for each type and each quarter. The average values of species- and individual number of each of the high- and the low trap obtained for the different quarters were also compared to the values of the full lunar cycle. To determine the significance level of differences we applied the approximate t-test.

RESULTS

Table 1 contains the daily average individual numbers of Macrolepidoptera species belonging to the different types in the high- and the low trap, separated by the quarter of moon. Table 2 gives the daily averages of species number broken down in the above manner. Both tables include the significance levels of differences too.

Table 1. *Daily average individual number in high- and low trap of various migration type Macrolepidoptera species in the different moon phases.*

Moon phase and migration type	High trap Av. ind. numb.	N	Low trap Av. ind. numb.	N	P(F%)
Non migrators					
Full moon	35.06 ++	31	19.93 +++	27	70.92
Last quarter	44.19	32	24.00 +	41	97.30
New moon	56.24 +++	41	37.63 +++	57	69.39
First quarter	34.56 ++	34	30.10	40	52.32
Full lunation	43.04	138	29.52	165	
Migrators					
Full moon	10.91	22	5.72 +++	18	55.39
Last quarter	7.87 ++	30	1.71 ++	35	99.87
New moon	13.61 +	41	1.56 ++	50	100.00
First quarter	10.44	25	1.82 +	28	99.98
Full lunation	10.98	118	2.70	131	
Vertical migrators					
Full moon	0.53 ++	19	0.20	15	94.90
Last quarter	1.87 ++	23	0.29	28	99.99
New moon	1.29	31	0.15	40	99.98
First quarter	0.68 +	24	0.24	21	93.21
Full lunation	2.12	97	0.21	104	
Supposed inland migrators					
Full moon	5.15 ++	20	3.93 ++	15	74.34
Last quarter	8.00	23	1.56	28	99.86
New moon	13.03 +++	29	2.76 ++	38	99.99
First quarter	5.00 +	21	1.26	27	99.54
Full lunation	8.28	93	2.14	108	

Note: +++ = significant at higher than 99% level | compared to full lunation
++ = significant at higher than 95% level
+ = significant at higher than 90% level
N = number of observation nights

Table 2. *Daily average species number in high and low trap of various migration type Macrolepidoptera species in the different moon phases.*

Moon phase and migration type	High trap Av. species numb.		N	Low trap Av. species numb		N.	P(F%)
Non migrators							
Full moon	13.00	+++	31	8.67	+++	27	86.28
Last quarter	17.16		32	13.44		41	63.67
New moon	20.90	+++	41	15.35	++	57	61.85
First quarter	13.38	++	34	11.70		40	56.52
Full lunation	16.41		138	12.90		165	
Migrators							
Full moon	3.05		22	1.83	++	18	55.64
Last quarter	2.93		30	0.91		35	98.87
New moon	3.51		41	0.94		50	99.89
First quarter	3.36		25	1.25		28	94.45
Full lunation	3.27		118	1.12		131	
Vertical migrators							
Full moon	0.26	++	19	0.20		15	56.37
Last quarter	1.04	+	23	0.25		28	98.17
New moon	0.81		31	0.10		40	99.85
First quarter	0.54		24	0.19		26	92.29
Full lunation	0.69		97	0.17		109	
Supposed inland migrators							
Full moon	1.25		20	1.07	+	15	76.42
Last quarter	1.52		23	0.86		28	68.59
New moon	1.31		29	0.55		38	62.39
First quarter	0.90	+	21	0.48		27	72.06
Full lunation	1.26		93	0.69		108	

Note:
+++ = significant at higher than 99% level
++ = significant at higher than 95% level
+ = significant at higher than 90% level
(compared to full lunation)
N = number of observation hights

DISCUSSION

The individual number in the high trap exceeds that in the low trap for all types of migration and all quarters of moon. With the non-migratory species this difference is significant in the last quarter only, in the case of migrators and supposed inland migrators in the first- and last quarter as well as at new moon, while with the vertical migrators it is highly significant in all quarters of moon.

It is evident that the larger catches of the high trap cannot be explained with a larger collecting area compared to the low trap. True, though, that the visual distance of the source of light increases in proportion to the square of height, but the intensity of light decreases in proportion to the square of distance (TAYLOR, 1986). Otherwise in a forest environment the greater visual distance would not be of any use (HOSNY, 1955).

At the time of observation the light intensity and the illumination of the surroundings were naturally the same for the high and the low trap. Thus, the collecting distance of the two traps is also the same, since it is the radius of the circle on the circumference of which the insects perceive the lamplight as equal in intensity to the illumination of the surroundings (NOWINSZKY et al., 1979; NOWINSZKY and Tóth, 1984). The larger individual number of the high trap is thus due to the fact that various species, in particular the migrators, fly in larger numbers in the 10 m layer of air than at a height of about 2 m.

Further we checked the observation of El-ZIADY (1957), who found the insects to fly higher at full moon. Considering the relatively small difference in height our present results do not provide indisputable proof of El-ZIADY's observation, one remarkable fact still seems to confirm his theory. The difference between the high- and the low trap in the individual number of migratory and supposed inland migratory and supposed inland migratory species is the smallest at full moon, and only then it is non significicant. One of the reasons for this may be that at that time the migratory moths fly still higher than that. This would confirm the opinion held by HERCZIG and BÜRGÉS (1981), namely, that the species placed in the group of supposed inland migrators also migrate.

As seen from Table 1. the individual number of migratory and supposed inland migratory sepcies in the low trap is the largest at the very time of full moon, so it is then that their flying activity reaches maximum. And this supports the statement of DANTHANARAYANA (1986) concerning the three-peak lunar periodicity of the flying activity.

In essentials, conclusions agreeing with the above can be drawn from the data of Table 2 too, as for the number of species belonging to the different types of migration.

On the basis of our results we suggest to extend the observation of migratory pests to cover the higher strata of air. Namely, it is not sure whether light traps place at a height of 2 m above ground level reliably signalize the presence of these species.

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Acta Phytopathologica et Entomologica Hungarica 44 (1), pp. 193–200 (2009)
DOI: 10.1556/APhyt.44.2009.1.21

Flying Height of Insects Connected with Moon Phases Used the Light-Trap Catch Data

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(Received: 22 January 2008; accepted: 10 April 2008)

We made an examination using the data of higher and lower light-traps of Talcal, Rezi and Kecskemét. We made comparison between the catch and the moon phases.

Our results, got from the data of Kecskemét light-trap, prove the proportion of caught samples both of fall webworm (*Hyphantria cunea* Drury) and of turnip moth (*Scotia segetum* Schiff.) is the most equable at the lower and higher levels at the time of full moon.

The proportion of Microlepidoptera individuals (Tarcal), caught by lower and higher light-traps at Tarcal, is the highest at new moon, but it is higher at full moon than at first and last quarter and the proportion of caught species number is also similar.

The proportion of Macrolepidoptera individuals (Rezi), caught by lower and higher traps is highest in the last quarter, the lowest in first quarter and at full moon. The proportion of caught species shows similar but more strikingly marked picture.

Keywords: light-trap, insects, moon phases, flying height.

Great many researchers have been studying the question of the height at which insect's fly. A clarification of the issue from the point of view of plant protection prognosis assumes special significance if there is sufficient evidence to prove that the height of flight is affected by the phases of the Moon. El-Ziady (1957) believes in the likelihood of insects flying higher at the time of a full Moon, so the catch is lower at this time than at other Moon quarters. He backed his assumption by the catch results of a suction trap placed at a height of 10 m. Earlier Williams (1936) found lower catch at full Moon. He thought it was because of the smaller gathering distance or moonlight has a direct influence on activity and reduces the number of flying insects. After more decades, there is not any recognised answer to this question.

Williams (1939) who used light-traps placed at distances of 2 and 10 m from the surface of the ground was a forerunner in examining the vertical dispersion of nocturnal insects. Taylor and Brown (1972) have found that some species fly in greater numbers to a light-trap placed higher (12 m), while others prefer traps at a lower height (1 m). Callahan et al. (1972) collected insects with 15 UV light-traps positioned at different levels going up

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to 320 m of a television tower. The highest number of moths was trapped at heights of 7–25 m. From 83–320 m, the dispersion was close on even, but a remarkably higher number of moths were trapped in zones between the red light signals. More than halves of the insects of the 35 families of 9 orders of insects trapped were Helothis zea Boddie specimens. The ratio of this species at 320 m was 82%, stunningly high. Sorry their results were not examined in relationship with Moon phases. Taylor et al. (1979) captured migratory moths with light-traps of an identical type placed at heights of 0.6 and 24.5 m, respectively, from ground surface in Kenya. The catch of the trap placed high was but a fraction of the one placed low. This proportion is 1:11.4 in the case of the turnip moth (*Scotia segetum* Schiff.).

Aly (1990a) operated two Robinson type light-traps. These traps were put in 1.5 m and 18.5 m height from the ground. He examined the success of light trapping of *Paederus alfierii* Koch (Staphylinidae: Coleoptera) in connection with the four moon quarters. The catch of lower trap was better at the time of new moon than full moon, but the difference was not significant in the higher one. Aly (1990b) showed in the catch of *Gryllus domesticus* L. (Gryllidae: Orthoptera) on the 1.5 m height trap, the light-trap catch is higher at new moon than full moon in summer of 1983. This event cannot be seen in the catch of 18.5 m high trap. Aly and Shafi (1991) did not notice significant difference at the different moon quarters in the catch of *Componotos maculatus aegyptiacus* Em (Formicidae: Hymenoptera) at 1.5 m height. The light-trap catch was more successful during fall months at full moon in 18.5 m height.

There were operated two Jermy-type light-traps by Vojnits and Voigt (1971) at Tarcal at experimental yard of Research Institute for Viticulture and Aenology. The light source was a 100 W normal electric bulb in both trap. One trap was put between to the grape line, the height was about 1.5 m and the other was at the end of the line in 2.5 m height. The distance was about 15 m between these traps. There were determined not only grape moths, but also other Microlepidoptera species. Generally, the lower trap caught more specimen as the higher one, but the European corn borer (*Ostrinia nubilalis* Hbn.) was caught in higher number by the upper trap.

There were three fractional light traps in operation between 1967 and 1969 in Kecskemét operated by Járfás. These traps were put in three different heights and there were separated in every hour. The light sources of fractional light-trap were three fluorescent lamps (F-33 type, 40 W). Their length was 120 cm, and they were above one another. Járfás published the catch of different levels of several species, but he did not examine the causes of differences (Járfás, 1979).

It was shown in a latter study (Bürgés et al., 2003) the specimen number of migrant moths is highest just at full moon in low trap, so their flight activity is high during this time. Bürgés (1997) published separately the Macrolepidoptera catch for each family using the data in lower and higher trap at Rezi. Most of species were caught in both traps, but the higher caught more number of insect as the lower one. The exception was only in case of Geometridae and Notodontidae families. Herczig and Bürgés (1981) operated two light-traps in a closed stand of chestnut and oak near the village of Rezi, in the mountain range of Keszthely. Both traps were outfitted with 125 W HGL bulbs. One of the traps was placed at a height of 2 m from ground surface, the other at a height of 10 m in the canopy of a chestnut tree. The two traps worked at a distance of 100 m from each other. The trap working at 10 m captivated four times as many migratory moths than the one operating at 2 m. The trap high up also caught species not breeding in the surroundings.

Material

We could use the whole Microlepidoptera data of traps at Tarcal. We thank for these data to Zoltán Mészáros.

Earlier József Járfás gave the fractional trap data of Kecskemét-Katonatelep (between 1967 and 1969) to use in our corporate studies. There are data of fall webworm (*Hyphantria cunea* Drury), turnip moth (*Scotia segetum* Schiff.) and European corn borer (*Ostrinia nubilalis* Hbn.) in it hourly separated according to the levels *(Table 1)*.

We used the whole Macrolepidoptera catch data traps at Rezi (in 1976, 1978 and 1979), but only those nights were examined when both traps were in operation.

Methods

We used in earlier study (Nowinszky, 2003) 30 phase angle groups, calculated 360 phase angle values of the full lunation. Now we made only 10 phase angle groups, because we had less light-trap catch data. There were 12 phase angle in every phase angle groups in former study. Now we had 36 ones, because we contracted three groups, but the notation was the same so we could compare with the former results. The notation of phase angle group with full moon (0°, or rather 360° ± 18°) is 0. There are group notations –3, –6, –9 and –12 from this one to new moon through the first quarter. There are group notations 3, 6, 9 and 12 from full moon to new moon through the last quarter. The phase angle group containing new moon is ± 15. The first moon quarter belongs to –6 group and last moon quarter belongs to +6 one.

Table 1

The catch data of examined species at different levels of fractional light-trap in Kecskemét between 1967 and 1969

Species Levels	*Hyphantria cunea* Drury		*Scotia segetum* Schiff.		*Ostrinia nubilalis* Hbn.	
	Number	%	Number	%	Number	%
Lower	1439	45.41	2349	41.28	394	27.94
Median	1178	37.17	2045	35.93	544	38.58
Higher	552	17.42	1297	22.79	472	33.48
Together	3169	100.00	5691	100.00	1410	100.00
Hours	875		950		702	

We took into consideration only those hourly data from Kecskemét ligh-trap during the examination, which had successful catch at least one trap. The number of caught specimen on each level was calculated hourly as a percental value of the whole number of insect was caught in the three traps. The percental data of examined species were categorized hourly and for every level into the above-mentioned phase angle groups, then they were summarized and averaged. The catch results were very similar in median and upper level so they were contracted and after it, we made a comparison between these results and catch in the lower trap.

We worked up according to the same method the Microlepidoptera and Macrolepidoptera data caught by light-traps at Tarcal and Rezi. We made the examinations using the contracted data of all species and not with separated for each species, because of the relatively not too much catch. We used only those data, when both traps were in operation. We assigned the number of caught individuals to the phase angle group of that night. We summarized the number of trapped individuals belonging to each phase angle group. We calculated the percental rate of individual number of lower and higher trap. We illustrated the results in the same way in all cases.

Results

There are shown the specimen rate of fall webworm (*Hyphantria cunea* Drury), turnip moth (*Scotia segetum* Schiff.) and European corn borer (*Ostrinia nubilalis* Hbn.), caught by the lower and higher light-traps, in *Figs 1, 2* and *3*. The results of Microlepidoptera and Macrolepidoptera species from Tarcal and Rezi are shown in *Figs 4* and *5*.

Discussion

Our results, got from the data of Kecskemét light-trap, prove the proportion of caught samples of both fall webworm (*Hyphantria cunea* Drury) and turnip moth (*Scotia segetum* Schiff.) is the most equable at the lower and higher levels at the time of full moon. These species fly in high proportion to 121 and 360 cm levels during full moon, than at the time of other moon phases. The proportion of caught specimen of European corn borer (*Ostrinia nubilalis* Hbn.) is highest just at full moon time in lower and higher levels. One reason can be insects fly in the air above 360 cm this time, but it can be also supposed they fly in great number near the ground level. We cannot decide from the data which reason is correct.

The proportion of Microlepidoptera individuals, caught by lower and higher light-traps at Tarcal, is the highest at new moon, but it is higher at full moon than at first and last quarter and the proportion of caught species number is also similar.

The proportion of Macrolepidoptera individuals, caught by lower and higher traps is highest in the last quarter, the lowest in first quarter and at full moon. The proportion of caught species shows similar but more strikingly marked picture.

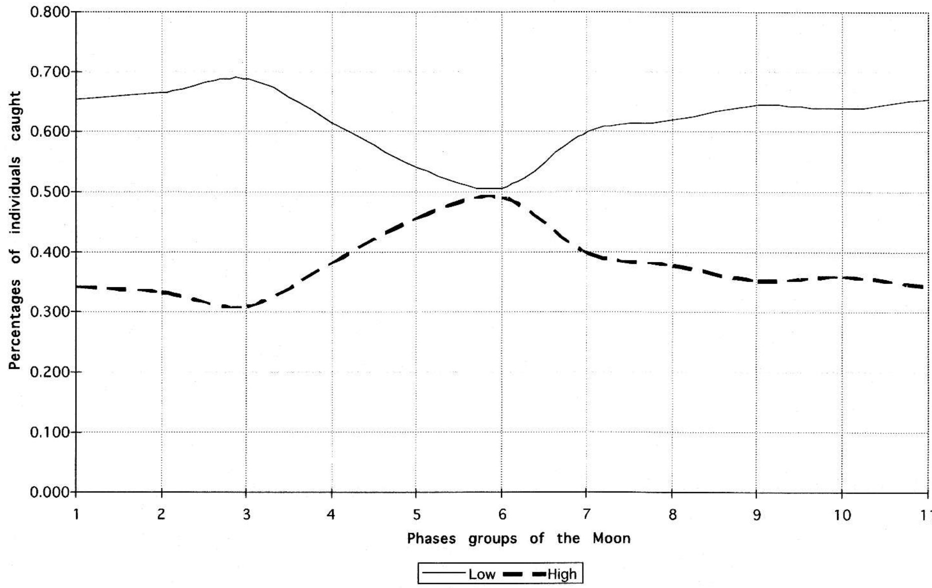

Fig. 1. Percentages of the individuals of the fall webworm moth (*Hyphantria cunea* Drury) at the low and high levels of Járfás-type light-trap in connection with the phases groups of the Moon (Kecskemét, 1967–1969)

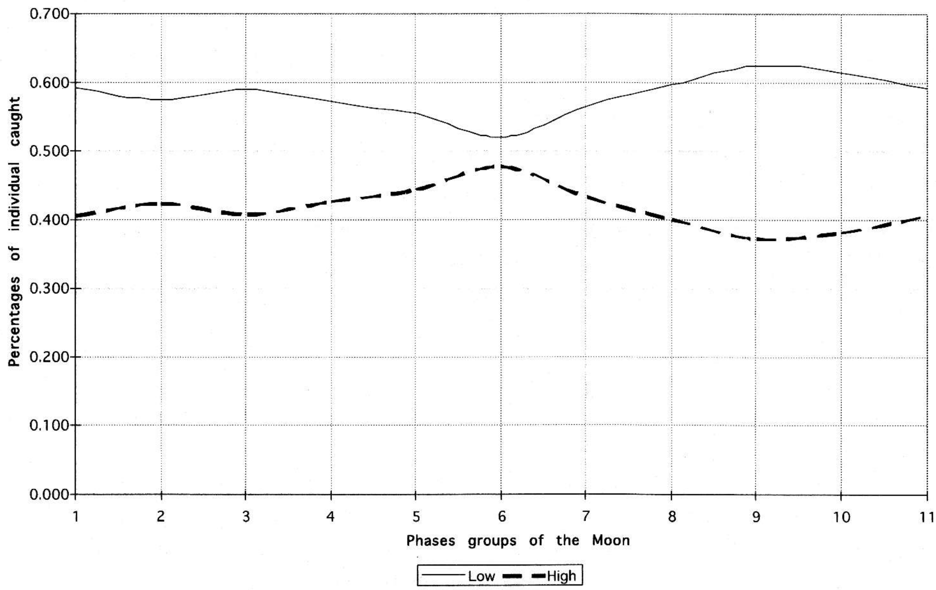

Fig. 2. Percentages of the individuals of the turnip moth (*Scotia Segetum* Schiff.) at the low and high levels of Járfás-type light-trap in connection with the phases groups of the Moon (Kecskemét, 1967–1969)

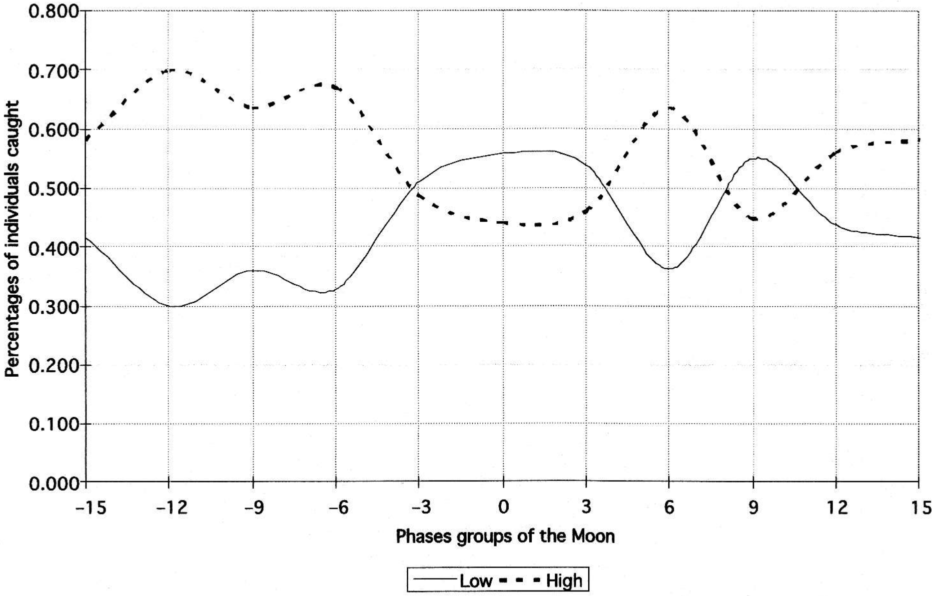

Fig. 3. Percentages of the individuals of the European corn borer (*Ostrinia nubilalis* Hbn.) at the low and high levels of Járfás-type light-trap in connection with the phases groups of the Moon (Kecskemét, 1967–1969)

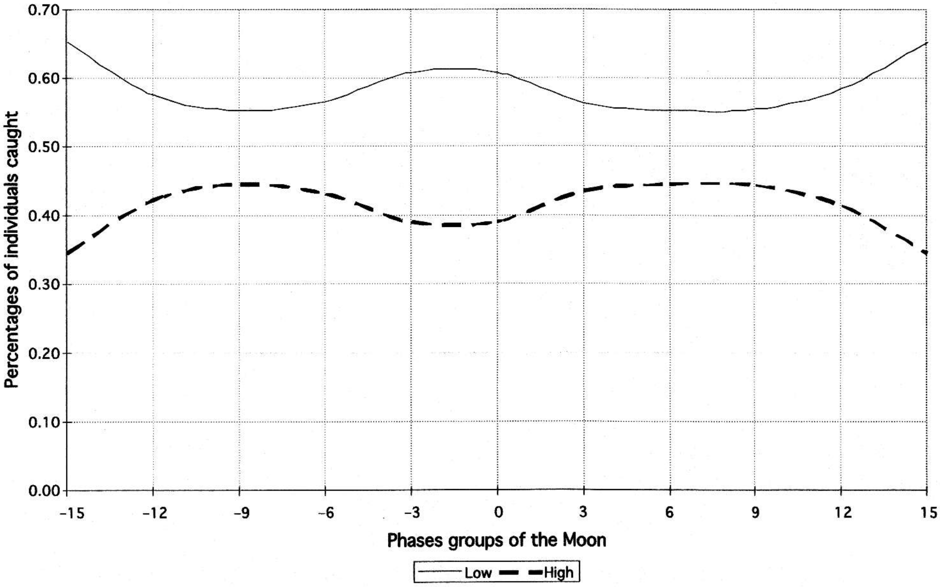

Fig. 4. Percentages of the individuals of Microlepidoptera individuals caught at the low and high light-traps in connection with the phases groups of the Moon (Tarcal, 1965–1968)

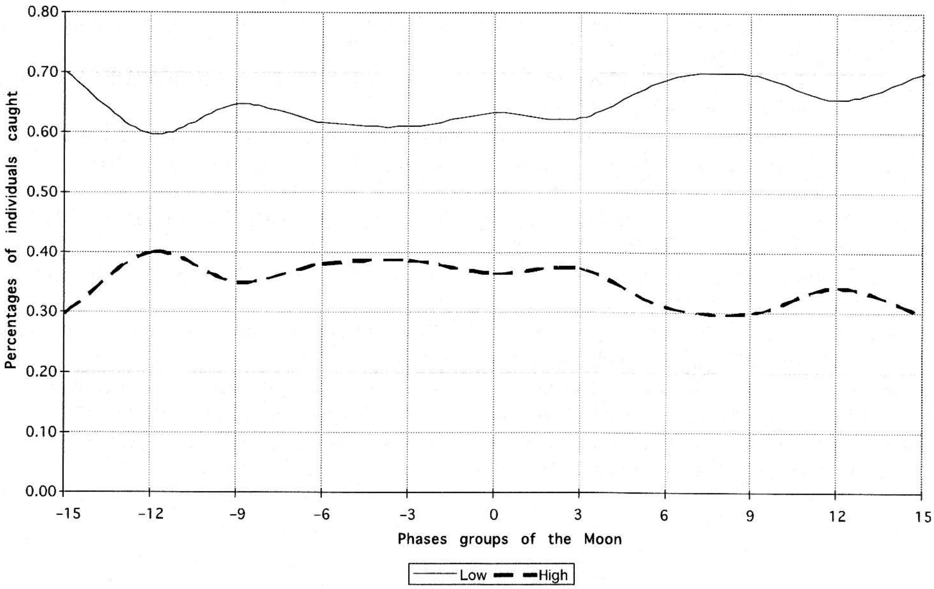

Fig. 5. Percentages of the individuals of Macrolepidoptera individuals caught at the low and high light-traps in connection with the phases groups of the Moon (Rezi, 1976, 1978, 1979)

Of course, the behaviour of some Microlepidoptera and Macrolepidoptera species can differ from the results got from the summarised data. It would be very important to put into operation light-traps in different higher levels at some observing stations and during longer period. It can be taken into consideration during making the plant protection forecast if there would be a proof, the individuals of several species fly in higher number in various heights during the time of different moon phases.

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NOCTURNAL ILLUMINATION AND NIGHT FLYING INSECTS

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(Received 12th March 2004; accepted 10th May 2004)

Abstract. The present study discusses the light trapping of insects depending on the environmental illumination, twilight polarization phenomena and the moon phases. The trapping data were taken of Hungarian national light-trap network. The important results are the followings: The Babinet-point, a polarization free spot of the sky at twilight, can be a role of orientation of insects. The height of the Moon above the horizon is in negative correlation with the number of the caught insects. The maximum individual number of species was collected at various moon phases.
Keywords: *light-trap, collecting distance, Babinet-point, moon phases*

Introduction

Great many studies in professional literature are devoted to the role of the Moon in modifying light trapping catch. The conclusions are contradictory and up to this day a good many questions have remained unclarified. True, the authors usually collected differing species at the most different geographical locations and have not even registered the Moon phase in every case.

Review of Literature

In astronomical terms, twilight means that the Sun is set just below the horizon. At the time of sunset and sunrise, the zenith distance (ZSun) is equally 90.5°. In the period of civil twilight (ZSun = 90.5°-96°), provided the sky is clear, the visible outlines of objects in the environment make appropriate orientation possible. The brightest celestial bodies which help orientation appear at the time of navigational twilight (Z Sun = 96°-102°). Complete darkness sets in at the end of astronomical twilight (ZSun = 102°-108°). From then on, provided the Moon or zodiacal light observable near the Equator does not enhance the illumination of the environment, only the brightness of the night sky is perceivable. Its mean value is $9*10^{-4}$ lux (Nielsen [116], Roach and Gordon [151]). Naturally, at dawn, the same events follow one another in reverse order.

The light of the sky at sunset and daybreak is strongly polarized. In some places, however, neutral spots can be observed in areas of a few arc-square grades where polarization is practically zero (Rozenberg [156], McCartney [101]). Babinet's point follows the Sun on its virtual trajectory by 15-25° in the evening and precedes it by the same value at daybreak, so it is observable at twilight. More recently, Hungarian researchers have also been devoting attention to the unpolarized points of the sky (Gál et al. [62], Horváth és Varjú [79]). The neutral points are presumably perceived by insects as discontinuities in a sky emitting a continuity of polarized light. Therefore we assume that these points

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might have a role to play in their orientation. From this point of view, Babinet's point especially may be of significance in the periods of evening and dawn twilight.

The question of the distribution of the catch by light-trap in the course of a night has been a subject of research for several decades. Williams [199] used a fractionating light-trap in four years of examining flight activity as it was changing over the night.

Tshernishev [187] claims that the flight activity of each species follows a special daily rhythm that usually corresponds to the time of flying to light. From this point of view he establishes four basic types of insects:

- Flight of short duration tied exclusively to twilight, can never be observed by night (most Ephemeroptera, Corixida, Coleoptera, Diptera and Hepialida species).
- Species of a flight of longer duration. They start their flight later, reaching the peak early in the evening. Some species fly all night (Trichoptera, Chironomida and a few east-African Ephemeroptera species).
- Intensive flight from sunset to close on sunrise, not letting up during the night (Tripuloidea and some Ephemeroptera species).
- Typical night flight with a well discernible nocturnal peak (Ophionina, Lepidoptera, especially the species of Noctuidae and *Serica brunnea* L.).

In the same work, the author lays down for a number of insect orders and for some significant species the values of illumination expressed in lux characterizing the beginning and the peak of the activity. The activity of most Lepidoptera species increases from 0.01 lux to 0.001 lux but decreases by illumination below that value.

The intensity of illumination is of outstanding importance from the point of view of the collecting area as well as regarding flight activity. For by a lower level of illumination in the environment, the light-source of the trap will be discernible from a greater distance. However, this possibility has been studied so far only in the context of the light of the Moon (Bowden and Church [23], Bowden and Morris [26]).

The fact that the polarized light of the sky has a role to play in the orientation of some insects has been known for about fifty years. Dantharanayana and Dashper [43] examined insect behaviour in response to polarized light by using three Pennsylvania type light-traps. It is quite remarkable that the result pertaining to moths contradicts an earlier finding by Kovarov and Montchadski [92] who claim that species of that order fly in masses to polarized light. We have not come across with any publication in professional literature discussing light trapping efficiency in an interrelationship with the position of neutral points.

Several researchers include moonlight in their list of factors that modify collecting, but owe us a detailed analysis of the workings of that influence (Ármai [4], Malicky [99], Harling [73], Hardwick and Lefkovich [72], Jermy [89], Lödl [96], Pedgley et al. [137]). Leinonen et al. [94] tested four different types of light-traps and bulbs in northern Finland. The 4 traps changed places every night, but on every fifth night were put back to their original places, in order to evade the influence of the Moon. Ito et al. [83] applied auto-correlation calculation to establish that collecting by light-trap has a 29-30 day periodicity. In actograph examinations, Danthanarayana and Gu [44] experienced a 27 day periodicity in the flight activity of *Epiphyas postvittana*, a period remarkably close to the length of the sideric lunar month (27.7 days). Ho and Reddy [76] have found that moonlight exerted a stronger influence on light trapping catch than on the catch by pheromon traps.

Findings by other researchers have been contradictory. Corbet [38], Hanna [70], Day and Reid [46], Chaston [34], Bidlingmayer [15], Hardwick [71], Mikkola [104], Bowden and Church [23], Bowden and Gibbs [24], Szabó and Járfás [176], Robertson [155], Pedgley [136], Holck and Meek [78] and Brinson et al. [30] either did not find adequate proof to confirm differences in insect activity during lunation, or just stated that the different species reacted to moonlight in different ways. Nabili et al. [112] hold that the lunar phase has no significant bearing on the effectiveness of light trapping useful insects, such as Coccinellidae (Coleoptera), Ophion sp. (Hymenoptera: Ichneumonidae), Chrysopa spp. (Neuroptera: Chrysopidae), Hemiptera: (Nabidae), Hemerobius spp. (Neuroptera: Hemerobiidae). A comprehensive study by Tshernishev [188] refers to several publications that contradict one another. Gregg et al. [65] did not find any difference accompanying the changing phases of the Moon when light trapping migrating noctuids (Noctuidae) and hawk-moths (Sphingidae). However, that may also be explained by the method they used. They arranged the 30 days of lunation into 6 groups, of 5 days each, and subjected them to a contingency test. However, the transformation of the optical parameters of the Moon during the lunar month is not an even process and similar optical conditions are not of identical duration, therefore the method applied does not seem to be satisfactory. Light trapping a mosquito species, *Anopheles aquasalis* Curry in Brazil, Flores-Mendoza and Lourenço-de-Oliveira [60], too, experienced no difference in the number of individuals caught in the presence or in the absence of moonlight.

Most authors, however, observed a decline in the catch under the influence of the Moon. The most fundamental studies are associated with the name of Williams [198] that devised for his specific, entomological purposes equipment to register moonlight (Williams and Emery [201]). He found that on a bright night by new moon, three times as many insects flew to light than at full moon. Under a cloudy sky, the ratio went down to 2:1, while the proportion of insects caught by new moon and full moon, respectively, was 2.7:1, cloud conditions ignored. Subsequently Williams [200] extended research to cover several orders of insects. He collected the highest number of individuals on the 20th day of the lunar month and the lowest on the first day, by full moon, that is. Williams et al. [203] offers two possible explanations:

- Moonlight reduces insect activity.
- Accompanied by moonlight, lamplight collects from a smaller area.

The past few decades did not come up with a satisfactory answer to that dilemma.

Moonlight reduces the quantity of insects trapped. This view is shared by Győrfi [67], Cleve [35], Mazochin-Pornsjakov [100], Hosny [80], Wéber [196], Barr et al. [11], Dzhafarov [55], Bréniére et al. [29], Balogh [9], Mirzayeva [105], Theowald [181], Voigt [195], Brown et al. [31], Agee et al. [1] Bowden [20], Tshernishev and Bogus [189], Schaefer [162], Persson [141], Robertson [152], [153], [154], Southwood [172], Oloy [133], Douthwaite [51], Vaishampayan and Shrivastava [192], Járfás [85], Skuhray and Zumr [170], Morton et al. [109], Herczeg and Vojnits [75], Banerjee et al. [10], Vaishampayan and Verma [193], Tucker [191], Taylor [180], Shrivastava et al. [167], Pedgley et al. [138], Dent and Pawar [47], Mészáros [103], Nag and Nath [113], Muirhead-Thomson [110], Rubio-Palis [157], Syed Nurul Alam [175], Finnamore [58], Dillon and MacKinnon [49], Steinbauer [173], Oxley [134].

Collecting in person in Madagascar, Howell [81] found that on moonless nights, the collecting sheet was covered by an uncountable multitude of insects. Various saturnid (Saturnidae) moths were light trapped by Wenzel in Venezuela (Maag [97]). He had modest catch on moonlit nights. The most favourable preconditions to successful trapping included cloudiness, warm sultriness and thunderstorm by new moon. Light trapping near full moon in Ecuador yielded very low numbers of specimens. The background illumination of the full moon makes artificial light sources practically invisible for insects. This effect is particularly strong in the tropics when the Moon is at its zenith (Brehm [28]).

According to Reinert [146], moonlight influences both light-trap effectiveness and the behaviour of mosquitoes. By full moon the light-trap will collect a smaller number of mosquitoes than by new moon. Garcia [63] collected Sphingidae species with mercury vapour light source in Venezuela. He trapped the highest number of individuals by waning Moon and the smallest number by full moon. In Burkina Faso, Constantini et al. [36] did not experience any influence of the lunar phases on the number of mosquitoes light-trapped indoors, however, out-of-doors, a smaller number of specimens were captivated at full than at new moon. According to a report by the Hock Company [77], in the light trapping of mosquitoes, there is a four-week periodicity accompanying the phases of the Moon. Collecting is successful on clouded and moonless nights. However, when 1-2 pounds of dry ice was hung up in an isolated container over the trap, there was a rise in the number of individuals caught and the influence of the Moon also diminished. In the light trapping of *Sopdoptera exampta* Walker (Lepidoptera: Noctuidae), big catches occurred much more often in the neighbourhood of a new moon than at the time of a full moon (Tucker [191]). The difference between nights with and without rain was insignificant. This refers to the fact that the relationship between rain and collecting has nothing to do with the Moon being covered by clouds. Light trapping the malaria mosquito species, *Anopheles culicifacies* Giles (Diptera: Culicidae) in India, Singh et al. [169] had a bigger catch on moonless than on moonlit nights. The difference was prevalent until midnight. Light trapping *Culicoides brevitarsis* Kieffer (Diptera: Ceratopogonidae), Bishop et al. [17] encountered a minimum by full moon. Whereas changing moonlight in the course of a night at the time of a full moon had no clear influence on the light-trap catch. Yela and Holyoak [204] examined with light-trap and bait trap the night-time activity of Noctuidae. The examination was going on for 2 years, encompassing 170 nights. The number of moths light-trapped diminished in the proximity of a full moon. The catch by the bait trap was not modified by full moon. The light-trap catch was, the bait trap catch was not increasing by growing cloudiness. According to Gustafson [66], the light-trap is not effective on cold nights, in rain, or when the Moon or other bright lights are visible in the area. The period from the last quarter to the new moon is the best time for light trapping. In that period, the Moon is visible little, if at all, in early evening. Butler et al. [33] found that moonlight restricted light trapping on cloudless nights. Moving from effective to less effective, he light-trap catch of *Chilo partellus* Swinhoe had the following order of success in India: new moon, first quarter, last quarter and full moon (Mahadevan and Chelliah [98]). Also in India, Rajaram et al. [145] light-trapped a higher number of specimens of 4 cotton pest species by new moon than by full moon, with differences in ratio though. Moonlight, in the first place by full moon, also slows down the activity of bats. According to Negraeff and Brigham [114], this has an explanation in the higher risk of catching a prey or the diminished number of insects.

The role of moonlight in reducing the catch is taken for granted by many researchers, so much so that they stop operating their light-traps at full moon, using it for collecting only at the time of the new moon and /or last quarter, perhaps in the period between the final and first quarter. They (Bragança et al. [27], Hall [69], Andreazze [3], Sant'Ana and Lozovei [159], Summerville and Crist [174], Toda and Kitching [183]) attempt to avoid the adverse impact of the Moon in this way. Tigar and Osborne [182], too, operated light-traps in 5 desert areas of Abu Dhabi by new moon every year. In an experiment, Csóka [40] claimed it was superfluous to operate a light-trap after moonrise, because he was convinced of the chances of a catch greatly reduced by moonlight.

Some researchers explain reduced catch by a slackening of flight activity and by a diminishing collecting area by others. The collecting area changes in line with the twilight or early morning illumination coming from the Sun, the light of the night sky and the light generated in its prevailing phase by the Moon. The light source of the trap is visible from a greater distance in weaker environmental illumination. The views found in professional writing are rather contradictory regarding the question of whether the changing light of the Moon influences the catch by modifying the collecting distance.

The collecting distance as a function of changing moonlight has been calculated by a number of researchers. Using a 125 W HPL light source, Dufay [53] determined the collecting distance as 70 meters at full moon and 830 meters at new moon. Studies by Bowden [19, 20], Bowden and Church [23] discussing in detail the fallback of light intensity from civil twilight to astronomical twilight as a function of the phase of the Moon are of fundamental importance. In these, Bowden examined with graphoanalytical method and arranged in charts the illumination generated by the Moon in its different phases in zones in the vicinity of the Equator, atmospheric light absorption also taken into account. He determined the collecting distances for his 125 W mercury vapour light source as 35 meters at full moon and 519 meters at new moon (Bowden and Morris [26]). Bowden [22] determined, by identical illumination, the collecting radius of three different lamps: 125W mercury vapour in the UV range: 57m at full moon and 736m at new moon, 160 W mercury vapour lamp with wolfram filament: 41m by full moon, 531m by new moon, 200 W wolfram lamp: 30m by full moon, 385m by new moon. Preuss and Preuss [142] established the height, direction and vertical distribution of the flight of nocturnal insects with the help of a telescope set up in the direction of the Moon. They compared their findings to their own light-trap catch data. They determined the collecting distance of the light-trap as 7m. Regarding the distance, Farrow [58] came to an identical conclusion. Observation by Rezbanyai-Reser (verbal message) confirms that light has an area of attraction of not more, perhaps less than 10-20 metres. Only those insects are flying to light that would probably have flied through the area anyway, in the absence of a lamp, too. In the case of a 100 W regular bulb, we determined these distances as 18m and 298m (Nowinszky et al. [122], Nowinszky and Tóth [124]). We also established, however, that the collecting distance had a provable impact on the quantity of the catch only in periods without moonlight when illumination was generated by the setting or rising Sun. The influence of the Moon on the catch exerts itself not only through the modification of the collecting area (Nowinszky et al. [131]).

Some important experiments have shown that insects fly into the trap only from the direct vicinity of the light source, a few meters at most. Recapturing tethered and free-flying marked imagoes of *Noctua pronuba* L. and *Agrotis (Scotia) exclamationis* L., Baker and his fellow researchers (Baker and Sadovy [7], Baker [6], Sotthibandhu and Baker [171]) found that the insects reacted to artificial light from the amazingly short distance of 3-17m, depending on the height of the light source. These authors rule out the possibility of moonlight exerting any influence on the collecting distance. They hold that the growing intensity of light slackens flight activity. The chance of recapturing insects released at different distances from the light-trap decreases in proportion to the growth of the distance (Szeőke [179], Morrison et al. [108]), while the proportion of the individuals trapped of the ones in the direct vicinity of the trap is identical (Bucher and Bracken [32]).

Other researchers are of the view that moonlight slackens the flight activity of insects. Over a period of three years, Nemec [115] collected the smallest number of *Heliothis zea* Boddie specimens at full moon, and the highest number at new moon. To find out about the reasons, he brought up the moths in total darkness in a laboratory. They became inactive as soon as illumination rose to over 0.1 lux. That observation, combined with his light-trap results, lead him to the conclusion that moonlight hindered flying activity. McGeachie [102] reached the same conclusion.

On the other hand, observations by Dufay [53] contradict the theory on the hindering impact of moonlight:

- Even in moonlight, nocturnal moths are there to be seen in the beam of car head-lights.
- The catch diminishes but does not stop altogether at a full moon.
- At the time of a lunar eclipse when the Moon is hiding, the catch is high, despite being low directly before and after the eclipse. This is a rather telling observation, as the eyes of nocturnal insect's adept to darkness with a delay of 5-9 minutes.

Personally engaged in collecting at the time of a lunar eclipse, Rezbanyai-Reser [147] once observed stepped up insect flight activity as soon as the Moon disappeared, and again, its gradual dying away after the Moon appeared in the sky.

Bowden and Morris [26] always calculated for an identical area the volume of their catch made in the course of the lunar month in areas reduced by the effect of moonlight. The highs of the standardized data occurring in the proximity of the full moon also contradict the theory on the hindering effect of moonlight. Our own experiments (Nowinszky and Tóth [126]) have also shown, after the corrections required by the change in the area of collecting were made, a maximum catch of two pestilent species (*Scotia segetum* Schiff. and *Scotia ipsilon* Hfn.) at full moon. In a subsequent work, Bowden [22] criticizes the remark by Baker and Sadovy [7] who had claimed that the large yellow underwing (*Noctua pronuba* L.) and the heart-and-dart moth (*Scotia exclamationis* L.) fly to light only from a distance inside 3m. Were that the case, Bowden holds, a large volume of light-trap catch over a single night would entail the existence of a population too large to be true. He believes the findings of Baker and Sadovy [7] might be valid for certain forms of behaviour in the direct vicinity of a strong light source, yet argues that their method of experimentation may be subject to criticism.

Jermy's assumption [88] that the presence of moonlight reduces the catch because it helps insects by enhancing their security of orientation is remarkable, although unchecked by concrete experiments. Wehner [197] claims that nocturnal insects, guided by the light of the Moon, are capable of orientation in space, despite the fact of this being a much more complicated task than orientation by the Sun at daytime. For the Moon is not above the horizon every night, the time of its rise and set changes from night to night, and its position alters much more drastically in the course of a night than that of the Sun in the course of a day.

A number of researchers have found that intensive moonlight does not reduce, in fact, in some cases, increases the catch by light-trap (Bogus [18], Pristavko [143], Cullen [39], Johnson [90], Duviard [54], Papp and Vojnits [135], Doiron and De Oliveira [50], Bowden and Jones [25], Járfás and Viola [86], Jeffrey and Dyor [87], Cook and Perfect [37], Shrivastava et al. [166], Saroja et al. [161], Linhares and Anderson [95], Ito et al. [83], Janousek and Olson [84]). Collecting two rice pests (*Scotinophora coarctata* F. and *Scotinophora lurida* Burmeister) with a 125 W mercury vapour lamp, Balasubramani et al. [8] observed a higher catch by the full, then by the new moon. The Malayan Black Bug (*Scotinophora coarctata* Fabricius) flies to light in large quantities. It can be light-trapped in the largest masses during the five days before and after the full moon (http://pne.gsnu.ac.kr/riceipm/ scotinop.htm.) Sharma and Badan [165] observed a catch maximum both at the time of the new and the full moon and a minimum in the vicinity of the first and last quarters. Sekhar et al. [164] claims, that the catch is higher in the period from the full to the new moon than from the new to the full moon. Collecting mosquito species, Dickson and Hatch [48] encountered a catch maximum in the first or last quarter.

According to some observations, flying activity is lengthened by the stay of the Moon above the horizon (Heikkinheimo [74]) and that leads to a richer catch (Nowinszky and Tóth [124], Tóth et al. [186], Nowinszky et al. [131]). On the other hand, Siddon and Brown [168] in a suction trap experiment encountered a catch maximum 11 hours after sunset in the 7 day period preceding the full moon and 2 hours after sunset, in other words, in the moonless periods of the night in the 7 day period following the full moon.

From the point of view of clarifying the relationship between the light of the Moon and light-trap effectiveness, studies examining the moonlight-related activity of insects by use of other methods are of great significance. For these may exclude the disturbing differences in the reaction of insects to the trap stimulus. Saha and Mukhopadhyaya [158] observed a difference in the copulation activity of the species *Orthomorpha coarctata* Saussure (Polydesmida, Paradoxosomatidae) in the first quarter of lunation. In their experience, the height of activity occurred half an hour before sunset, 3-5 days before the full moon and the new moon. Kerfoot [91] reports, those nocturnal bees carried on with their collecting activity as long as the Moon stayed above the horizon. Some water insect larvae display increased liveliness of activity in the presence of moonlight (Ribbands [148]), an experience not shared by some other authors (Andersen [2], Chaston [34]). Some mosquitoes, gnats and tsetse flies become more aggressive when the Moon is visible (Vanderplank [194], Ribbands [148], Monchdadskiy [107], Muradov [111]). On the other hand, observation to the opposite effect is reported by Bhatt et al. [13]. Desert ants carry on with their daytime feeding activity on moonlit nights (Hunt [82]). Riley et al. [150] have observed in radar experiments that the presence of moonlight protracts the activity of insects flying at twilight. Sáringer [160], too, believes in the possibility of moonlight making the day longer for insects with a perception threshold of luminous intensity below that of the Moon. Therefore in the case of some species, moonlight should also be considered in any study of the photoperiodic reactions. According to Schaefer [162], the flight maximum observed by radar was not reflected in the light-trap catch in strong moonlight. Using a radar device, Drake [52] and Riley et al. [149] who also used radar as well as infrared optics found no relationship between the direction of the orientation of migratory insects and the position of the Moon, therefore they do no see the theory of orientation by the Moon confirmed. From the catch of a Jermy-type light-trap and bait trap of the same construction, Gyulai and Nádler [68] have come to the conclusion that a light-trap will catch a higher number of insect species and individuals in most parts of the year. However, at spring, in the autumn and by strong moonlight, catch results are balanced out over the year. Suction traps often demonstrate an activity peak, not indicated by light-traps, in the period of the full moon (El-Ziady [57], Bidlingmayer [14], Perfect and Cook [140]). In a subsequent suction trap examination, Bidlingmayer [15] found no difference between the collecting results in the period of the full moon on the one hand and the new moon on the other. Bidlingmayer [16] also established that the number of mosquitoes collected in the suction and bait traps from the time of the new moon to that of the full moon grew by 2-3% every day. Bowden's [21] corrected light-trap data were basically the same as those of the suction trap. Using a suction trap, Davies [45] demonstrated an activity peak in the evening and in early morning at the time of the new moon, on other nights this was modified in line with the phase of the Moon and at the time of the full moon shifted in time to coincide with the time of the rise of the Moon and the middle of the night. The light-trap catch did not confirm evening and early morning activity. In pheromone trap experiments, Sekhar et al. [163] found no difference in the number of *Helicoverpa armigera* Hbn. moths collected at the time of the full moon on the one hand and that of the new moon on the other. Mean catches of the African sweet potato weevils, *Cylas brunneus* and *Cylas puncticollis*, did not differ significantly between new and full moon caught by pheromone trap (Laboke and al. [93]). Tshernishev and Dantanarayana [190]) established in laboratory experiments that the activity of the three noctuid species (*Helicoverpa armigera* Hbn., *Helicoverpa punctigera* Wallengren and *Heliothis rubescens* Walker) studied with the help of an infrared actograph reached its peak by full moon and by new moon, and its low from the second day following the new moon to the two days preceding the full moon. Williams and Singh [202] have reported on the following suction trap catch results in the + 3 day proximity of the various Moon phases: full moon: 204, last quarter: 589, new moon: 1 259, first quarter: 562 specimens. El-Ziady [57] modifies the original question by Williams [198] on the modest catch at the time of the full moon in the following way:

- Moonlight has a direct influence on activity and reduces the number of flying insects.
- It is possible that insects stay at the shaded, darker places at the time of the full moon.
- It is equally perceivable that insects fly in the higher layers of the atmosphere in that period.

On the other hand, Danthanarayana [41] in his suction trap experiments detected a major peak in the catch at the time of the new moon and a smaller one at the time of the full moon. According to Danthanarayana [42], the flight activity of insects has a three peak lunar periodicity: in the first and last quarters and directly after the period of the full moon. The latter peak however, remains obscured in light-trap collecting as it occurs in the period characterized by the smallest collecting area. The lunar period of flight activity gets superimposed on the circadian rhythm. In his view, the three peak lunar periodicity might be related to migration. In these periods, insects fly in the higher layers of the atmosphere, thus reaching heights where they get transported by horizontally moving masses of air. In our earlier work (Nowinszky et al. [130]) we demonstrated that only in traps operated at 2 m and 10 m is the difference in the specimen number of migratory species insignificant at the time of the full moon, in the period of other lunar phases, the light-trap lying lower collects a much smaller number of individuals. This fact might support the assumption of Danthanarayana, although in the absence of a satisfactory amount of investigation in Hungary, we cannot come out with a well-founded argument on this question. And in the absence of high traps, the possibility of further research is ruled out. However, the outcome of an experiment by El-Ziady [57] might be an important contribution: using a suction trap placed at a height of about 9m (30 feet), he collected the highest number of flies (Diptera) at the time of the full moon.

Danthanarayana and Dashper [43] observed a peak in the activity of nocturnal insects at the time of the full moon and in the proximity of the first and the last quarters. The latter two maximums are related to polarized moonlight, which is of the highest intensity in the same two lunar quarters. Kovarov and Montchadski [92] found that a light-trap using polarized light was twice as effective as the one using regular light. In an earlier study (Nowinszky et al. [122]), we detected in the combined light-trap catch data of 7 species three catch maximums in the course of the lunar cycle. However, in the place of the first maximum at the time of the full moon, we found a smaller local catch maximum in the period of the new moon. The abundance of catch in the first and last quarters can be explained with the high ratio of polarized moonlight, while the catch high in the vicinity of the new moon, when there is no moonlight, might follow from the fact that this is the phase characterized by the largest collecting area. Mizutani [106] could not confirm the influence of polarized moonlight on the catch, but then he had a mere 17 nights at his disposal and there was a strong wind at the time of collecting. An experiment by Sotthibandhu and Baker [171] shows that the large yellow underwing (*Noctua pronuba* L.) finds its bearings on moonless, bright nights by the stars positioned some 95° from the North Star.

All in all, not to this day have researchers arrived at a common platform regarding the influence of the Moon on the flight activity of insects and on the light-trap catch. Therefore, making use of the enormous mass of collecting data supplied by the Hungarian national light-trap network and the hourly catch of Járfás' fractionating light-trap in Kecskemét, we examined this question in several studies (Nowinszky [119]).

Material and Methods

In our work, we used data of national light-trap network pertaining to the species listed in *Table 1*. The material of the Kecskemét fractionating light-trap, we processed data on turnip moths (*Scotia segetum* Schiff.) and heart-and-dart moths (*Scotia exclamationis* L.).

Table1. *Data of the species examined from the material of the national light-trap network.*

Species	Number of Light-traps	Years	Individuals	Data
Coleoptera: Alleculidae				
Hymenalia rufipes F.	3	5	604	3602
Lepidoptera: Cossidae				
Dyspessa ulula Brkh.	33	14	2893	1351
Lepidoptera: Plutellidae				
Plutella maculipennis Curt.	26	3	3953	4821
Lepidoptera: Hhyponomeutidae				
Hyponomeuta malinellus L.	24	3	1591	994
Lepidoptera: Notodontidae				
Clostera pigra L.	2	10	1238	963
Lepidoptera: Lasiocampidae				
Odonestis pruni L.	25	17	2363	947
Lepidoptera: Lymantriidae				
Lymantria dispar L.	55	20	4721	3326
Porthesia similis Fuess	12	14	1195	786
Lepidoptera: Noctuidae				
Scotia vestigialis Schiff.	15	19	1109	3396
Amathes c-nigrum L.	7	12	4108	12401
Mamestra suasa Schiff.	28	10	6502	5447
Brachyonicha sphinx Hfn.	17	10	2142	3623
Lepidoptera: Geometridae				
Abraxas grossulariata L.	12	11	889	1105
Erannis marginaria Brkh.	10	9	1671	2077

We used our own software devised for the purpose to calculate the times of sunset and sunrise and the start of civil, navigational and astronomic twilight as well as the values of illumination in the environment expressed in log lux (Tóth et al. [185], Tóth and Nowinszky [184], Nowinszky and Tóth [125]). The same software made it possible for us to define for any given point of time the light of the twilight sky from the setting or rising Sun, illumination generated by the Moon always in correlation with the given lunar phase and the light of the starry sky which is constant (0.0009 lux). The software also considers the extent of cloudiness. Our own software also helped us to calculate the position of Babinet's point above the horizon. In the current study we have no scope to outline the theoretical bases and actual succession of calculations. However, let me refer to our earlier work (Tóth et al. [185], Nowinszky et al. [122]), where all these were described in detail, with the software in question and our results included (Nowinszky and Tóth [125], Nowinszky and Tóth [129]).

From the material of the Kecskemét fractionating light-trap we have used collecting data pertaining to the fall webworm moth (*Hyphantria cunea Drury*) and the turnip moth (*Scotia segetum* Schiff.). In the context of the position of Babinet's point, we examined light trapping efficiency concerning the catch of turnip moths (Scotia segetum Schiff.) and heart-and-dart moths (*Scotia exclamationis* L.). And with regard to the collecting distance, we processed the catch data pertaining to all three species. We computed the collecting distance of the Kecskemét fractionating light-trap for different values of environmental illumination and the ensuing probabilities of approach in a way described in an earlier study (Nowinszky et al. [122]). In what follows we give you the result without repeating the process of calculation. With the exact time of the catch within each hour unknown, the data were always calculated for the 30th minute following every full hour. By the distance of collecting we mean the radius of a circle with a circumference made up of points that receive an equal amount of illumination from the light-source and the environment. This is the formula to determine the radius:

$$r_o = \sqrt{I/E} \qquad \text{(Eq. 1)}$$

Where: ro = the collecting distance, I = the intensity of illumination by the light-trap (candela), E = the intensity of environmental illumination (lux).

If the illumination in the environment comes exclusively from the starry sky, the maximum collecting distance with a Jermy-type light-trap is this:

$$r_o = \sqrt{80/0.0009} = 298\text{m} \qquad \text{(Eq. 2)}$$

And with the Kecskemét fractionating light-trap using F-33 light-tubes:

$$r_o = \sqrt{255/0.0009} = 532\text{m} \qquad \text{(Eq. 3)}$$

At full moon, when the environmental illumination comes partially from the Moon, the collected distance with a Jermy-type light-trap is the following:

$$r_o = \sqrt{80/0.25+0.0009} \approx 18\text{m} \qquad \text{(Eq. 4)}$$

And with the Kecskemét fractionating light-trap using F-33 light-tubes:

$$r_o = \sqrt{255/0.25+0.0009} \approx 32\text{m} \qquad \text{(Eq. 5)}$$

We are to assume that the flight of an insect at distance r from the light-trap is equally probable in every direction. In that case, the probability (probability of approach) of the insect flying in the direction of the two-dimensional plane determined by the tangents to a circle with radius r_o is the following:

$$P(A) = (1/p) \arcsin (r_o/r) \qquad \text{(Eq. 6)}$$

From the catch data we calculated relative catch (RC) values by species, generations and hours. In the swarming periods of the different generations, we calculated for each night the times of sunset and sunrise as well as the start of civil, navigational and astronomic twilight in both the evening and early morning hours and the onset of night time illumination, the accompanying values of environmental illumination expressed in lux and the period in which the Moon stayed above the horizon. We arranged collecting hours into the range of illumination to which they belonged over a longer period of time, separating moonlit hours and those without moonlight. Within each range of illumination, we averaged the accompanying relative catch values. The level of significance of the difference between the catch by the same illumination before and after midnight as well as the catch belonging to consecutive ranges was checked by a t-test (Nowinszky et al. [120]).

We computed the whole collecting area for the twilight and night hours both with and without moonlight. Without considering the hour of collecting, yet making a distinction between the hours of twilight and night with and without moonlight, we arranged these areas into classes, and then drew averages (Nowinszky et al. [131]). By use of our own method, we calculated three point moving averages of the accompanying relative catch data. Then we attempted to reveal the possible connection by correlation calculations by species.

The assumed effect of Babinet's point on the orientation of insects considering both evening and daybreak collection data in a contracted form, we studied then compared with each other the modifying effect on the catch of the Moon on the one hand and Babinet’s point on the other. We arranged in three classes the values of environmental illumination below -1 log lux, -2 log lux and -3 log lux. In each class, we separated two groups depending on the position of the Moon and Babinet's point above the horizon:

- The Moon and Babient's point were both above the horizon (M+Bp+).
- The Moon was not, Babinet's point was above the horizon (M-Bp+).

In all illumination classes and groups, we summed up then averaged the relative catch values of the relevant hours. Then we examined the differences, if any, between the catch data pertaining to the different species and classes of illumination. We checked the significance levels of the differences with a t-test.

Then, disregarding environmental illumination, we went on analysing those cases in which both the Moon and Babinet's point were above the horizon. Here we wanted to find out whether there is any difference in the light trapping efficiency of the different species depending on whether the Moon or Babinet's point was higher on the horizon. Since Babinet's point was always positioned below 45° above the horizon, we examined cases when the Moon, too, did not rise higher than 45°. We separated our data depending on whether the Moon or Babinet's point was positioned lower above the horizon. All in all, also distinguishing between evening and early morning hours, we studied the differences in the catch results of four different eventualities. Both in the evening and early morning hours, we compared the catch results in the following situations:

- The Moon and Babinet's point are both below 45° above the horizon, but the Moon is positioned lower.
- The Moon and Babinet's point are both below 45° above the horizon, but Babinet's point is positioned lower.

Just like before, we summed up, then averaged the relative catch values by species and checked the significance level of the differences with a t-test.

Based on a study by Austin et al. [5], Pellicori [139] and our own earlier work (Ekk et al. [56], Szabó et al. [177], Nowinszky and Tóth [123], [124], [126], Nowinszky et al. [122]), we have sketched the relative luminousness of the Moon and the ratio of its polarized light as a function of the phase angle. Based on our earlier work (Tóth and Nowinszky [184]) were calculated with the help of software of our own development (Nowinszky and Tóth [125]).

Looking at the Kecskemét collection data of the turnip moth (*Scotia segetum* Schiff.) and the heart-and-dart moth (*Scotia exclamationis* L.), we were first trying to find an answer to the question of whether the differing heights of the Moon above the horizon influenced the effectiveness of light trapping? The catch data from the fractionating light-trap provide us with the specimens caught in each full hour, within that, however, we have no knowledge of the exact time of trapping, therefore the data related to the height of the Moon above the horizon were calculated electronically, with our own software, always pertaining to the 30th minute of each hour (Nowinszky and Tóth [125]). We processed the catch of only those nights when the Moon was observable both below and above 45° on the horizon.

We arranged in classes, and then averaged the values of the height of the Moon above the horizon following Sturges’ method (Odor and Iglói [132]). One by one, the relative catch values of the species examined were correlated to the values of the height of the

Moon above the horizon determined for each given hour of the catch. These were then averaged in each class. We checked with a t-test the differences between the average relative catch values in the successive classes. We made correlation calculations for both species between the height of the Moon above the horizon and the accompanying 3 point moving average of the relative catch.

We calculated the phase angle value of the Moon for the 24th hour (UT) of each night in the swarming periods of the various species. Then we formed 30 phase angle groups of the 360 degrees of the complete lunar cycle. The group of the phase values in the ± 6o vicinity of the full moon (0° or 360°) was marked 0. Starting from this, the groups through the first quarter in the direction of the new moon were marked -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. And the groups from the full moon via the last quarter in the direction of the new moon are marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The phase angle group containing the new moon was ±15. Each group contains 12 phase angle values. The following phase angle groups fall in the four typical lunar quarters: full moon (-2 - +2), last quarter (3 - 9), new moon (10 - -10) and first quarter (-9 - -3). We arranged all the nights of the swarming periods of the species examined in one of the above phase angle groups, and then averaged the accompanying relative catch data of the various species. To reduce the misleading effect of other, simultaneously existing environmental factors, we performed a 10 point digital filtering of the average values (Nowinszky et al. [131], Nowinszky and Tóth [127, 128]) by use of the Hanning filter formula (Gold and Rader [64]) which contains the following filter parameters:

$$F(1) = \frac{2}{P1} - \frac{2}{P2} \quad \text{and} \quad F(k) = \sum_{k=2}^{T} \left(\sin\frac{2\pi k}{P1} - \sin\frac{2\pi k}{P2}\right) \frac{\cos(\frac{\pi k}{T})}{2\pi k} \qquad \text{(Eq. 7 and 8)}$$

Where P1 = the lower limit of the filter, P2 = the top limit of the filter, T = P1 - P2, k = 2,... T. The filtered values and the basic data are obtained by a convolution of the above filter parameters.

On the swarming curves received after the Hanning filtering had been performed, maximum and minimum catches are found in the same groups of phase angles as on the curves drawn on the basis of the original catch data, but the maximum values lay higher and minimum values lower. So filtering had reduced the disturbing effect of other, simultaneously existing environmental factors made the curves more typical and highlighted the catch maximums and minimums. We did not perform any filtering of the Kecskemét data, as we needed the original catch values for subsequent calculation.

Results

The catch results in the context of environmental illumination of the turnip moth (*Scotia segetum* Schiff.) and the fall webworm moth (*Hyphantria cunea* Drury) are shown in *Table 2.*

***Table 2.** Light-trap catches of the Scotia segetum Schiff. and the Hyphantria cunea Drury in connection with the environmental illumination, in periods with and without moonlight.*

Twilight and illumination	Zenith distance of the Sun	Moonlit and without moonlight periods	Scotia segetum Schiff.		Hyphantria cunea Drury	
			RC	N	RC	N
Sunset 188 lux	90.5°	Without moonlight	0.612	38	0.612	94
Civil twilight	90.5°-96°	Without moonlight	1.897	102	0.766	177
188-3.3 lux		Moonlit	0.421	37	0.905	59
Navigation twilight	96°-102°	Without moonlight	2.284	86	0.683	152
3.3-0.01 lux		Moonlit	1.074	54	1.647	103
Astronomical twilight	102°-108°	Without moonlight	1.861	87	1.001	154
0.01-0.001 lux		Moonlit	1.071	53	1.055	122
Nocturnal illumination	108°alatt	Without moonlight	1.289	292	*0.915*	553
0.0009 lux		Moonlit	1.316	221	*1.267*	479
Astronomical twilight	102°-108°	Without moonlight	0.804	78	1.050	154
0.01-0.001 lux		Moonlit	1.131	62	1.952	100
Navigation twilight	96°-102°	Without moonlight	0.516	88	1.000	171
3.3-0.01 lux		Moonlit	0.920	52	1.633	82
Civil twilight	90.5°-96°	Without moonlight	0.256	126	0.578	220
188-3.3 lux		Moonlit				
Sunrise188 lux	90.5°	Without moonlight	0.052	24	0.122	90

RC = relative catches, N = Number of observing data. Underlined and italic numbers indicate the twilight periods in which the relative catch is significantly (at least at a 99% and 95% level) higher than that of the night.

Table 3 contains the catch results by light-trap of the species examined as a function of the collecting distance, in hours without moonlight. As we could establish no relationship between the collecting distance and the catch in moonlit hours, we omit publication of the relevant results. With regard to the position of Babinet's point over the horizon, the catch results pertaining to turnip moths (*Scotia segetum* Schiff.) are seen in *Table 4* and those concerning heart-and-dart moths (*Scotia exclamationis* L.) are seen in *Table 5 Table 6* shows the results of light trapping depending on the height of the Moon above the horizon based on the material of the Kecskemét light-trap.

Table 3. *Light-trap catch of the species examined at times of civil, navigational and astronomic twilight, in hours without moonlight in the function of the collecting distance (in metres).*

Scotia segetum Schiff.			**Scotia exclamationis L.**			**Hyphantria cunea Drury**		
Distance	**RC**	**N**	**Distance**	**RC**	**N**	**Distance**	**RC**	**N**
8.9	0.856	362	1.9	0.380	319	1.5	0.974	353
33.7	0.912	54	4.3	0.371	71	34.1	1.233	56
76.5	1.036	51	11.6	0.431	59	77.3	1.566	70
126.3	1.293	33	37.7	0.736	61	129.3	1.188	31
184.3	1.306	17	72.9	0.997	59	185.4	1.402	27
228.9	1.093	22	137.0	1.180	61	241.0	1.740	30
276.7	1.033	26	242.3	1.134	60	300.8	1.341	43
334.9	1.065	66	314.4	1.134	61	359.2	1.285	13
373.0	1.124	48	348.4	1.260	59	434.1	1.610	22
416.2	1.203	27	365.1	1.174	57	492.2	2.037	13
469.5	1.404	20	425.1	0.997	67			
r = 0.631 (significance = 95%)			r = 0.783 (significance = 99%)			r = 0.688 (significance = 95%)		

Table 4. *Light-trap catch of the turnip moth (Scotia segetum Schiff.) in connection with the position of the Moon and the Babinet- point over the horizon.*

Position of the Moon and Babinet-point above the horizon	**log lux - 1.....**		**log lux - 2.....**		**log lux - 3.....**	
	RC	**N**	**RC**	**N**	**RC**	**N**
Both the Moon and the Babinet-point are above horizon	*1.033*	104	*0.686*	89	0.246	5
The Moon is below the horizon, the Babinet-point is above the horizon	*1.219*	91	*1.253*	168	0.608	30

Both the Moon and the Babinet-point are lower than 45º,	*Evening*		*At dusk*	
	RC	*N*	*RC*	*N*
but the Babinet-point is higher,	1.008	84	*0.614*	49
but the Moon is higher	1.040	41	*1.123*	63

RC = relative catches, N = number of observing data. Italic numbers indicate if the differences of relative catch values one after the other are those significantly higher than 95%.

Table 5. *Light-trap catch of the turnip moth (Scotia exclamationis L.) in connection with the position of the Moon and the Babinet- point over the horizon.*

Position of the Moon and Babinet-point above the horizon	**log lux - 1.....**		**log lux - 2.....**		**log lux - 3.....**	
	RC	**N**	**RC**	**N**	**RC**	**N**
Both the Moon and the Babinet-point are above horizon	*0.773*	117	1.015	85	0.777	10
The Moon is below the horizon, the Babinet-point is above the horizon	*0.954*	118	1.034	214	0.858	14

Both the Moon and the Babinet-point are lower than 45º,	*Evening*		*At dusk*	
	RC	*N*	*RC*	*N*
but the Babinet-point is higher,	*0.745*	77	*0.811*	78
but the Moon is higher	*1.394*	48	*2.141*	54

RC = relative catches, N = number of observing data. Italic numbers indicate if the differences of relative catch values one after the other are those significantly higher than 95%.

Scotia segetum Schiff.			Scotia exclamationis L.		
Height of the Moon above horizon (°)	Relative catches	Number of data	Height of the Moon above horizon (°)	Relative catches	Number of data
7.5	1.82	14	7.4	2.11	13
11.9	1.47	15	12.1	2.11	13
17.1	1.31	15	16.9	2.06	13
21.7	1.21	15	21.9	1.83	13
26.8	1.28	15	26.6	1.68	13
31.9	1.20	16	32.0	1.55	15
37.3	0.99	16	36.9	1.41	12
41.9	1.07	15	41.5	1.45	14
47.0	0.97	24	46.9	1.29	21
51.8	0.69	14	51.9	0.86	15
58.7	0.26	14	56.8	0.11	11
r = - 0.933 (Significance level is higher than 99 %)			r = - 0.867 (Significance level is higher than 99 %)		

Table 6. *Light-trap catch of the turnip moth (Scotia segetum Schiff.) and the heart-and-dart moth (Sctoia exclamationis L.) related to the height of the Moon over the horizon (in degrees) (Kecskemét, 1967-1969).*

Of the material of the national light-trap network, guided in our selection by an effort to give as wide a representation as possible to the reflection of taxonomic categories, we put forth some of our new findings concerning characteristic types of behaviour re-flecting the influence of the Moon in *Figures 1-7.*

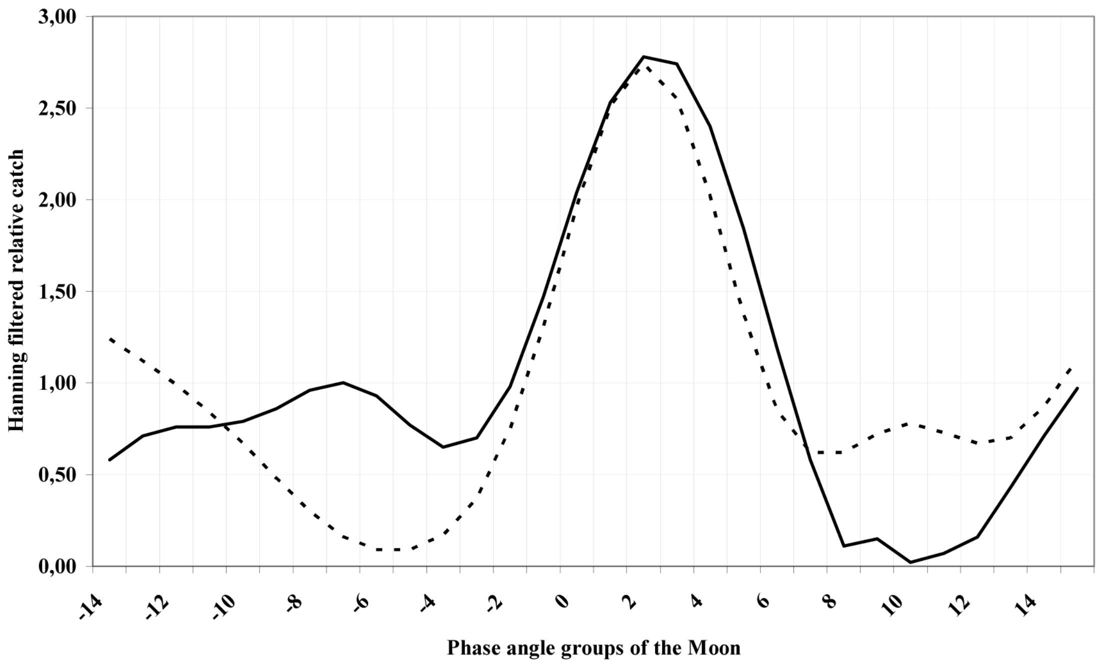
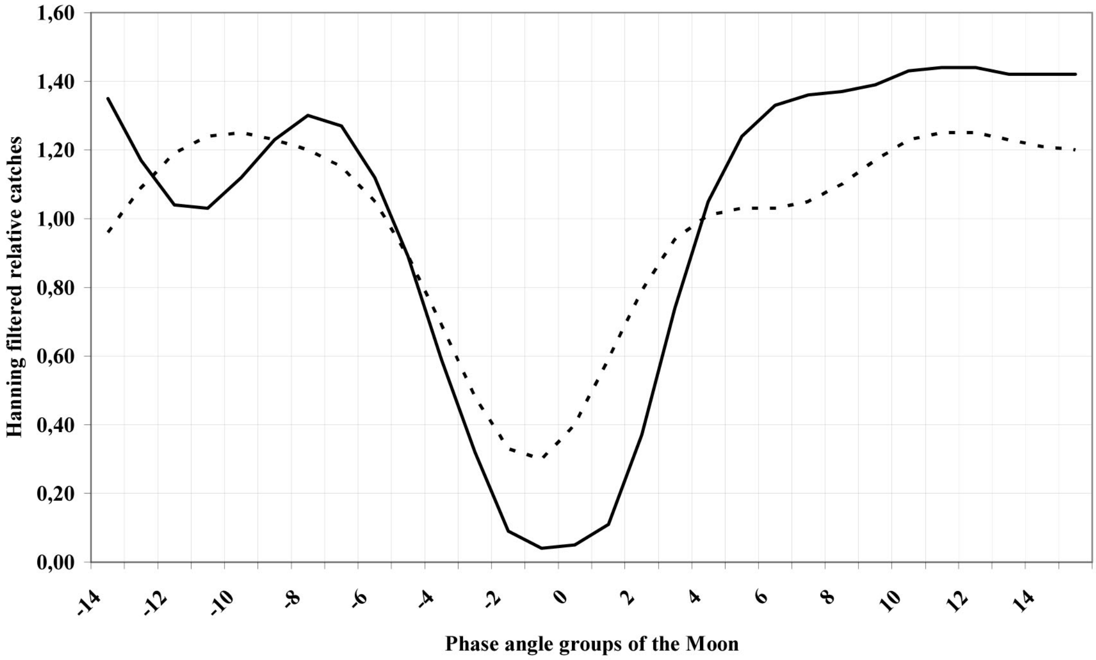


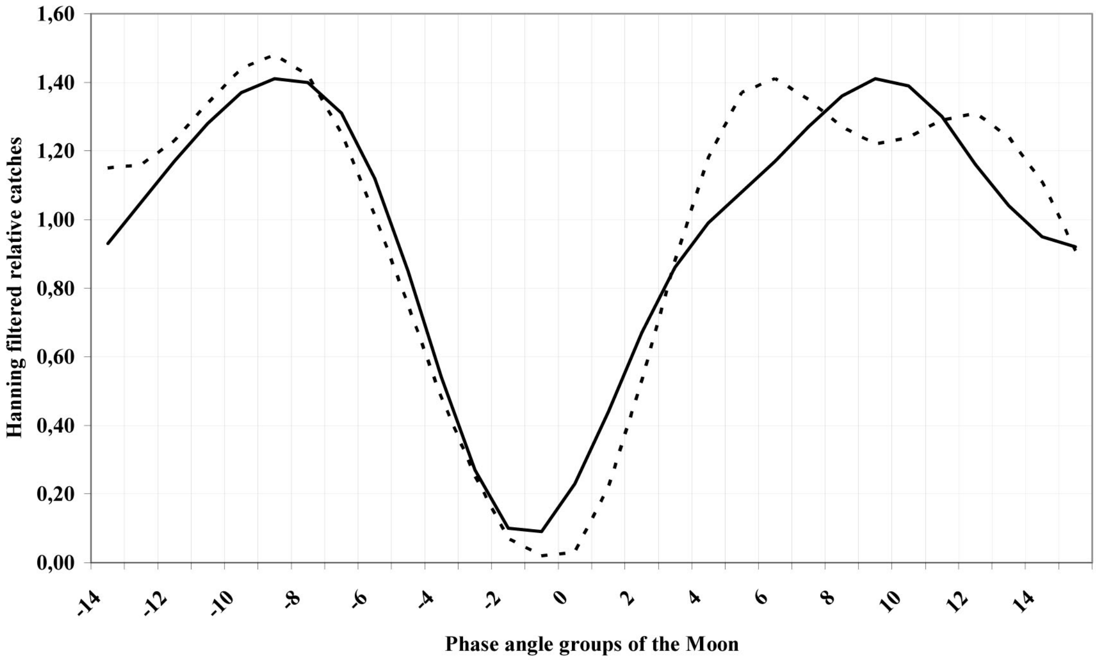
Figure 1. *Hanning filtered relative catches of the Erannis marginaria Brkh. (continuous line) and the Hymenalia rufipes F. (dotted line) depending on the phase angle groups of the Moon. (A single explicit catch maximum at full moon or directly after.)*

Figure 2. *Hanning filtered relative catches of the Hyponomeuta malinellus L.. (continuous line)*



and the Mamestra suasa Schiff. (dotted line) depending on the phase angle groups of the Moon. (High catches from the last quarter to first one, not falling back at the new moon.)

Figure 3. *Hanning filtered relative catches of the Amathes c-nigrum L.. (continuous line) and the*



Lymantria dispar L. (dotted line) depending on the phase angle groups of the Moon. (Two nearly identical catch maximums in the first and last quarters.)

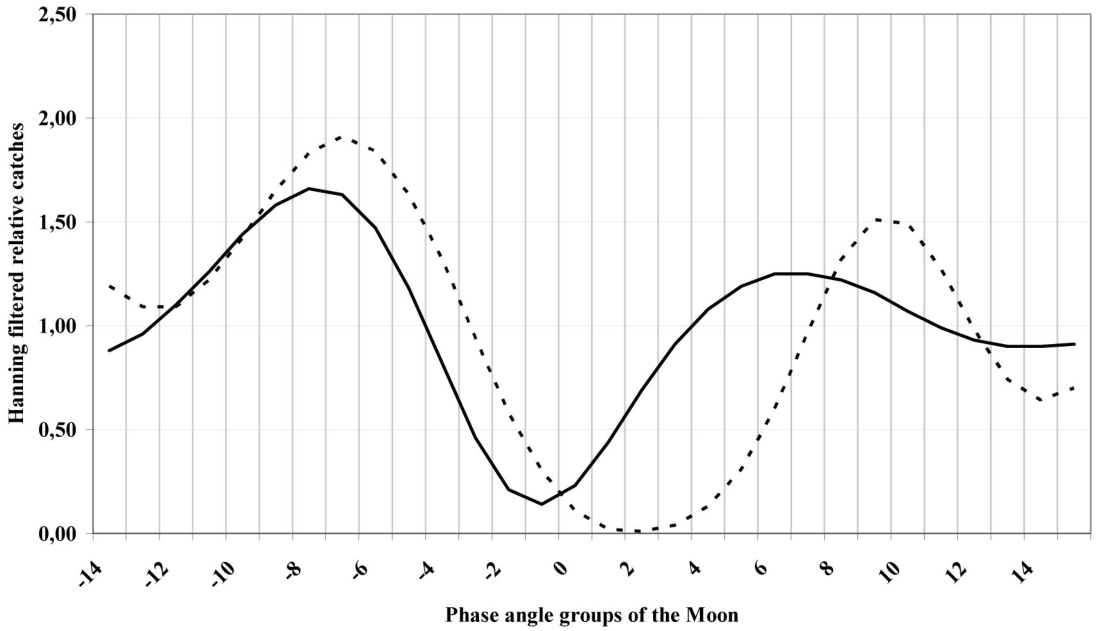


Figure 4. Hanning filtered relative catches of the Pygaera pigra L. (continuous line) and the Brachyonica sphinx Hfn. (dotted line) depending on the phase angle groups of the Moon. (Two catch maximums, the stronger in vicinity of the first quarter.)

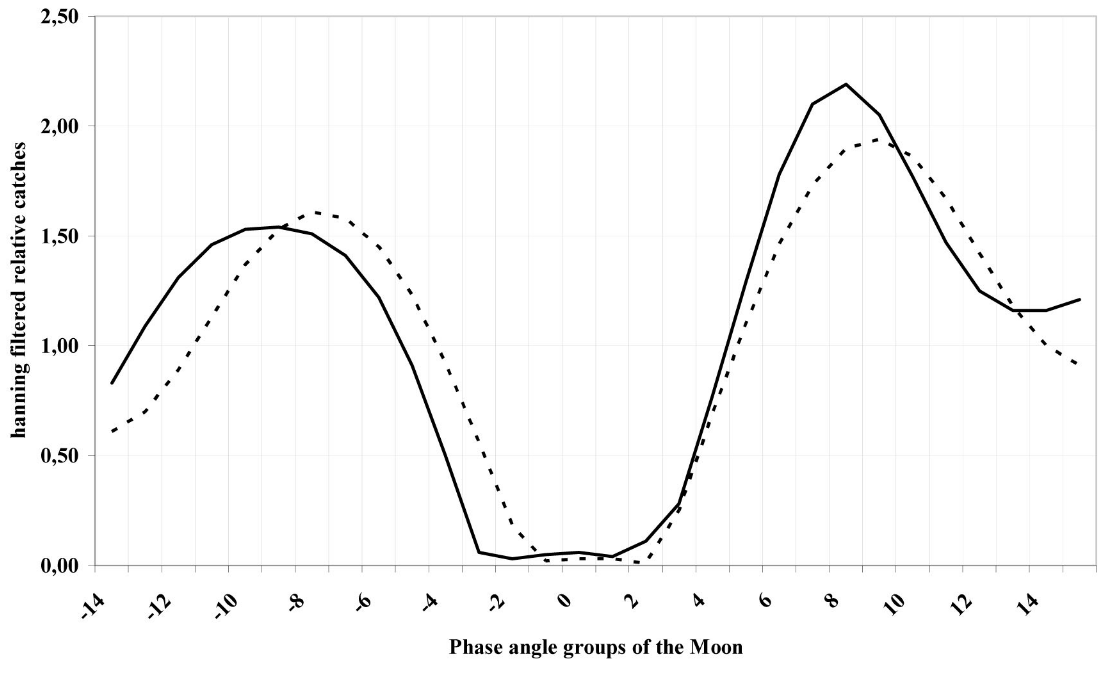


Figure 5. Hanning filtered relative catches of the Odonestis pruni L. (continuous line) and the Porthesia similis Fuess. (dotted line) depending on the phase angle groups of the Moon. (Two catch maximums, the stronger in vicinity of the last quarter.)

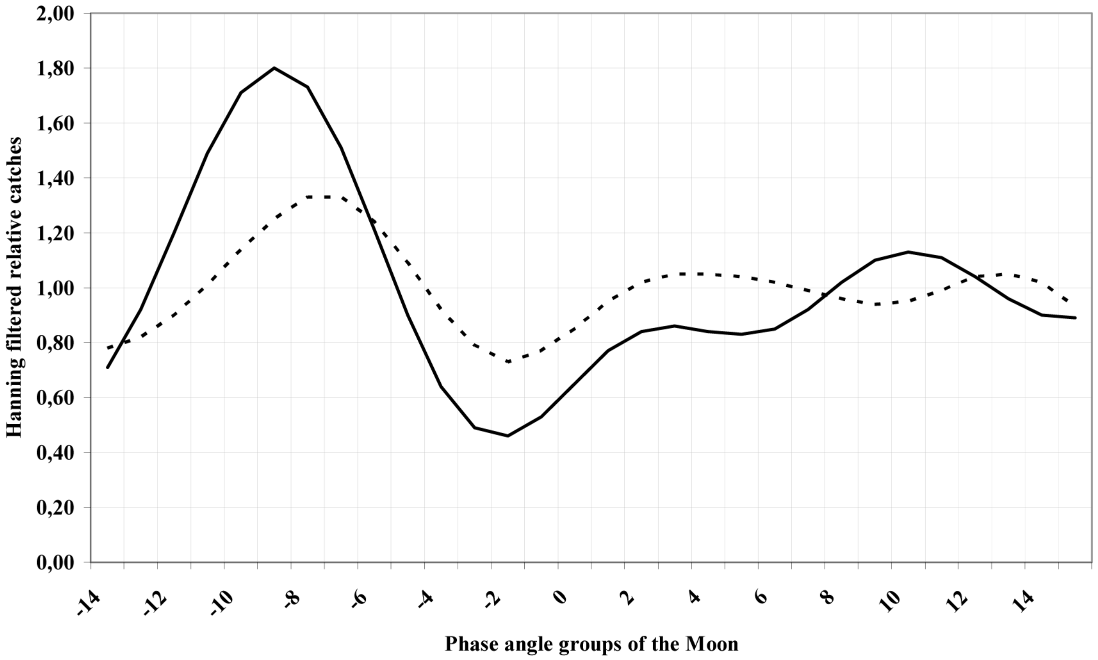
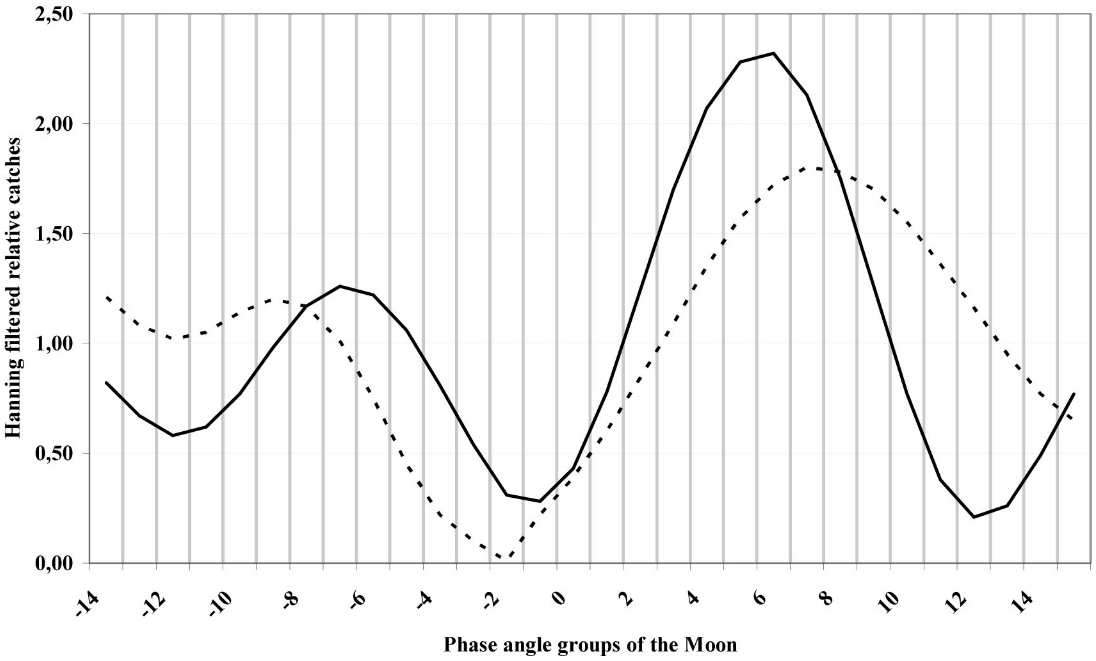


Figure 6. Hanning filtered relative catches of the Scotia vestigialis Schiff. (continuous line) and the Plutella maculipennis Curt. (dotted line) depending on the phase angle groups of the Moon. (Single explicit catch maximum at first quarter.)

Figure 7. Hanning filtered relative catches of Abraxas grossulariata L. (continuous line) and



Dyspessa ulula Brkh. (dotted line) depending on the phase angle groups of the Moon. (Single explicit catch maximum at last quarter.)

Discussion

Illumination generated by the Sun and the Moon changes not only on the different days of the swarming period, but also in the course of each night, therefore it is an extremely important factor modifying collecting.

In the case of the turnip moth (*Scotia segetum* Schiff.) we find that in the periods without moonlight, every range of illumination, with the expectation of the middle hours of the night, is accompanied by significantly higher catch results before than after midnight.

In the middle of the night when the light of the nocturnal sky is the only natural source of light to ensure the illumination of the environment, the catch before and after midnight is the same, presumable because of the small time difference. Whichever of the three forms of twilight illumination may prevail, the catch after sunset is significantly higher than at the time of sunset or in the hours of illumination by night. However, the relative catch values accompanying civil, navigational and astronomic twilight show no variation. It is extremely remarkable that the number of moths caught during the successive twilight's after midnight goes on decreasing significantly (*Table 2*).

Our earlier results (Nowinszky et al. [121]), however, have also made it clear that this phenomenon is explained neither by temperature regularly dropping by dawn, nor by increasing relative humidity. Our examinations have proved that in all comparable cases by identical illumination and temperature as well as by identical illumination accompanied by relative humidity, the catch was always significantly higher before than after midnight. It is remarkable, however, that the above circadian rhythm is modified by the presence of the Moon above the horizon: the activity of flying to light does not lose from its liveliness until the navigational twilight of the early morning hours, in fact significantly more moths fly to light at dawn than under the same illumination conditions in the periods without moonlight. However, during the total solar eclipse of August 11th, 1999, the light-traps in Vas county did not catch a single insect (Puskás et al. [144]). Sudden short darkness at daytime does not disturb the circadian rhythm.

Our examination related to the fall webworm moth (*Hyphantria cunea* Drury) has produced an opposite result. In the hours of civil, navigational and astronomic twilight and by identical temperature and humidity, the imagoes of this species show greater activity in flying to light after midnight. It is remarkable, however, that in every sphere of illumination, the number of moths caught is higher in the moonlit periods.

In the hours without moonlight, the catch relevant to all three species increases as the distance of collecting grows (*Table 3*). However, this relationship cannot be proved when illumination is generated partly by the Moon. Although moonlight reduces the distance of collecting, the catch results do not go down accordingly. So the Moon exerts is influence not only through the area of collecting.

In all three spheres of illumination and regardless of the Moon being positioned above or below the horizon, the light trapping of both species will be more successful when Babinet's point is below the horizon (*Table 4* and *Table 5*). When the Moon and Babinet's point are both below 45° over the horizon, the catch will be more successful if the Moon is positioned higher. We presume that the Moon and Babinet's point both play a role in the orientation of insects, but of the two the one seen higher will be of greater importance. If Babinet's point is positioned higher, the insect may escape the light-trap, perceiving the former as a discontinuity in a sky emitting a continuity of polarized light, and it can hardly mistake that discontinuity for an artificial source of light as it is perceivably does in the case of the Moon. So, unlike the Moon, Babinet's point bolsters the security of orientation.

Gál et al. [61] observed patterns including the positions of the Arago and Babinet neutral points of the moonlit night sky and sunlit day sky are practically identical if the zenith angle of the Moon is the same as that of the Sun. The biological relevance of the polarization pattern of the moonlit night sky in the polarization vision and orientation of night-active insects is possible.

In our assumption, the Moon, when staying above the horizon, provides insects with guidance of orientation, therefore they avail of light stimuli in the first place to find their bearings in space. In that situation, light trapping is more efficient, as, provided certain conditions are given, the insect might mistake the light of the artificial sources that have been around for only a few millennia for the light of the Moon and therefore will be trapped. As shown in *Table 6*, the height of the Moon above the horizon is in negative correlation with the 3 point moving average of the relative catch. A remarkably strong and significant fallback occurs in the catch of both species when the Moon is 45° above the horizon. If the Moon is observable higher than that, the light-trap will collect few insects. We might try to interpret this observation on the basis of experiments by Baker and Sadovy [7] and Baker [6]. Insects flying on the surface of the ground will see the top of a 360-cm column of light at an angle of 45° from a distance of 3.6m. That distance fits the 3-17m determined by Baker et al. as the distance from which insects react to artificial light. If the insects fly higher than the surface of the ground, they will always see the top of the source of light from an angle less than 45°. So, provided Baker is right, we have an explanation for why the catch is high in the moonlit hours of the night only when the Moon is on the horizon at an angle smaller then 45°, as only then will insects see the top of the trap and the Moon at the same height and only when that happens can they mistake the artificial light for the light of the Moon. So, the critical point in the position of the Moon above the horizon below which we have a high catch and over which we have a low catch is 45°. It remains a problem though that the Kecskemét light-trap was equipped with fluorescent tubes instead of a point like source of light. Because if the height of the Moon above the horizon and its vertical diameter are indeed the most important factors causing confusion, it is not clear how the insect might mistake the column of light for the Moon? Another possible explanation might be this: if the Moon stays low above the horizon, moonlight will penetrate through a thicker layer of air and so its spectral composition shifts to the domain of longer wavelengths. In this case, the light source of the trap may substitute the light waves of shorter wavelengths, to which the insect eye is extremely sensitive, and the catch grows. However, this hypothesis is in sharp contradiction with all the findings we have had so far which appear to confirm that collecting is efficient when the risk of making the mistake runs high. Following from the Mie effect, moonlight gets scattered and consequently polarized much more when penetrating through a thicker layer of air than in the case of arriving in the vicinity of a right angle. This fact, well compatible with our results, may increase the effectiveness of collecting. An analysis of the catch data presented in a study by Szabóky [178] is an interesting contribution to the subject, although it cannot be regarded as decisive evidence in support of our results. The author referred to registers the exact time, with accuracy to the minute, of the landing of 57 specimens of *Anarta myrtilli* L. on the sheet as he was collecting with a 125 W mercury vapour lamp. In 43 cases of the points of time listed, the Moon was not above the horizon and 14 cases were positioned lower than 45°.

Our research into the relationship between the lunar phases and collecting by light-trap have given an answer to the question of what phase angle domains are favourable or unfavourable from the point of view of light trapping the different species. As confirmed in *Figures 1-7*, this has not been observed with any of the species. The Moon has been proved to modify collecting, while it was also established that the various spe-cies display different behaviour in the face of moonlight. Based on more recent research we have been engaged in, we have set up 7 basic types of behaviour:

1. A single explicit catch maximum at full moon or directly after.
2. High catch from the first to the last quarter, not falling back at the time of the new moon.
3. Two nearly identical catch maximums in the first and last quarters.
4. Two catch maximums, the stronger of the two observed in the vicinity of the first quarter.
5. Two catch maximums, the stronger of the two observed in the vicinity of the last quarter.
6. A single catch maximum in the first quarter.
7. A single catch maximum in the last quarter.

The influence of the Moon on light trapping varies by species, a fact that cannot be explained by either the degree of taxonomic relationship, or by the difference in the swarming periods. It is quite likely that the various species respond in different ways to the optical characteristics of the Moon, which have their maximums always in different phase angle groups. For instance, in Hungary, in the hours of light trapping (6 p. m. – 4 a. m. UT), light intensity and the duration of the stay of the Moon above the horizon is the longer in the 2nd phase angle group following the full moon, while the extent of polarization is the highest in the first and last quarters. On the other hand, the colour temperature of a regular light-trap (2900 °K) comes closest to the colour temperature of the Moon (4100 °K at full moon according to Bernolák [12]) between the first and last quarters and the new moon (-10 and 11 phase angle group) (Nowinszky et al. [131]). Although the optical characteristics presumably exert their influence in their complexity on the insects collected, individuals of the various species might react to the various features in different ways.

The sensitivity to light of the species in first type is the highest at the time of the full moon, or directly after in the +1, or +2 phase angle group. Danthanarayana [42] also reported on the catch maximums observed on such occasions. However, this group contains only a small proportion of the species studied so far. Most species examined display strongly slackening activity at the time of the full moon. Moonlight is unpolarized at the full moon, while negative polarization can be observed directly before and after, the period in which the colour temperature of the Jermy-type light-traps comes closest to that of the Moon. It is in this latter fact that can be a probable reason for the maximum observed at this time.

In the type two, catching maximum can be seen at the time of last quarter, new moon and first quarter, and deep minimum at full moon.

It is a common feature of the last five types that one or two distinct catch maximums are observed in the vicinity of the first and/or last quarters. The two maximums might be of the same size, but one might be significantly higher than the other. With these types positively polarized moonlight probably has a positive influence on activity. However, it happens in several cases that the maximum is not exactly in the phase group containing the first and the last quarters, instead, gets somewhat shifted in the direction of the new moon, non the less, in this case, too, there is a remarkable fall-back in the volume of catch at the time of the new moon.

Based on the findings of other scholars as well as our own investigation we take it as confirmed that neither the smaller size of a collecting area nor reduced flying activity are reasons of general validity in way of explaining the influence of the Moon on light-trap effectiveness.

Changes of the area of collecting cannot explain with general validity the differences in the catch results related to the lunar phases. Although, beyond doubt, the illumination generated by the Moon reduces the area of collecting, yet, this fact can have significance only exceptionally from the point of view of light-trap effectiveness. Because in this case should be observe a single catch maximum, and that at the time of the new moon. But as demonstrated the catch data, this is typical of but a few species. A catch maximum is observed with most species in the first and/or last quarter. Hourly collecting data, too, did not make any decline of the catch in relationship with the size of the collecting area apparent in moonlit hours. Therefore a smaller collecting area cannot be regarded as a general reason for the more moderate catch experiences in the vicinity of the full moon. So, regarding the majority of species, the influence of the Moon manifests itself not only through modifications of the area of collecting.

Moonlight does not reduce the flight activity of the insects either. For the catch maximum in the case of most species occurs in the vicinity of the first or the last quarter, or most often, in the neighbourhood of both. So moonlight increases instead of decreasing activity and the catch. It is quite remarkable; on the other hand, that in the vicinity of the full moon, i.e. at the time of negative polarization, there is a clearly distinguishable catch minimum with most species. The negative polarization reduces the quantity of insects collected by light-trap. Had moonlight, regardless of its phase at the time, reduced the activity of insects, there would be no catch maximum in the first and last quarters either. Collecting with other methods by the researchers quoted above do not confirm either the slackening of flight activity at the time of a full moon.

In the absence of traps in high positions, there has been no Hungarian research to confirm or refute the theory expounded by El-Ziady [57] who claims that insects fly in higher layers of the atmosphere at the time of the full moon, although this phenomenon could be detected in the case of some migratory species. Admittedly, the corrected catch results of the silver Y moth (*Autographa gamma* L.) were good also at full moon in the Jermy type traps operating at a height of 2m.

At the time of the full moon – both when there is negative polarization and when there is no polarization – the Moon steps up flight activity. The low catch results observed with most species at this time are related to the insects' security of orientation. Our own findings appear to confirm the theory of Jermy [88] who has been assuming that moonlight might increase the security of orientation, at the same time revealing the difference following from the positive and negative polarization of moonlight. We presume that at the time of positive and negative moonlight polarization, insects rely for orientation primarily on light stimuli, while in the vicinity of the full moon, probably owing to the presence of negative polarization, the difference some species perceive between moonlight and artificial light is bigger than in other lunar phases. Therefore while the Moon continues to supply them with information helping their orientation, the risk of a mix-up diminishes, in other words, the security of orientation increases and the catch falls back. This theory is confirmed by an observation made by Cleve [35] who found that insects fly from one light-trap to the other, but very rarely fall into the trap at the time of the full moon. Other species, on the other hand, can be effectively collected also at times of negative polarization. For some, so far unknown, reason the security of orientation does not increase for them (Nowinszky [118]).

Light trapping has been taking place at the most different geographical locations, under changing weather and light conditions and in different seasons. Also, researchers have been collecting different species, flying at varying hours of the night with light-traps of different types. It is possible therefore that the contradictions manifest in the findings are only apparent and further research on the most important questions may lead to new results to be used with benefit in prognostics in the foreseeable future.

At the same time, our latest findings have also supplied us with fresh evidence to prove that despite several decades of research, the influence of the Moon on light trapping has to this day remained one of the most complex and least known problems.

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J. Entomol. Res. Soc., 16(3): 11-25, 2014 *ISSN:1302-0250*

Light-Trap Catch of Caddishflies (Trichoptera) in the Carpathian Basin and Anatolia in the Four Quarert of the Moon

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ABSTRACT

The study deals with the effect of Moon on light trapping of caddisflies (Trichoptera) species. The light-traps have operated in the following years: 1980, 1981, 1982, 1984, 1988, 1992 and 2000 at seven Hungarian sampling sites. Diken and Boyaci (2008) operated light-traps in year 2004 at Eğirdir Lake (Turkey). We analysed of eleven species from four families in Hungary and eight species belonging to four families in Turkey. Relative catch values, calculated from daily catching data, were calculated by the four moon quarters: New Moon, First Quarter, Full Moon and Last Quarter.

The significant catch maxima of different species in different moon quarters can be found.

We could investigate only those species which were caught in great number by traps. Our results confirm that the Moon affects the lives of caddisflies (Trichoptera) and this fact is important in reproduction of caddisflies, taxonomy studies, protection of aquatic habitats and nature conservation research as well.

Key words: Caddisflies, light-trap, moon quarters, Carpathian-Basin, Anatolia.

INTRODUCTION

The most important sampling tool for the entomological research of the night flying insects is the light-trap, which is used by researchers worldwide nearly a hundred years ago. The number of collected specimens is influenced by a number of environmental factors and the moonlight is one of the most important factors. The examined caddisflies species, studied in our work, live in the moderate zone in different climatic territories. The swarming distribution of caddisflies is influenced by more factors such as the favourable or unfavourable change of meteorological elements to the swarming. It was demonstrated that higher evening temperature can increase the intensity of swarming. According to previous several studies most of individuals fly at ascendant air temperature (Waringer, 1991; Hirabayashi *et al*., 2011). There are some factors, beyond the meteorological conditions, that make trapping more successful. These are: the numerous aquatic elements in the environment (fountains, runnels, rivers and lakes), the groups of vagrant imagos which can fly also large distances and they reach the light-trap at different periods. These insects can extend the efficiency of catch and also the number of species and individuals. Our study searched the influence of different moon quarters for light-trap catch of caddisflies (Trichoptera).

The caddisflies (Trichoptera) are one of the most important groups of aquatic insects, the seasonal activity is therefore essential to understanding the ecological investigations (Kiss, 2003).

The caddisflies (Trichoptera) imagos generally are active at night and they fly well to artificial light. Therefore the most suitable method is the light trapping to know their swarming period (its beginning and end and peaks), the swarming activity if investigated species and mass proportion according to Crichton and Fisher (1978), Crichton (1988), Malicky (1980), Urk *et al*. (1991), Waringer (1991), Szentkirályi (1997) and Kiss (2003). It is important in this research the characterization of caddisflies species and their function in nature conservation research.

Numerous studies are devoted to the role of the Moon in modifying light trapping catch. Most authors observed a decline in the catch under the influence of the Moon. Williams (1936) offers two possible explanations: Moonlight reduces insect's activity (particularly Lepidoptera: Noctuidae), or if there is moonlight at night, the traps ollect the insects from smaller area. Important experiments by Dacke *et al*. (2003) proved that the African scarabid beetle (*Scarabeus zambesianus* Péringuey) is able to navigate with the use of polarization sky pattern of moonlight.

Only a few authors mention that the moonlight decreases the light-trap catch of the caddisflies. Mackay (1972) found that the number of caddisflies caught by black light trap was low on nights of full moon, especially when the moon was above the horizon. Jackson and Resh (1991) used sex pheromones to catch for three caddisflies (Trichoptera) species, *Dicosmoecus gilvipes* (Hagen, 1875) (Limnephilidae), *Gumaga nigricula* (McLachlan, 1871) (Sericostomatidae) and *Gumaga griseola* (McLachlan, 1871). They found that the intensity of light affects the flight activity, but not the daily periodicity of flight. According to Janzen (1983) less caddisflies - like moths - are attracted by artificial light in the moonlit night. Corbet (1958, 1964) using Robinson-type light traps (125W mercury vapour bulbs) collected Trichoptera species over a hundred consecutive nights on the shore of Lake Victoria. The light-trap catch of the *Athripsodes ugandanus* Kimmins, 1953 (Leptoceridae) was found to have two peaks in the first and last quarter. We did not find in the literature other than our previous study (Nowinszky *et al*., 2010) dealing with the light-trap catch of the caddisflies (Trichoptera) in connection with the moon phases.

The swarming of caddisflies starts mainly after dusk and peaks before midnight at the early or late evening, but flying of many species continues till dawn (Tshernyshev 1961; Jackson and Resh, 1991). According to Ward (1992) the most of Trichoptera species are active at dusk and at night. The flight behaviour of each species is very important to know because it may explain the different behaviour in the lunar quarters.

MATERIAL AND METHODS

The light-trap collection points in Hungary, their geographical coordinates, the species lists, their caught specimens and the number of nights on which trapping occurred are shown in the Table 1. The data come from our own collection, but the data of *Oecetis ochracea* Curtis are from Újhelyi (1971).

The light-trap used in Hungary consists of a 125 W mercury vapour lamp and 1 m in diameter of a protecting cover. Under the lamp there is a collecting funnel, its diameter is 40 cm, and leads into a glass bin. Pure chloroform was used as killing agent. Our light-traps operated every night of every year between 1st April and 31st October.

We processed the data of Anatolia (Turkey) from the study of Diken and Boyaci (2008). They collected the shore of Eğirdir Lake (37°50'N-38°15N' and 30°04'-30°51'E) in Turkey in Isparta province between April and October 2004. The light-traps of Diken and Boyaci (2008) were set up in different three stations in the lake shore. The light-trap type used in their research was operated with the fluorescent BL tube. Trichoptera sampled once a week, during two hours, after the sunset. Published data of Diken and Boyaci (2008) can be seen in Table 2.

It was necessary to our work to determine the four typical moon quarters - New Moon, First Quarter, Full Moon and Last Quarter - in the investigated periods. The phase angle is the value of φ angle at the Moon in plane triangle of Sun - Earth - Moon system (Nowinszky *et al*., 1979).

The lunar phase angle values were calculated with our own computer program, at 10 p. m. (UT) is Hungary and 8 p. m. (UT) in Turkey.

Based on the number of specimens caught in Hungary and Turkey, we calculated relative catch values for each species and swarming. Relative catch (RC) is the ratio of the number of specimen caught in a given sample unit of time and the average number of specimen caught in the same time unit calculated for the whole brood. If the number of the specimen trapped equals the average, the value of relative catch is: 1.

The relative catch (RC) values of each species is assigned to phase angle values of the catching nights. The lunar phase angle values and the corresponding relative catch values along the four lunar quarters (full moon = 0° or 360°, first quarter = 90°, new moon = 180° and the last quarter = 270°) have been categorized around and then hold a quarter each have been summarized and averaged them. The data of species that behave same way were plotted together.

We listed our collecting data - separately for males and females - as a four moon quarter surroundings. The four quarters of the Moon's moonlight were divided into by photometric characteristics of the moonlight in different phase angles. The total lunar month, angle of 360 months (approximately 30 days) included

7-7 days (72-72 phase angles) belong to the First Quarter and Last Quarter. This time the polarization of moonlight is positive, the plane of polarization is perpendicular to the plane of the horizon. The plane angle of polarization lies to the plane direction of slight. 5 days (phase angle 48) belong to the Full Moon. At the time of a Full Moon the moonlight is unpolarized. With the increase of the phase angle, negative polarization is observable that is the oscillation plane of the electrical vector lies in the plane of sight.

Table 1. The species caught, the trapping sites and years, number of individuals and nights own collection and *Oecetis ochracea* Curtis unpublished data from Újhelyi (1971).

Species and light-trap station	*Geographic coordinates*	*Number of individuals*	*Number of nights*
Rhyacophilidae			
Rhyacophila fasciata Hagen 1859			
Szilvásvárad Szalajka stream, 1980	48°64'N; 20°23'E	103	141
Nagyvisnyó Nagy brook, 1981	48°08'N, 20°25'E	110	168
Hydropsyche contubernalis Mc Lachlan 1865			
Ecnomidae			
Ecnomus tenellus Rambur 1842			
Nagy-Eged, Csomós farm-stead, Eger, 1981	47°54'N; 20°22'E	239	81
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	4047	101
Hydropsychidae			
Hydropsyche instabilis Curtis 1834			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	1761	89
Nagy-Eged, Csomós farm-stread, Eger, 1980	47°54'N; 20°22'E	76	146
Bükk, Mountains, Vöröskő-Valley, 1981	48°34'N; 20°27'E	2656	123
Bükk, Mountains, Vöröskő-Valley, 1982	48°34'N; 20°27'E	7169	99
Hydropsyche bulgaromanorum Malicky 1977*			
Szolnok, Tisza River, 2000	47°10'N, 20°11'E	22343	109
Limnephilidae			
Ecclisopteryx madida Mc Lachlan 1867*			
Nagyvisnyó, Nagy brook, 1981	48°08'N, 20°25'E	54	78
Nagyvisnyó, Nagy brook, 1984	48°08'N, 20°25'E	502	102
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	431	98
Limnephilus lunatus Curtis 1834			
Szilvásvárad Szalajka stream, 1980	48°64'N; 20°23'E	341	98
Limnephilus flavicornis Fabricius 1787			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	99	125
Limnephilus rhombicus Linaeus 1758*			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	249	126

Table 1. The species caught, the trapping sites and years, number of individuals and nights own collection and Oecetis ochracea Curtis unpublished data from Újhelyi (1971).

Species and light-trap station	*Geographic coordinates*	*Number of individuals*	*Number of nights*
Limnephilidae			
Potamophylax			
Potamophylax nigricornis Pictet 1834			
Bükk, Mountains, Vöröskő-Valley, 1982	48°34'N; 20°27'E	3666	89
Halesus digitatus Schrank 1781			
Szilvásvárad, Szaljka stream 1980	48°64'N; 20°23'E	839	90
Bükk Vöröskő-Valley, 1981	48°34'N; 20°27'E	104	70
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	1287	104
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	1037	129
Goeridae			
Goera pilosa Fabricius 1775*	48°13'N, 20°25'E	1037	129
Silo pallipes Fabricius 1781*			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	199	110
Szilvásvárad, Szalajka stream, 1981	48°64'N; 20°23'E	641	110
Nagyvisnyó, Nagy brook, 1984	48°08'N, 20°25'E	86	106
Odontoceridae			
Odontocerum albicorne Scopoli 1763			
Szilvásvárad, 1980	48°64'N; 20°23'E	316	120
Szilvásvárad, 1981	48°64'N; 20°23'E	451	114
Bükk Vöröskő-Valley, 1982	48°34'N; 20°27'E	618	112
Bükk Vöröskő-Valley, 1983	48°34'N; 20°27'E	845	131
Nagyvisnyó, 1984	48°08'N, 20°25'E	65	59
Leptoceridae			
Oecetis ochracea Curtis 1825			
Hódmezővásárhely	46°25'N, 20°19'E	1175	59
Kenderes	47°13'N, 20°25'E	1187	59
Kompolt	47°44'N, 20°14'E	1351	59
Kisvárda	48°13'N, 22°04'E	678	59

Table 1. The species caught, the trapping sites and years, number of individuals and nights own collection and Oecetis ochracea Curtis unpublished data from Újhelyi (1971) Continue.

Species and light-trap station	*Geographic coordinates*	*Number of individuals*	*Number of nights*
Leptoceridae			
Mikepércs	47°26'N, 21°38'E	1448	59
Tarhos	46°48'N, 21°12'E	1486	59
Velence	47°14'N, 18°39'E	256	59

Table 2. The species caught, the trapping sites and years, number of individuals and nights from published data of Diken and Boyacı (2008).

Light-trap station and species and geographic coordinates	*Number of individuals*	*Number of nights*
Eğirdir Lake between 37°50'N, 30°04'and 38°16'N, 30°57'E		
Ecnomidae		
Ecnomus tenellus Rambur 1842	4028	7
Hydropsyche		
Hydropsyche bulbifera McLachlan,1878	383	20
Hydroptilidae		
Hydroptila angustata Mosely,1939	543	20
Hydroptila aegyptia Ulmer,1963	7068	21
Agraylea sexmaculata Curtis, 1834	848	17
Orthoctrichia costalis Curtis, 1834	40	9
Leptoceridae		
Mystacides nigra Linnaeus, 1825	756	20
Oecetis ochracea Curtis,1825	29340	20
Athripsodes longispinosus Martynov,1909	25517	21
Ceraclea senilis Burmeister,1839	251	18
Oecetis furva Rambur,1825	94	15
Phryganeidae		
Phryganea grandis serti Sipahiler, 2000	968	7

Finally 11 days (168 phase angles) belong to the New Moon; there is no measurable polarization of moonlight of course (Nowinszky *et al*., 1994).

We determined in which moon quarter flew higher number the different species to light-trap.

Relatively little data were available for each species, so the species where the swarming peak can be found in the same Moon Quarter, were included. This ensured that significant results are obtained.

RESULTS AND DISCUSSION

With the help of t-tests we have found that some species flew in a significantly higher number to traps during a particular moon quarter.

Light-trap catch of five caddisflies species living in the Carpathian Basin (Hungary) (*Goera pilosa* Fabricius, 1775, *Hydropsyche instabilis* Curtis, 1834, *Hydropsyche contubernalis* McLachlan, 1865, *Limnephilus auricula* Curtis, 1834 and *Limnephilus flavicornis* Fabricius, 1787) were significantly higher in the Last Quarter of the Moon compared to the other three ones (Fig. 1).

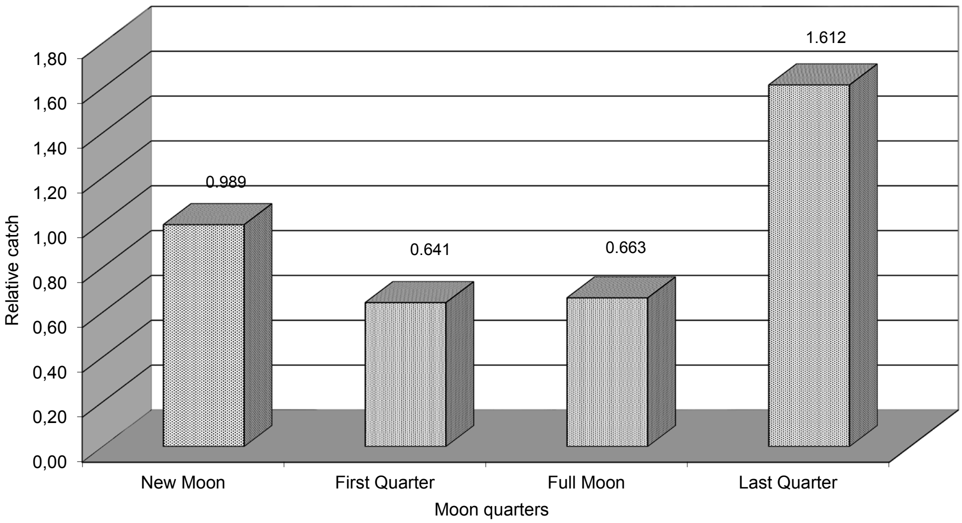

Fig. 1. Light-trap catch of *Goera pilosa* Fabr., *Hydropsyche instabilis* Curtis, *Hydropsyche contubernalis* McLachlan and *Limnephilus flavicornis* Fabr. in connection with the Moon Quarters (Hungary). Significant catching peak (P < 0.01) is at the Last Quarter.

The Moon can be seen in Last Quarter in the early morning sky and during this time is found the highest percentage of the ratio of polarized moonlight. The insects are able to use the polarized moonlight for their spatial orientation (Nowinszky *et al*., 1979, Danthanarayana and Dashper, 1986, Dacke *et al*., 2003). These species are also likely to fly at dawn. Tshernyshev (1961) and Jackson and Resh (1991) also stated that many caddisflies species fly until dawn.

We have found that the catch of *Ecclysopteryx madida* McLachlan, 1867 and the *Limnephilus rhombicus* Linnaeus, 1758 in the Carpathian Basin and *Ceraclea senilis* Baurmeister, 1839 and the *Phrygane grandis serti* Sipahiler, 2000 at Lake Eğirdir was high in the Last Quarter and also at New Moon (Fig. 2 and 3). Probably these species can fly to long distance during one night, therefore the high percent of polarized moonlight and also the biggest collecting distance at New Moon (Nowinszky, 2008) extends the success of light-trap catch.

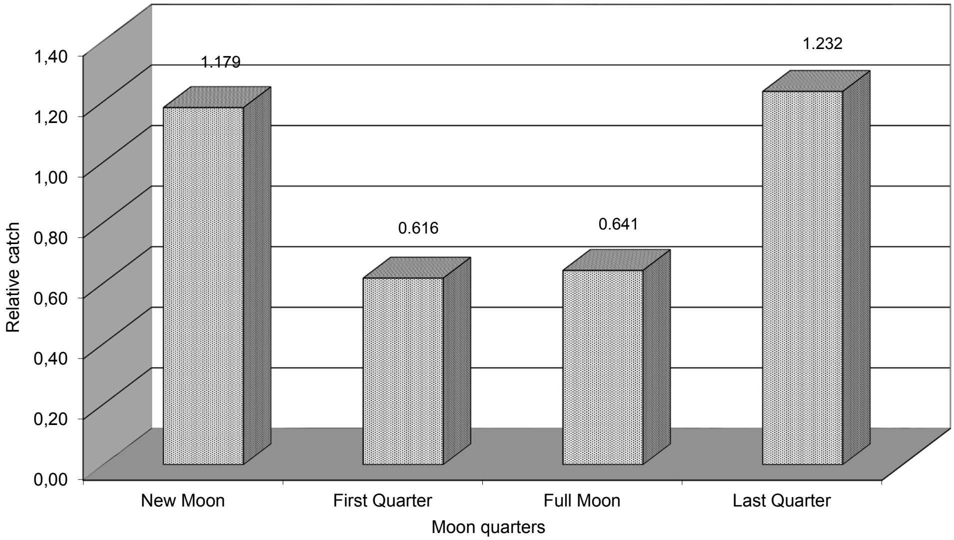

Fig. 2. Light-trap catch of the *Ecclysopteryx madida* McLachlan and *Limnephilus rhombicus* L. in connection with the Moon Quarters. Significant catching peaks ($P < 0.05$) are at the New Moon and Last Quarter (Hungary).

The catch of *Limnephilus ignavus* McLachlan, 1865 and *Potamophylax rotundipennis* Brauer, 1857 is really effective only at New Moon. These species are able to take advantage of the large collection distance (Fig. 4).

The catch peak is at New Moon and Full Moon for *Ecnomus tenellus* Rambur, 1842 and *Silo pallipes* Fabricus, 1781 in the Carpathian Basin and *Orthoctrichia costalis* Curtis, 1834, *Mystacides nigra* Linnaeus, 1758 and *Oecetis ochracea* Curtis, 1825 at Lake Eğirdir (Fig. 5 and 6), but the catch peak of *Hydropsyche bulgaromanorum* Malicky, 1977 is at Full Moon (Fig. 7). This is surprising, because there were no catch maximum in relation with moths at Full Moon according to previous studies (Nowinszky, 2008). The moon is almost full moon all night, staying above the horizon. It is assumed that the presence of Moon can give the major orientation information for these insects.

According to Wehner (1984), insects active at night helped by the light of the Moon, are capable of finding orientation in space, despite the fact that being able to do so is much more difficult than getting orientation by the Sun at daytime. Orientation of some species may be more important by the vision of the Moon during whole night, as the polarized portion of the moonlight.

The success of catch is best in the First Quarter for *Halesus digitatus* Schrank, 1781, *Limnephilus lunatus* Curtis, 1834, *Odontocerum albicorne* Scopoli, 1763 and *Rhyacophila fasciata* Hagen, 1859 (Fig. 8).

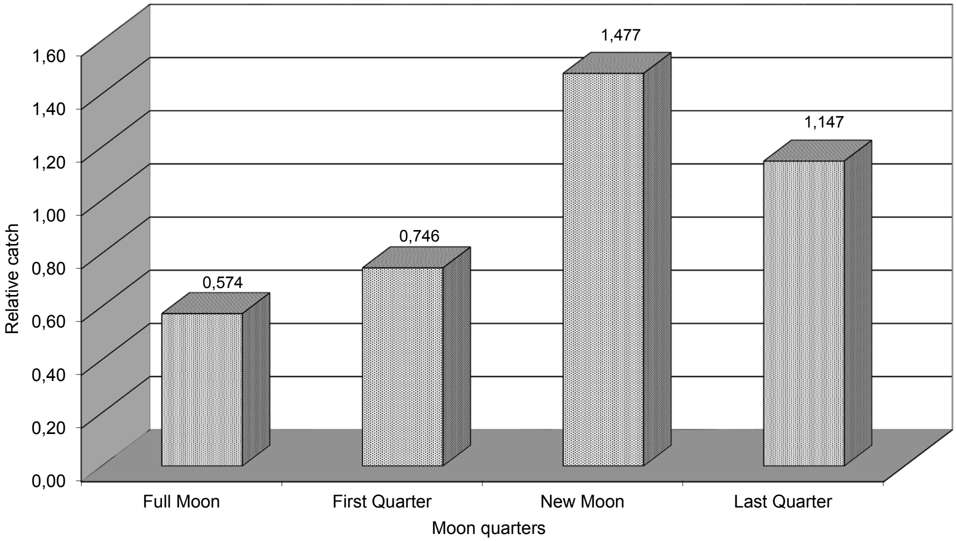

Fig. 3. Light-trap catch of the *Ceraclea senilis* Baurmeister and *Phrygane grandis serti* Sipehiler in connection with the Moon Quarters. Significant catching peaks (P < 0.05) are at the New Moon and Last Quarter (Turkey).

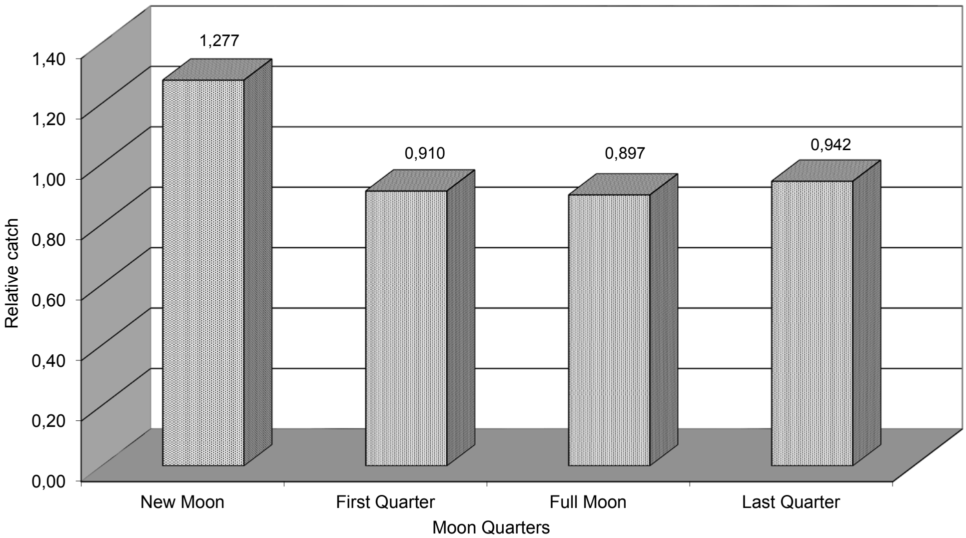

Fig. 4. Light-trap catch of *Potamopylax nigricornis* Pictet in connection with Moon Quarters Significant catching peak (P< 0.05) is at the New Moon (Hungary).

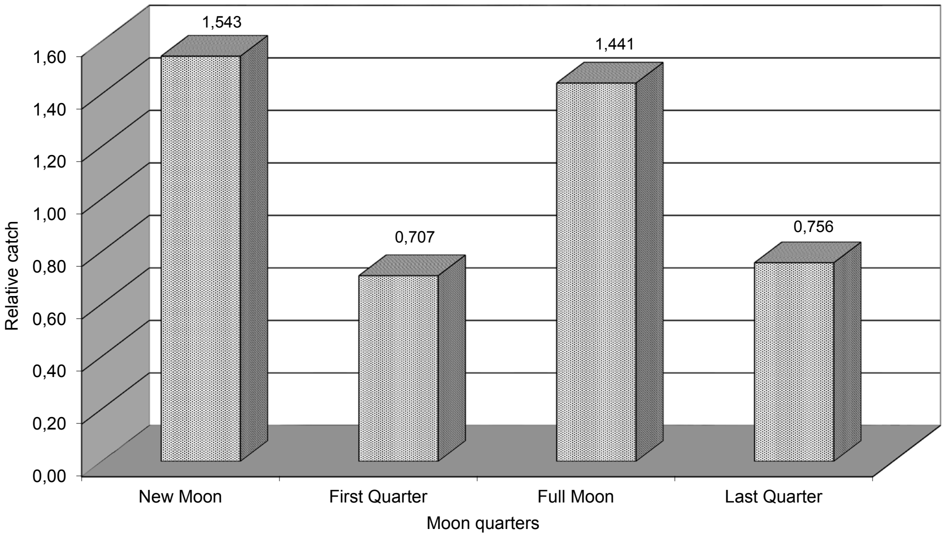

Fig. 5. Light-trap catch of the *Ecnomus tenellus* Rambur and *Silo pallipes* Fabr. in collection with the Moon Quarters. Significant catching peaks ($P < 0.01$) are at the New Moon and Full Moon (Hungary).

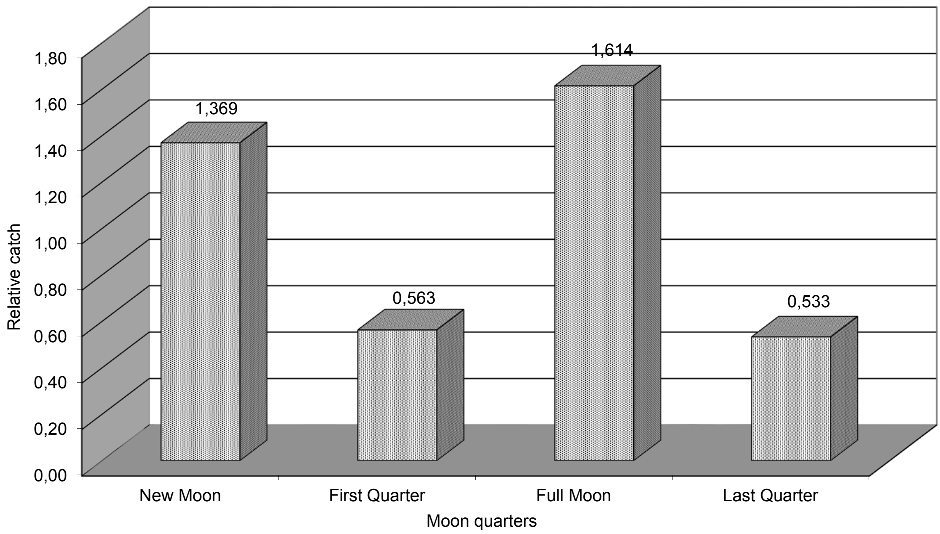

Fig. 6. Light-trap catch of the *Orthoctrichia costalis* Curtis, *Mystacides nigra* Linnaeus and *Oecetis ochracea* Curtis in connection with the Moon Quarters. Significant catching peaks ($P < 0.05$) are at the Full Moon and New Moon (Turkey).

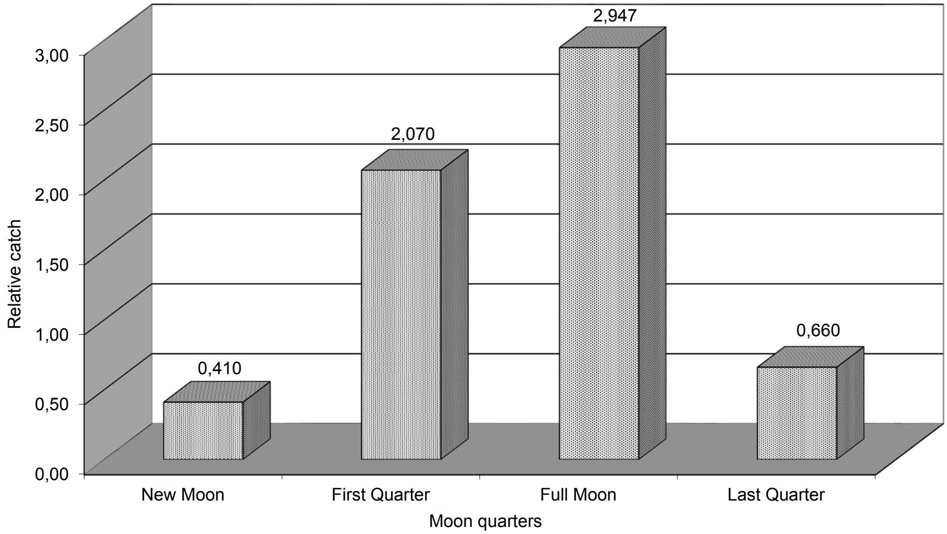

Fig. 7. Light-trap catch of the *Hydropsyche bulgaromanorum* Malicky in connection with the Moon Quarters. Significant catching peaks (P < 0.05) are at the First Quarter and Full Moon (Hungary).

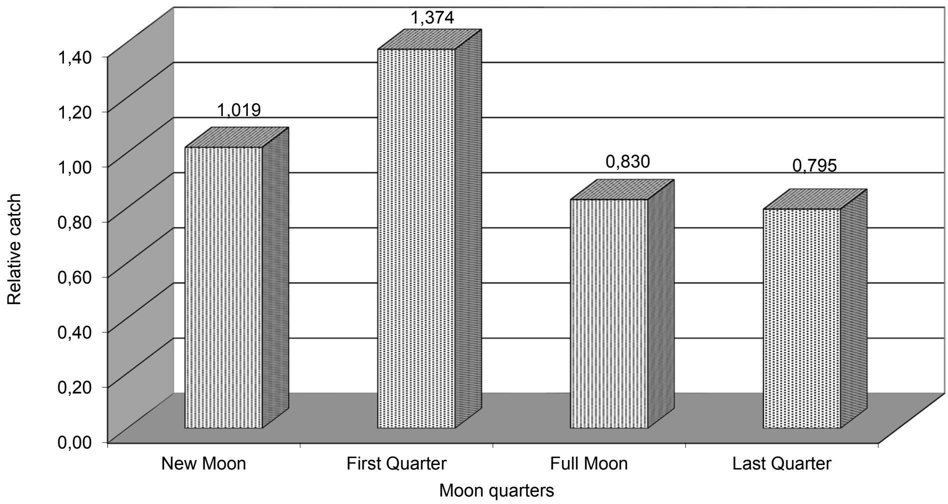

Fig. 8. Light-trap catch of the *Halesus digitatus* Schrank, *Limnephilus lunatus* Curtis, *Odontocerum albicorne* Scop. and *Rhyacophila fasciata* Hagen in connection with the Moon Quarters. Significant catching peak (P < 0.01) is at the First Quarter (Hungary).

Perhaps the reason is, the Moon can be seen at gloaming and evening sky this time. These species probably fly in large mass in this period. This result enhances the same observations of Tshernyshev (1961) and Jackson and Resh (1991). Diken and Boyaci (2008) also caught the specimen of *Ecnomus tenellus* Rambur, 1842 and *Hydroptila angustata* Mosely, 1939 at Lake Eğirdir in the First Quarter (Fig. 9).

It is striking, however, that *Ecnomus tenellus* Rambur was collected successful both in the Carpathian Basin and in Asia Minor, but period of successfull catch is completely different. The explanation may be that the Turkish researchers' light-trap operated only at dusk.

The Turkish researchers experienced the catching maximum of *Hydroptila aegyptia* Ulmer, 1963 (Fig. 10) at the New Moon and First Quarter. In Hungary Újhelyi (1971) collected the specimen of *Oecetis ochracea* Curtis specimens at the New Moon and First Quarter (Fig.11).

Expect of the *Ecnomus tenellus* Rambur and *Oecetis ochracea* Curtis) the caught species in Hungariy and Turkey were not the same.

Therefore, unfortunately, we were not able to compare of catching results of all species.

Our results proved that a little difficult to draw reliable conclusions swamping the lunar impact. All four moon quarter can be seen swarming peaks.

The light-trap catch of *Ecnomus tenellus* Rambur is equally the highest at New Moon and Full Moon in Hungary and Turkey. We therefore conclude that the flight activity of this species is more dependent on the phase angles of the moon as from local environmental impacts. In contrast, the catch of *Oecetis ochracea* Curtis is high in both countries at the Full Moon, however, another peak is at New Moon in Turkey, but the second peak can be experienced at First Quarter in Hungary. The local environmental effects may play a big role according to our assumption on this species. Our results contribute to better understanding of lifestyle of the investigated species.

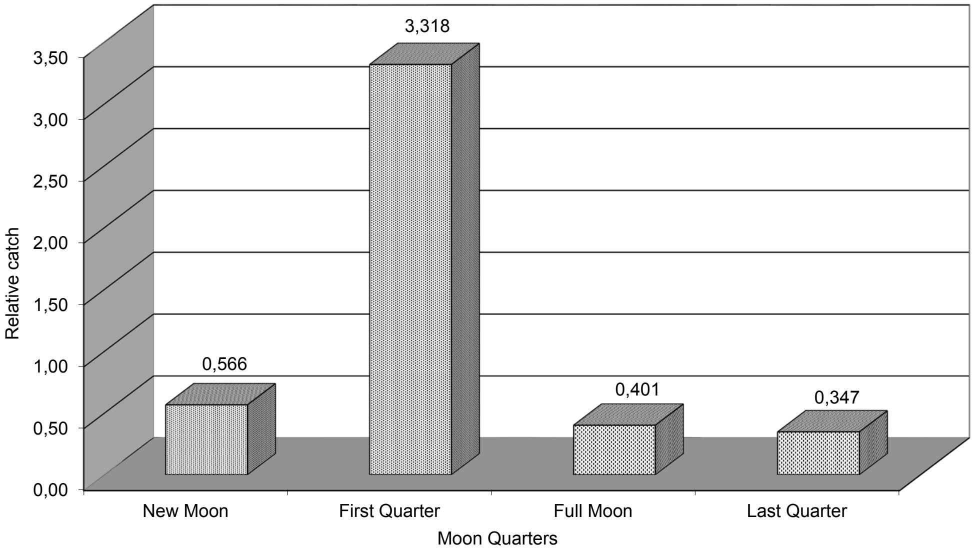

Fig. 9. Light-trap catch of the *Ecnomus tenellus* Rambur and *Hydroptila angustata* Mosely in connection of the Moon Quarters. Significant catching peak ($P < 0.01$) at the First Qarter (Turkey).

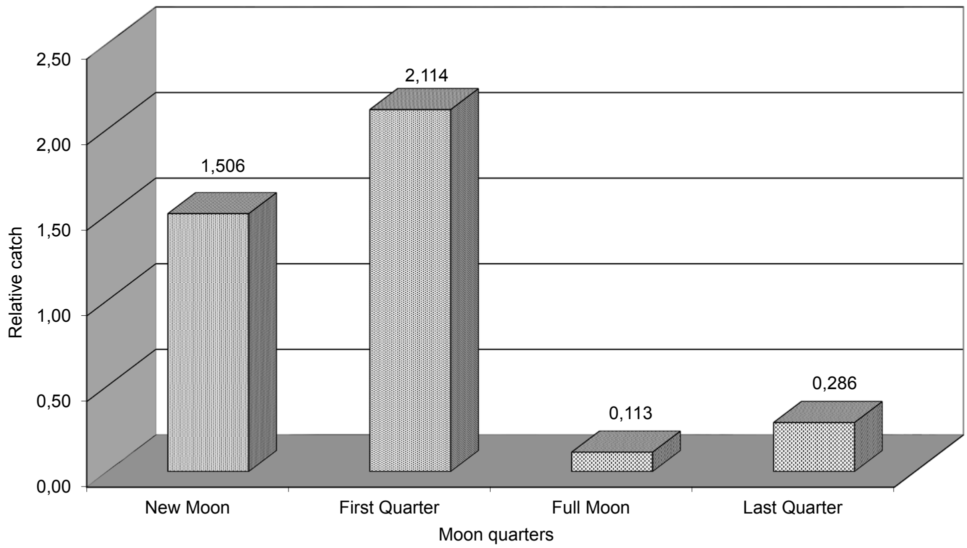

Fig. 10. Light-trap catch of *Hydroptila aegyptia* Ulmer in connection with the Moon Quaters. Significant catching peaks (P < 0.05) are at the First Quarter and New Moon (Turkey).

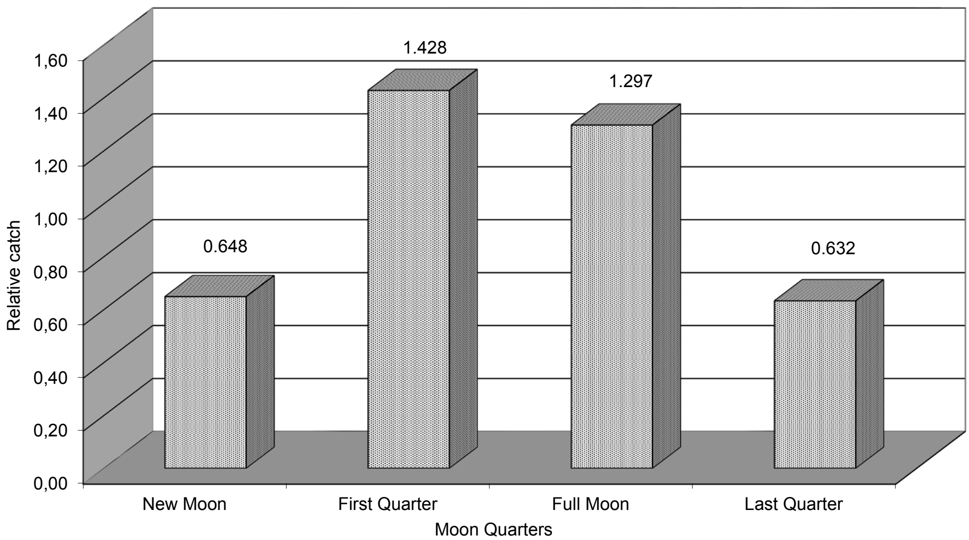

Fig. 11. Light-trap catch of *Oecetis ochracea* Curtis in connection with Moon Quarters (Data from 6 traps of the Hungarian National Light-trap Network, 1960 (Újhelyi, 1971). Significant catching peaks (P < 0.05) are at the New Moon and First Quarter.

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Received: April 02, 2013 *Accepted: September 19, 2014*

LIGHT TRAPPING AS A DEPENDENT OF MOONLIGHT AND CLOUDS

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(Received 26th July 2010 ; accepted 10th September 2010)

Abstract. We examined in our study the theoretical catching distance and the catching results of the Járfás and Jermy type light-traps in the function of the moon phases and the clouds. The clouds determine the theoretical catching distances of both the Járfás and Jermy type light-traps fundamentally. The ratio of theoretical catching distances of completely overcast and clear sky is approximately 2.4:1. This difference does not appear however in the catching results. The catching of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in moonless hours is the most successful when the sky is totally through, if it is not raining. In opposition to this, the catch decreases by the increase of the cloud cover in moonlit hours. The most moths were found in the light-trap when the sky was almost clear. The increase of cloud cover results in a reduction of the catch. The number of the Macrolepidoptera individuals and species are higher when the sky is clear than overcast in the event both the all and low clouds. It was also found that the height of cloud base also modify the light-trap catch. If the cloud base is low the light-trap catch is also low, in the opposite it is high.
Keywords: *Light-trap, moon phases, clouds, catching distance*

Introduction

Most of the authors experienced a drop in the efficiency of trapping as a result of moonlight. According to (Williams, 1936) the reasons for a smaller catch at a Full Moon might be as follows: Moonlight reduces the activity of insects and so the active population accessible for the light trap is smaller, or the light of the lamp collects moths from a smaller area in moonlit environment.

The researchers' opinion differs, some of them ascribe the smaller catching distance, others ascribe the moderate trapping result which can be experienced at the time of the Full Moon to the reduced activity. Some researchers take the role of the clouds into consideration. The cloud cover moderates the obstructive effect of the moonlight according to more researchers.

The clouds and the moonlight joint effect were already studied by (Williams, 1936). To examine the influence of cloud (Williams, 1936) divide the nights in the lunar months in two ways.

- In accordance with the lunar month: nights during the week of Full Moon, nights during the weeks intermediate moon (first- and Last Quarters) and nights during the week of New Moon.
- In accordance with the clouds: as regards the state of the sky, into three divisions: nights with more than 90 % of the sky clear (=clear), nights with 10 -

90 % of the sky clear (= intermediate) and nights with more than 90 % cloudy (= cloudy).

The interrelation of these two main divisions gives nine possible combinations as follows:

- Full Moon – clear, Full Moon – intermediate, Full Moon – cloudy
- First- and Last Quarters – clear, First- and Last Quarters – intermediate, First- and Last Quarters – cloudy
- New Moon – clear, New Moon – intermediate, New Moon – cloudy.

The nights with heavy wind where eliminated from calculations.

According to (Williams, 1936) results there was a tendency for the clear to be lower than the cloudy and for the Full Moon to be lower than the New Moon. The division Full Moon – clear sky give in each case the greatest negative deviation, and the division New Moon – cloudy sky give the greatest positive deviation.

The ratio of catches in the Noctuidae is shown to be 2.7:1 when New Moon was compared to Full Moon and 11.75:1 when cloudy sky are compared with clear sky. The ratio between New Moon – cloudy and Full Moon – clear is 4:1. Finally the relation New Moon – clear sky gives larger catches than Full Moon – cloudy sky 1.35:1.

Robertson (1939) reports on similar results. The cloud and moonlight have a marked effect on the light trap catches of Tipulinae. Optimum conditions are ensured by the absence of moonlight and a complete cloud cover. By contrast the conditions of Full Moon and the absence of clouds are the least favourable for the activity. Between these extremes, there is a consistent increase in catch with the increasing absence of moon and presence of clouds. The catch under optimum conditions is eight or nine times as large as in the least favourable conditions.

Garcia (1978) worked with light-traps in Venezuela, between 1973 and 1974. The largest catches of Sphingids were during the period when the moon was waning and the least catch was during Full Moon period. The cloud cover increased the effectiveness of the catch.

Bowden (1982) described the collecting radius of three different lamps with the same illumination. He also tabulated the correction values for the codes of the 10 categories of cloud types, according to which the catch rises with the increase of cloud cover.

In southern Spain, Yela and Holyoak (1997) investigated the effects of moon-phase on activity of adult Noctuid moths using light trap for 170 nights over of 2 year period. The number of individuals caught in the light trap decreased during the Full Moon period. Increased cloud cover increased catches in light traps. Cloud cover decreases the ambient light from the moon, making the light traps more visible.

According to Butler et al. (1999), the moonlight in the absence of cloud cover reduced moth catch in blacklight traps.

The most successful light trap collections were experienced by Robert (2001) during New Moon phase or on overcast nights. Mosquitoes came to lights in greatest numbers when nights were cloudy and smaller numbers when nights were clear and the moon was bright.

According to McCormick (2006-2007) the Bogong Moths (*Agrotis infusa* Boisduval) migrate and fly actively under cloudy conditions and during a New Moon.

Other researchers however experienced that clouds increases the catching distance though, but does not increase the efficiency of light trapping, but indeed reduces it.

Wéber (1959) depicted graphically the measure of a cloud cover and the number of insects caught. Unambiguously he established a contrary relationship, in other words the more the clouds covered the sky the fewer insects assembled to the light.

Edwards (1961) operated a Robinson-type UV trap during 93 nights to collect Huhu Beetle (*Prinoplus reticularis* Whitem, Col.:Ceramb.) in New Zealand. He describes an example in which the activity of beetles increased temporarily during Moon rise, followed by a decrease when the moon was obscured by clouds.

Járfás (1969) found that the silver Y moth (*Autographa gamma* L.) flight to light-trap better when there was no cloudy the sky. He observed a similar light flying on moonlit nights as well. Járfás and his colleague (Járfás and Viola, 1978, 1982) published similar statements in their later works onto the Dark Fruit-tree Tortrix (*Pandemis heparana* Den et Schiff.), and Pine Chafer (*Polyphylla fullo* L.) relevantly. Járfás (1979) experienced growing light-trap catch of codling moth (*Cydia pomonella* L.) when the measure of the cloud cover decreased. The light-trap caught most moths (57%) at clear sky. The higher catching results in moonlit and clear nights are linked to the orientation of the insects presumably. Flying of moths may increase to the light-trap together with the dusk while there are free areas of a cloud cover on the sky, because to the light compass orientation the insect receives enough light. If the light compass orientation of insects becomes impossible, the insect switches to orientation an other manner. This is not the inside truck for flying onto the light. The light-trap caught about three times of European Corn Borer (*Ostrinia nubilalis* Hbn.) at clear sky than full cloud cover.

Cordillot (1989) reports that clouds influences the light trapping of the European Corn Borer (*Ostrinia nubilalis* Hbn.) unfavourably because presumably it hampers their visual orientation.

The studies discussed above show that despite several decades of research into the influence of the moonlight and clouds on light trap catch, our knowledge in this field remains insufficient.

Materials

The necessary data required to our work were calculated with our own software. This software for our earlier research (Nowinszky and Tóth, 1987) was carried out by the late astronomer György Tóth for TI 59. The software was transcribed for modern computers by assistant professor Miklós Kiss: for which we express our sincere appreciation. The software calculates the phase angle of the Moon and its position above the horizon, the illumination (lux) taking the cloud cover into consideration for any given geographical place, day and time.

All our data regarding to all and low clouds and height of cloud base related data were taken from the Annales of the Hungarian Meteorological Service. Data in these books are recorded for every 3rd hour in okta (eighth part). We have used the value given for a given hour as well as for the subsequent two hours.

We have also processed catch data of the fractionating light trap of Kecskemét on 5722 individuals of the Turnip Moth (*Agrotis segetum* Den. et Schiff.). This special light trap system was designed and operated by József Járfás between 1967 and 1969 at Kecskemét-Katonatelep. The light source of the fractionating light trap consists of 3 pieces of 120 cm long F-33 type 40W light tubes placed above each other. Independent from the time of dusk and dawn, the trap was operated every day between 6 p.m and 04 a.m (UT). Killing jars were changed hourly by a jar-switching mechanism. These trapped insects were identified by József Járfás.

For our research, we used the complete Macrolepidoptera material of the Jermy type light trap (Jermy, 1961) operated in the Kámon Botanical Garden in Szombathely between 1962 and 1970, including data of 3395 adult broods. The light source is a 100W normal electric bulb 200 cm above the ground. Chloroform was used for the killing. This light-trap caught 37711 moths on 1980 nights.

Methods

First we determined the theoretical collecting distances of the Járfás- and Jermy type light-traps for the New Moon and Full Moon periods. For this test, the 5th August 1967 (New Moon) and the 19th August 1967 (Full Moon), dates were taken into account. We calculated the values of environmental illumination (lux) on 23 hours of both nights into attention the cloud codes. From these environmental illumination values we defined the theoretical catching distances. We compared our actual catching results with the theoretical catching distances.

The Jermy type light-trap provided one catching data for one night only. The phase angle data of the Moon was calculated for every midnight of the flight periods (UT = 0 h), and – in the case of fractionating light traps – for the 30th minute of every hour. Of the 360 phase angle degrees of the full lunar 30 phase angle divisions were established. The phase angle division including a Full Moon (0° or 360°) and values 0 ± 6° was equated to 0. Beginning from this group through the First Quarter until a New Moon, divisions were marked as -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The next division is ±15, including the New Moon. From the Full Moon through the Last Quarter towards the New Moon divisions, were marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each division consists of 12 degrees (Nowinszky, 2003). These phase angle divisions can be related to the four quarters of lunation as follows: Full Moon (-2 – +2), Last Quarter (3 – 9), New Moon (10 – -10) and First Quarter (-9 – -3). The nights and hours of the periods under examination were all classified into these phase angle divisions. We have also separated the hourly catching nights of fractionating light traps with or without moonlight.

The Jermy type light-trap supplied only one catching data nightly. Because of this in this case we calculated the data of phase angle onto the midnight (UT = 0 hour) of every night of the swarming periods.

We have calculated the relative catch values of the number of specimens trapped by species, broods and hourly data also separately for hours with and without moonlight from the fractionating light-trap data. Relative catch (RC) is the ratio of the number of specimen caught in a given sample unit of time (1 hour or 1 night) and the average number of specimen caught in the same time unit calculated for the whole brood. If the number of the specimen trapped equals the average, the value of relative catch is: 1.Only those nights and hours were taken into consideration when the catch was successful. Our earlier research (Nowinszky, 2003), convinced us that although the Moon has an influence on the efficiency of trapping, it never makes collecting impossible.

We included the relative catch values to the codes of catching hours averaged, and then separately for the moonlit and the moonless hours, then they were represented. We have given the parameters of regression equations and significance levels.

From the Jermy type light-trap data the nightly averages of the individuals and species catch were calculated.

We examined first around the Full Moon, First- and Last Quarter the influence of cloud for the catching. We sorted the okta codes in three groups according to the measure of the cloud cover. These are the following: clear (0, 1, 2), intermediate (3, 4, 5) and cloudy (6, 7, 8). Number of individuals and species caught were sorting in okta groups, were averaged and the significance levels of differences are counted with t-test.

To the additional examinations we selected the period of the Full Moon (phase angle divisions -2, -1, 0, +1 and +2) from the catch data because the Moon in 85.3 % are at this time stayed above the horizon. We do not consider the catching data of the periods of New Moon when there is not measurable moonlight and the data of the First- and Last Quarters, too. Not known the insects trapping in which hour of the night happened, and not know it that the Moon stayed above the horizon then, or not. We excluded the nights on which was rain, independent of his quantity from the examination. We sorted the nightly catching average values of the individuals and species to all the clouds, okta codes belong to the 2000 metres lower clouds and the values of height of cloud base (metres). We depicted the results on graphs, granted the regression equations parameters and the significance levels.

We included the relative catch values of both examined species to the hours of the catching owing okta codes, we averaged them, then separate hours without the moonlit one and the moonlight, we depicted them.

Results

The *Fig.1* and *Fig. 2* shows the theoretical catching distances of Járfás- and Jermy type light-traps in the surrounding of New Moon and Full Moon, depending on the clouds.

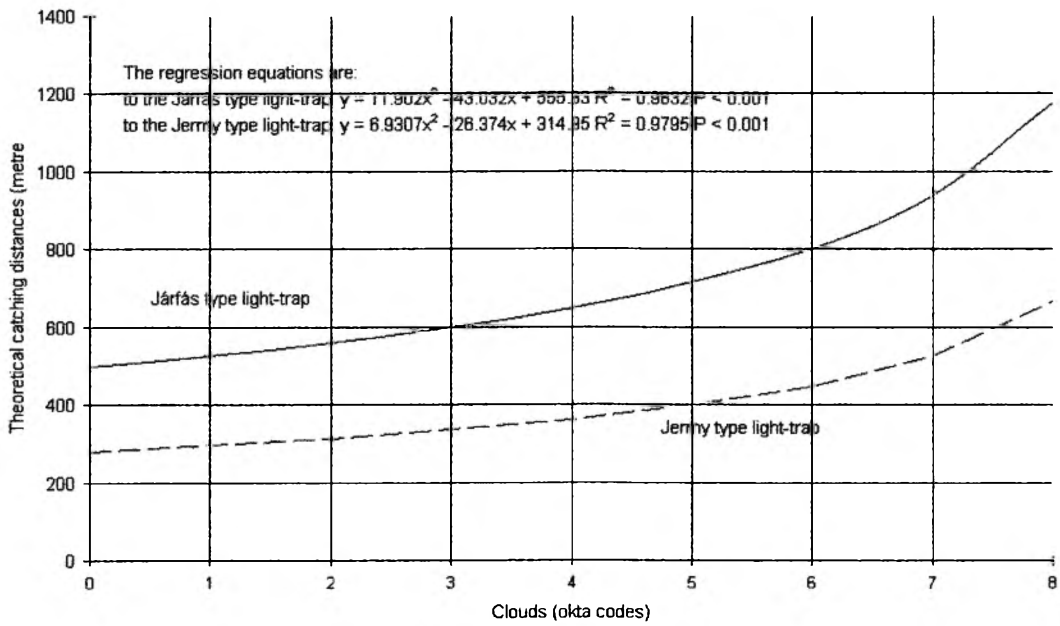

Figure 1. *Theoretical catching distances of the Járfás and Jermy type light-traps depending on the clouds around the New Moon*

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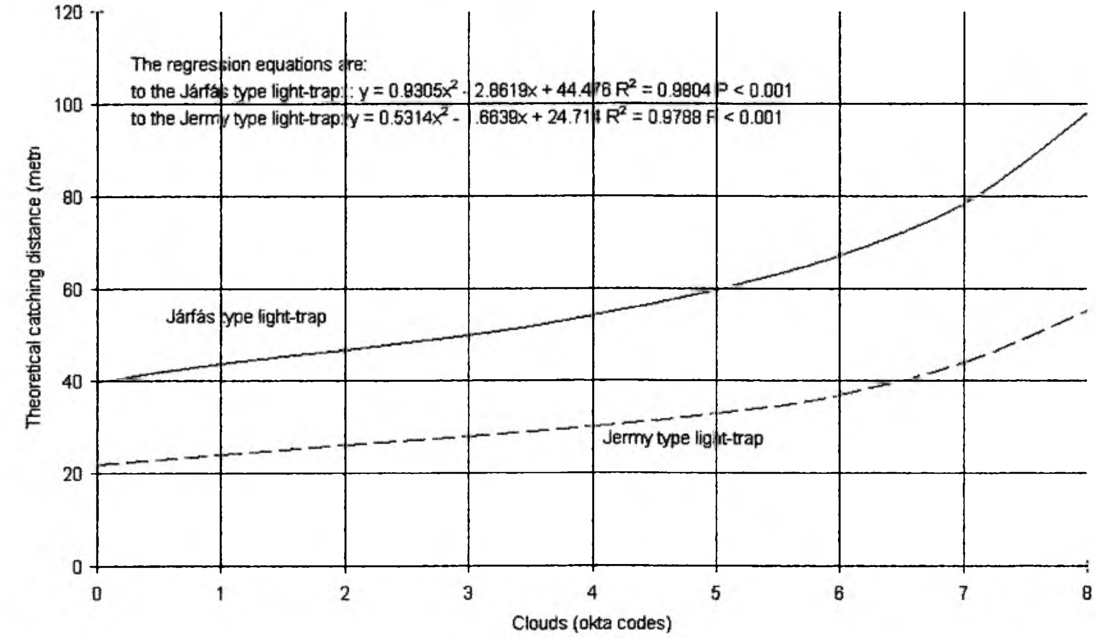

Figure 2. *Theoretical catching distances of the Járfás and Jermy type light-traps depending on the clouds around the Full Moon*

The catching results of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) can be seen in *Fig. 3* and *Fig. 4*

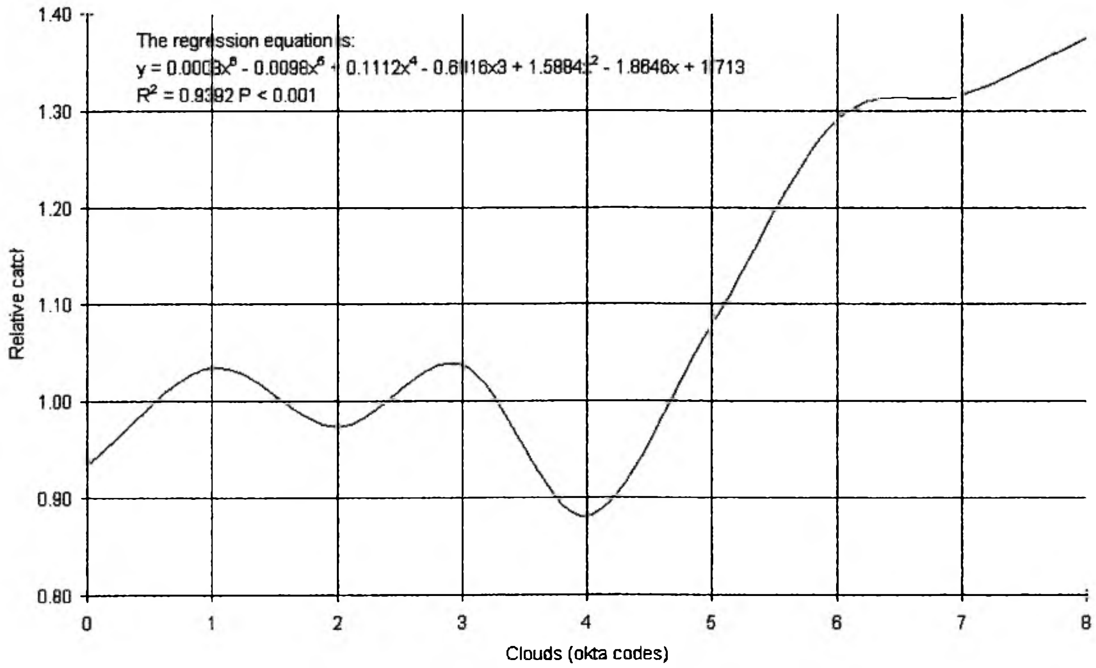

Figure 3. *Light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) depending on the clouds in moonless hours (Kecskemét, 1967-1969)*

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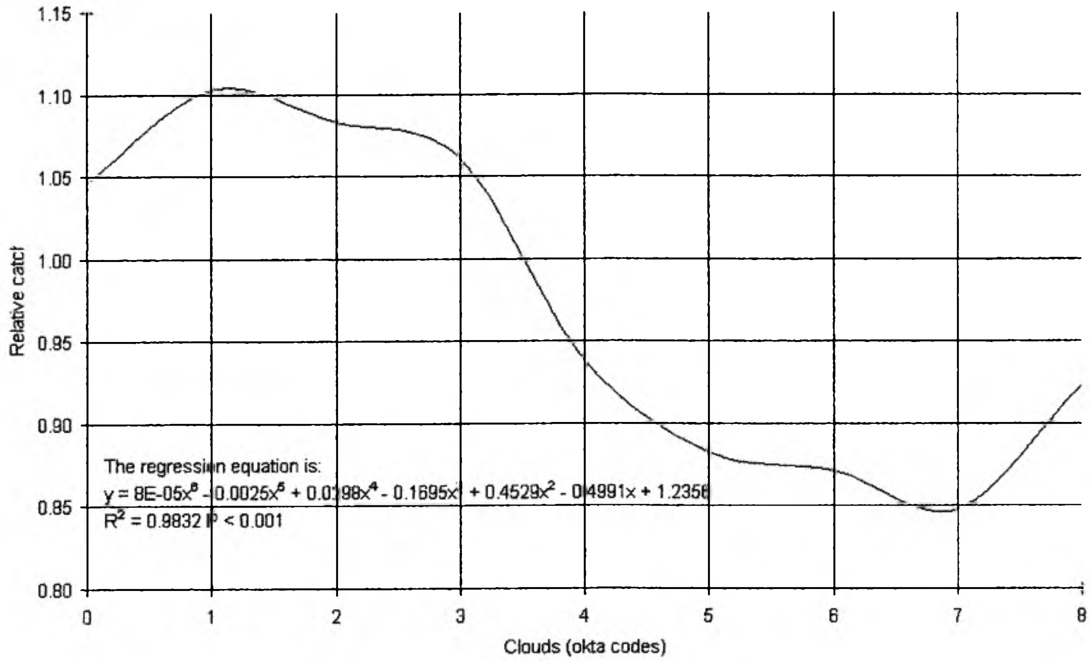

***Figure 4.** The light-trap catch of the Turnip Moth (Agrotis segetum Den. et Schiff.) depending on the clouds in moonlit hours (Kecskemét, 1967-1969)*

The averaged numbers of individuals and species depending on the all clouds around the New Moon and Full Moon caught in Kámon Botanic Garden can be seen in *Fig. 5* and *Fig. 6*

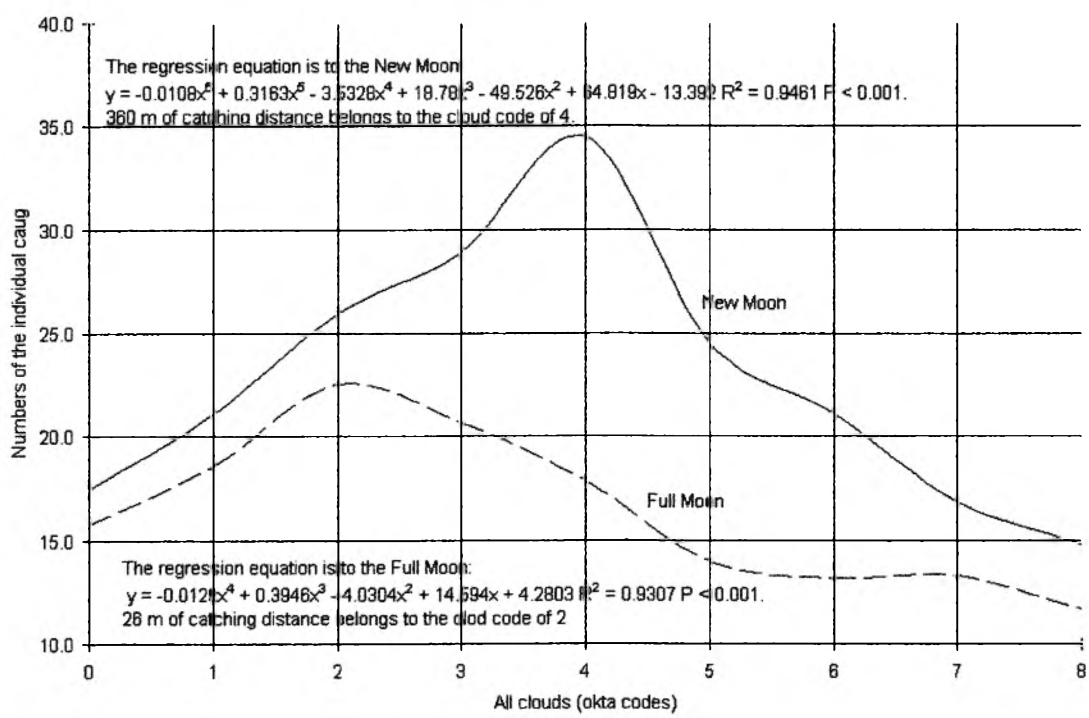

***Figure 5.** Light-trap catches of the Macrolepidoptera individuals depending on the all clouds around New Moon and Full Moon in the Kámon Botanic Garden between 1962 and 1970*

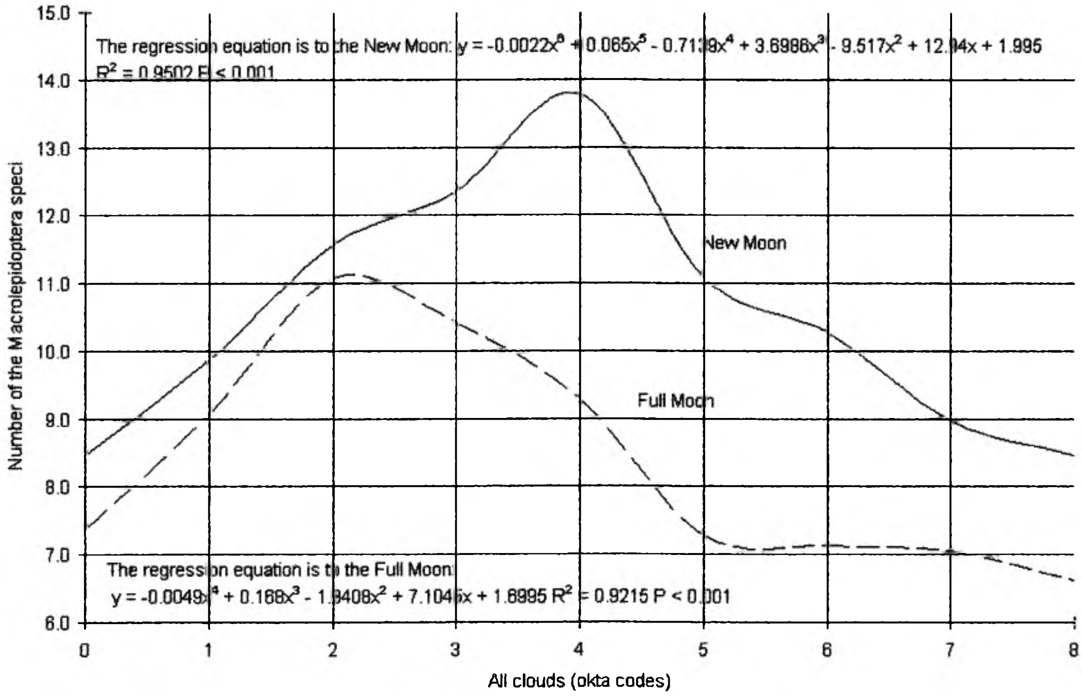

Figure 6. *Light-trap catches of the Macrolepidoptera species depending on the all clouds around New Moon and Full Moon int he Kámon Botanic Garden between 1962 and 1970*

Fig. 7 and *Fig 8* illustrate the catching results of the individuals and species in connection with the low clouds.

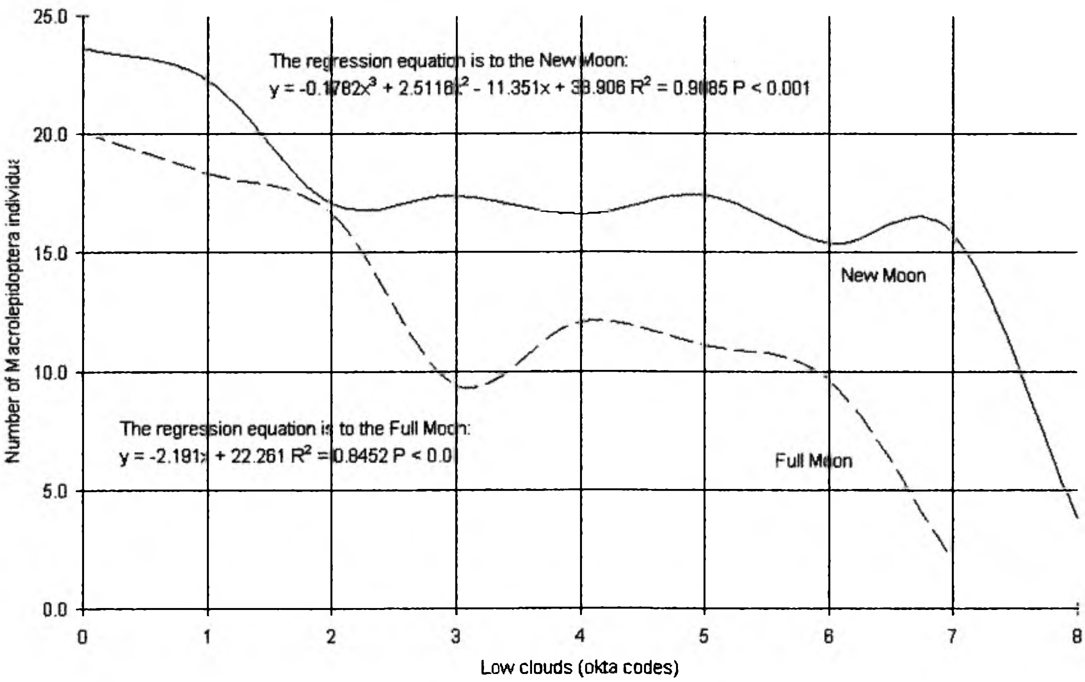

Figure 7. *Light-trap catches of the Macrolepidoptera individuals depending on the low clouds around New Moon and Full Moon in Kámon Botanic Garden between 1962 and 1970*

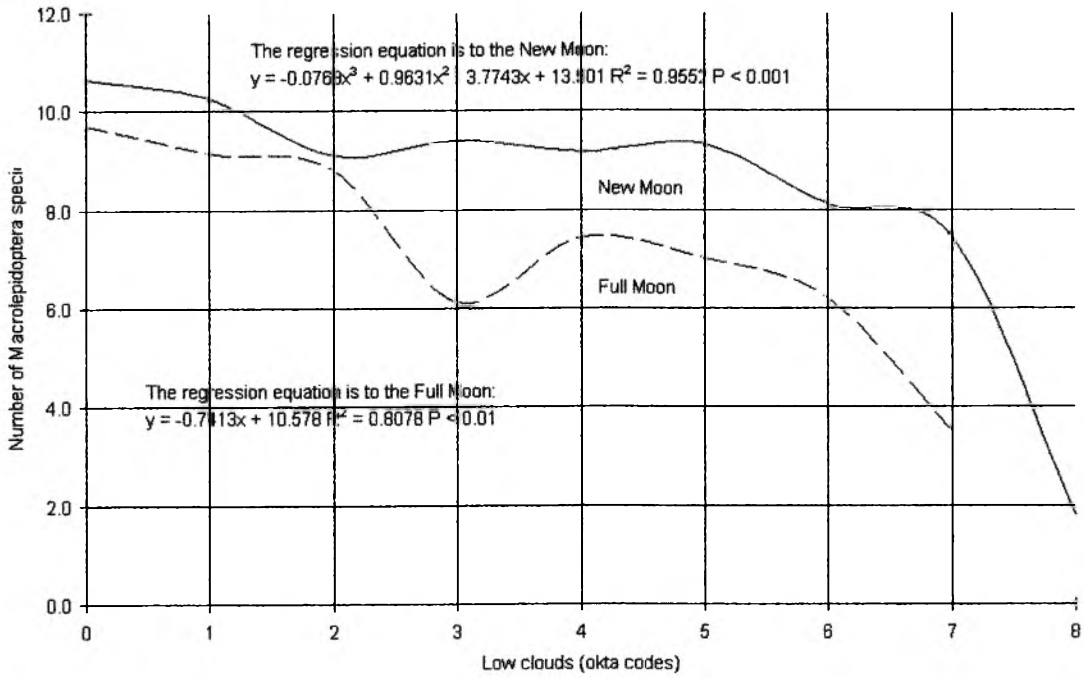

***Figure 8.** Light-trap catches of the Macrolepidoptera species depending on the low clouds around New Moon and Full Moon in Kámon Botanic Garden between 1962 and 1970*

The *Table 1* and *Table 2* imply the light trapping individuals' and species' number in the function of the cloud cover, the four quarters of the Moon.

***Table 1.** Number of Macrolepidoptera individuals caught by light-trap in Kámon Botanic Garden in Szombathely between 1962 and 1970 depending on the moon phases and clouds*

Clouds	*Clear (0-2)*		*Intermediate (3-5)*		*Cloudy (6-8)*	
Moon phases	*Individuals*	*Data*	*Individuals*	*Data*	*Individuals*	*Data*
New Moon	24.93	196	19.49	243	18.66	135
First Quarter	29.48	118	17.94	135	13.37	87
Full Moon	21.97	89	18.02	104	12.86	63
Last Quarter	26.91	117	16.97	162	24.18	80

Notes: Data = Number of observing data. Significance levels: New Moon: Intermediate – Cloudy $P < 0.05$; First Quarter: Clear – Intermediate $P < 0.01$, Clear – Cloudy $P < 0.01$; Full Moon: Clear– Cloudy $P < 0.05$; Last Quarter: Clear – Intermediate $P < 0.01$, Intermediate – Cloudy $P < 0.05$.

***Table 2.** Number of Macrolepidoptera species caught by light-trap in Kámon Botanic Garden in Szombathely between 1962 and 1970 depending on the moon phases and clouds*

Clouds	*Clear (0-2)*		*Intermediate (3-5)*		*Cloudy (6-8)*	
Moon phases	*Species*	*Data*	*Species*	*Data*	*Species*	*Data*
New Moon	11.96	196	9.74	243	9.35	135
First Quarter	13.09	118	9.27	135	7.47	87
Full Moon	10.61	89	9.19	104	6.60	63
Last Quarter	13.39	117	9.42	162	10.79	80

Notes: Data = Number of observing data. Significance levels: New Moon: Intermediate – Cloudy $P < 0.01$; First Quarter: Clear – Intermediate $P < 0.01$, Clear – Cloudy $P < 0.01$; Full Moon: Intermediate – Cloudy $P < 0.05$; Last Quarter: Clear – Intermediate $P < 0.01$.

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The *Fig. 9* and *Fig.10* show the modifying influence of the height of cloud base for the light-trap catch around the New Moon and Full Moon.

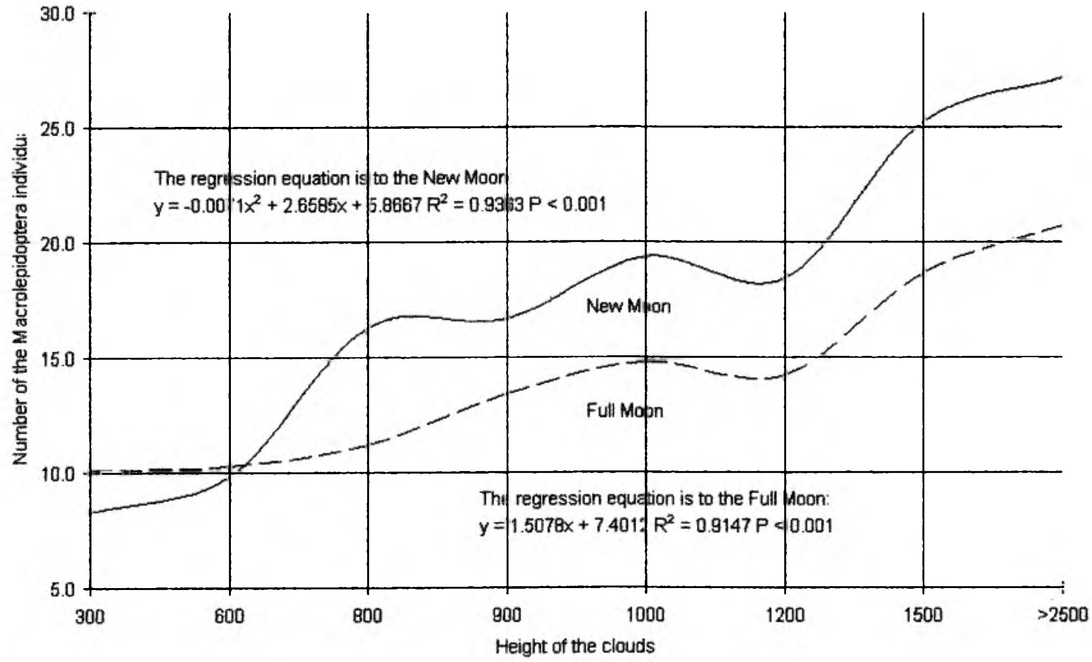

Figure 9. *Light-trap catches of the Macrolepidoptera individuals depending on the height of clouds around New Moon and Full Moon in Kámon Botanic Garden between 1962 and 1970*

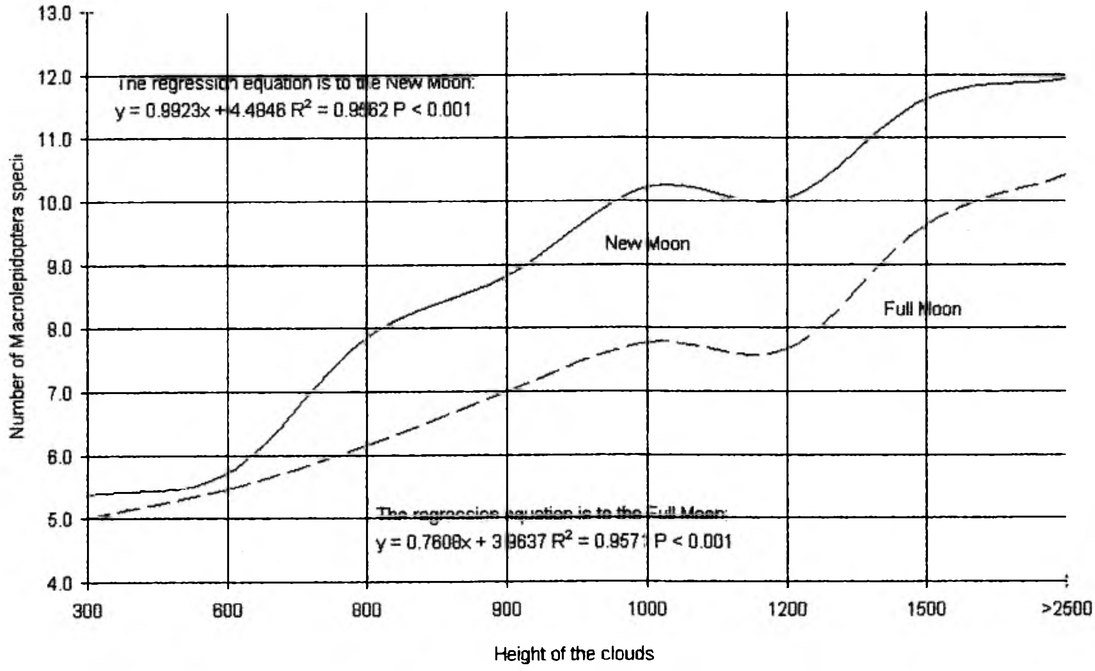

Figure 10. *Light-trap catches of the Macrolepidoptera species depending on the height of clouds around New Moon and Full Moon in Kámon Botanic Garden between 1962 and 1970*

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Discussion

The clouds determine the theoretical catching distances of both the Járfás and Jermy type light-traps fundamentally. The ratio of theoretical catching distances of completely overcast and clear sky is approximately 2.4:1. This difference does not appear however in the catching results.

It can be verified by our examinations that the catching of Turnip Moth (*Agrotis segetum* Den. et Schiff.) in moonless hours is the most successful (RC = 1.374) when the sky is totally through, if it is not raining (*Fig. 3*). However, if there is rain, the relative catch is only 0.518. The difference is significant at P < 0001.

In opposition to this, the catch decreases by the increase of the cloud cover in moonlit hours (*Fig. 4*). The most moths were found in the light-trap when the sky was almost clear. The increase of cloud cover results in a reduction of the catch.

The explanation for this phenomenon might be that the moon will help in the insects in orientation (Nowinszky, 2008). Notice that moonlit hours have been demonstrated catches associated with fully cloud. This case occurs when the sky is clear over a part of the hour; the Moon appears, however, in different part of the hour, the sky is completely overcast, but rain does not fall.

The results shown in *Fig. 5-8* also demonstrates that the number of the Macrolepidoptera individuals and species are higher when the sky is clear than overcast in the event both the all and low clouds.

Table 1 and *2* clearly show that the individuals and species caught by the Jermy type light-traps in all four moon phases are higher in bright than the overcast skies.

It was also found that the height of cloud base also modify the light-trap catch. If the cloud base is low the light-trap catch is also low, in the opposite it is high (*Fig. 9* and *Fig. 10*).

Our examinations justify that the behaviour of single Macrolepidoptera species may be different naturally, onto the catch of most species more successful the moonlit and bright nights. Our results contradict Williams (1936) and for the results of more other researchers. In our opinion the overcast sky increased of a catching distance before with decades the number of the individuals caught may have been higher really. We deduce from our own results that the reducing effect of catching distance of the moonlight may have prevailed limitedly only because of the vegetation in the botanic garden however. Since it is the botanic garden on the city's area though, from the centre some 2 km extends, the urban public lighting, the neon signs and the light seeping out from the flats caused light pollution although this concept was not used yet then.

The collection distance was not significantly bigger at the time of New Moon because of this, than at the time of a Full Moon. The orientation of the moths happened based on light stimuli when the clouds did not cover the moon though; this fact increased the efficiency of the trapping. Baker (1987) and Dacke et al. (2003) proved that certain moths and beetles use for their orientation the Moon and polarized moonlight.

The catching results of a fractionating light-trap confirm the species examined orient based on light stimuli in moonlit hours and bright sky. The catch is higher because the reducing effect of a smaller catching distance with a smaller effect at this time. The longer catching distance prevailed in moonless hours for the Turnip Moth (*Agrotis segetum* Den. et Schiff.) In the our studies appeared recent past we established that light pollution grew in the latter decades impugn the influence of the changing of catching distance on the light trapping result (Nowinszky, 2006 and 2008).

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Indian Journal of Agricultural Sciences **81** (2): 152–55, February 2010

Light trapping of *Helicoverpa armigera* in India and Hungary in relation with the moon phases

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Received: 11 June 2009; Revised accepted: 8 December 2010

ABSTRACT

The scarce bordered straw (*Helicoverpa armigera* Hbn.) was caught by light-trap to ascertain whether the behaviour of European population is the same with Indian ones in connection with moon phases, collecting distance, polarized moonlight and the light pollution. The Indian authors have found that the caught moths were very low at full moon, and high around the new moon. On this contrary, we did not establish difference between the catches of scarce bordered straw (*Helicoverpa armigera* Hbn.) at full moon and new moon in Hungary between 1993 and 2006.

The light pollution in India was lower at that time than this time in Hungary. The collecting distance in India was differing significantly at new moon and full moon. The light pollution equalized the collecting distance all the lunar months in Hungary. Hungarian catch results are modified primarily by polarized moonlight in the period between the first and the last quarters.

Key words: *Helicoverpa armigera*, Hungary, India, Light trapping, Moon phases

The scarce bordered straw (*Helicoverpa armigera* Hbn.) scathes various cultivated plants all over the world except America. Hardwick (1965) recognized three subspecies of H. *armigera* Hbn, i.e *H. armigera* in Africa, Europe, continental Asia, Sri Lanka and Japan, *H. armigera conferta* in eastern Indonesia, New Guinea, Guam, Australia, New Caledonia, New Zealand, Fiji, and the Friendly Islands (Tonga) and *Heliothis armigera commoni* from Canton Island (02°50'S 171°40'W) in the central Pacific Ocean. Specimens typical of *H. armigera* and *H. armigera conferta*, as well as intermediates between the two subspecies have been found in Sumatra, eastern Java, and the Philippines.

In 1993, *H. armigera* Hbn. appeared in light-trap catch in Hungary. From that time, its catch is regular, the representative number had small fluctuations and it was permanently higher. The peak was in 2003. There are researches all over the world and in Hungary to examine its lifestyle, spreading, migration and gradology. In the recent past, a book was published by Èamprag *et al*. (2004) and it contains the results of researches until now.

Both the light-trap and pheromone trap is a useful device for cognition of population changing. Indian researchers determined most specimen fly to the light-trap at new moon, but less ones reach trap at full moon. The catch was successful from new moon until full moon (Sekhar *et al*. 1996, Pedgley *et al*. 1987). On the other hand, Sekhar *et al*. (1995) did not find any difference in pheromone trap success during different moon phases. Vaishampayan and Verma (1982) were collecting *H. armigera* Hbn. in India. They used the common name, gram podborer. Collecting was more successful in the waning than in the waxing period. They presume that the response of moths is weaker to the stimulus of the light trap in the vicinity of a full moon.

In this study, we examined *H. armigera* Hbn. whether the behaviour of European population is the same than Indian ones in connection with moonlight.

MATERIALS AND METHODS

Vaishampayan and Verma (1982) used Pennsylvania-type light-trap, the light-source was 250 W HGL bulb placed in a height of 3 m above the ground.

The trap was in operation near Jabalpur between 1975–76 and 1978–79. They caught a total of 18 732 moths in these years.

The fact that the same subspecies of *H. armigera* Hbn. is flying in India and Hungary (Hardwick, 1965) gave us a possibility for and interesting comparison. Using the catching data and results of Vaishampayan and Verma (1982) collecting in the Jabalpur region of India between 1975 and 1979, we could calculate specimen numbers for the different days of the lunar month. We have processed these with our own method and compared the outcome with the results

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gained by processing data from Hungary for 1994–2006.

There were used data of Hungarian agricultural light-trap network to the examinations between 1993 and 2006. There are used Jermy-type light-traps in this network (Jermy 1961). The light source of traps was 100 W normal bulb at 2 m height. We used chloroform as killing material. In 1993, there were only 6 traps in operation, but in 2003 only 40 ones collected moths. In this period, there were successful trapping during 1 432 nights and traps caught altogether 21 578 specimens. The number of observation data was 7 845, because more traps were in operation during one night. By observation data, we mean the catch of a species on one night at one observation post, regardless of the number of specimens, but now we did not calculate those nights when trapping was unsuccessful. The moonlight reduces the success of trapping, but it did not make it fully impossible.

The full moon time data we needed to create our lunar phase classes were downloaded from the Astronomical Applications Department of US Naval Observatory: http://aa.usno. navy.mil/cgi-bin/aap ap.pl.

For every midnight of the flight periods (UT = 0 h), we have calculated phase angle data of the moon. On the 360 phase angle degrees of the full lunation we established 30 phase angle divisions. The phase angle division including a full moon (0º or 360º) and values 0 ± 6º was named 0. Beginning from this group through the first quarter until a new moon, divisions were marked as -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The next division is ±15, including the new moon. From the full moon through the last quarter in the direction of the new moon divisions, were marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each division consists of 12 degrees (Nowinszky 2003). These phase angle divisions can be related to the four quarters of lunation as follows: full moon (-2 – +2), last quarter (3 – 9), new moon (10 – -10) and first quarter (-9 – -3). The nights of the periods under examination were all classed into these phase angle divisions.

Data on the illumination of the environment were calculated with our own software. This software for TI 59 computer had been produced by the late astronomer György Tóth specifically for our joint work at the time (Nowinszky and Tóth 1987). The software calculates the illumination of the sun at dusk, the light of the moon and the illumination of the starry sky – all in lux – for any given geographical place, day and time, separately or summarized. It also calculates with cloudiness.

Cinzano *et al*. (2001) published a world atlas listing the most important data by countries. In this work, the authors consider artificial illumination above 10% of the natural background illumination as light pollution. According to their data, in 1996 and 1997, artificial illumination exceeded 11% of the natural illumination in all areas (100%) of Hungary, and 33% in 81.9% of the country. The same values were 14.9% and 34.7% in India. Two decades before the study by him, it had not been necessary to consider light pollution in India, but it was in the recent years in Hungary.

We also considered light pollution data in calculating collecting distances for the Jermy-type light-trap. Our estimation was based on a study be Cinzano *et al*. (2001). In our study, we calculated both for India and Hungary with average illumination values of a full moon for the time of light trapping.

The collecting distance can be calculated with the help of the following formula (Nowinszky 2006):

$$r_0 = \sqrt{\frac{I}{E_N + E_H + E_{CS} + E_F}}$$

Where: r_0 = collecting distance, I = illumination from the lamp [candela], E = the illumination coming from the environment [lux] the latter consisting of the light of the setting or rising sun (E_N), the moon (EH), the starry sky (E_{CS}) and light pollution (E_F).

For a lunar month chosen as a sample, we calculated collecting distances at 0:00 (local time) of each night. In case of both light traps, cloud cover was taken into consideration and for the Jermy-type light trap we also counted with light pollution (Table 1).

In a former study (Nowinszky *et al*. 1979), we established percentage values for polarized moonlight in connection with the lunar phases, with due consideration to studies by Dollfus (1961) and Pellicori (1971) (Table 2).

Table 1 Theoretical collecting distances (m) of the Jermy-type and the Pennsylvania-type light-trap in connection with the moon phases and cloud cover

Cloud cover	Clear	Intermediate	Cloudy
Moon quarters	Jermy-type light-trap operating with a 100 W normal bulb for first quarter suitable light pollution		
First quarter	41	46	55
Full moon	19	25	45
Last quarter	44	49	55
New moon	57	57	57
Moon quarters	Jermy-type light-trap operating with a 100 W normal bulb for full moon suitable light pollution		
First quarter	19	19	20
Full moon	14	16	19
Last quarter	19	20	20
New moon	20	20	20
Moon quarters	Pennsylvania-type light-trap operating with a 250 W mercury vapour lamp without light pollution		
First quarter	229	313	866
Full moon	92	126	347
Last quarter	274	375	1036
New moon	1023	1399	3456

Table 2 The percentages of the polarized moonlight depending on the phase angle divisions

First quarter	Polarized moonlight (%)	Full moon	Polarized moonlight (%)	Last quarter	Polarized moonlight (%)
–9	6.324	–2	–0.412	3	2.511
–8	6.576	–1	–0.115	4	3.927
–7	6.285	0	0.000	5	5.412
–6	5.788	1	–1.115	6	6.869
–5	4.950	2	–0.412	7	7.941
–4	3.687			8	8.714
–3	2.412			9	8.765

Positive numbers denote the horizontally the negative ones the vertically polarized moonlight. At the time of a full moon the moonlight did not polarized.

Based on the number of specimens caught in India and Hungary, we calculated relative catch values for each brood. Relative catch (RC) is the ratio of the number of specimen caught in a given sample unit of time (1 hr or 1 night) and the average number of specimen caught in the same time unit calculated for the whole brood. If the number of the specimen trapped equals the average, the value of relative catch is: 1. Only nights and hours with some catch were included in the calculations, as our earlier works (Nowinszky 2003), had convinced us that although the moon has an influence on the efficiency of trapping, it never makes collecting impossible.

Examining the influence of lunar phases, we compared the catch of Pennsylvania-type and Jermy-type light traps in different phase angle divisions. We analyzed the correlation between collecting distances and relative catches in the case of the Pennsylvania-type light trap and between polarized moonlight and relative catches for the Jermy-type light trap. We did not distinguish horizontally or vertically (oscillating) polarized moonlight, as in one of our earlier studies (Nowinszky 2008) we found no significant difference between the catch of traps set up in environments characterised by different kinds of polarization. Our results, including regression equations and significance levels, are displayed in Figures.

RESULTS AND DISCUSSION

The results are shown in Figs 1, 2.

Our results are not the same as statements of Indian researchers. This fact is amazing, because both populations (in India and Central Europe) belong to the same subspecies (Hardwick 1965). The wave length of light sources, used in India and Hungary are not the same, but we did not make comparison between the number of caught moths. We wanted to investigate where can be found catching minimum and maximum in lunar month.

There is a very intensive decrease around full moon in India, but we can see maximum catch at new moon. The

The regression equation: $y = 0.008x^2 - 0.2531x^2 + 2.4113$ $R = 0.8221$ $P < 0.001$ Significance level between First Quarter and Full Moon $P < 0.001$, First Quarter and New Moon $P < 0.001$ Full Moon and Last Quarter $P < 0.05$, Full Moon and New Moon $P < 0.001$, Last Quarter and New Moon $P < 0.01$ The correlation between collecting distance and relative catch $R = 0.8924$ $P < 0.001$

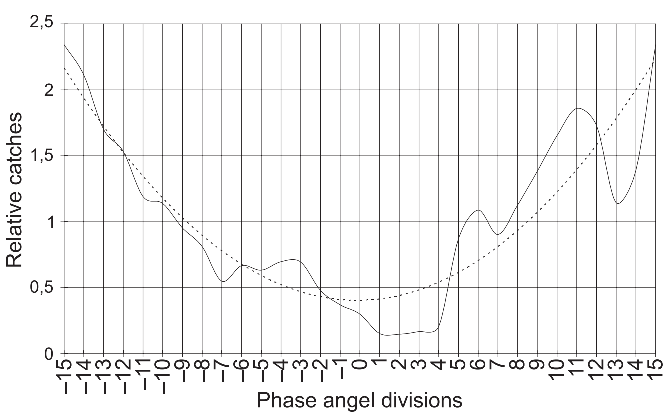

Fig 1 Light-trap catch of the scarce bordered straw (*Hellcoverpa armigera* Hbn.) In India (Jabalpur) between 1974 and 1979 depending on the phase angle divisions from the data of Vaishampayan and Verma (1982)

The regression equation

$y = 2E–07x^6–2E–05x^5+ 0,0006x^4–0,011x^3 + 0,0914x^2–0,2955x+1,1671$

$R^2 = 0,5989$ $P < 0,001$

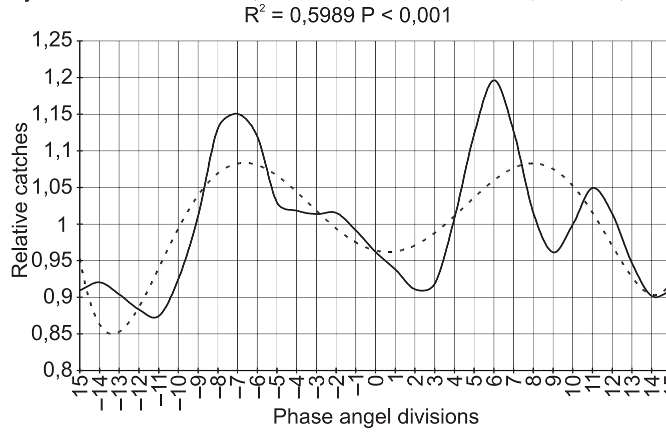

Fig 2 Light-trap catch of the scarce bordered straw (*Hellcoverpa armigera* Hbn.) in Hungary between 1993 and 2006 depending on the phase angle divisions

success of catch is almost the same around new moon and full moon in Hungary, but there are two little catch peaks near the first and last quarter, when the polarized proportion of moonlight is the highest. In our previous study (Nowinszky *et al*. 1979), we also found the highest catch at the same quarters monitoring consolidated light-trap catch results of 7 species.

Perhaps the cause of difference between results in India and Hungary is not because of the variance of light-trap types. Researchers use several light-trap types all over the world. Generally, the observations show intensive decrease around full moon. Recently, intensive light pollution can be noticed in Europe (Cinzano *et al*. 2001). Therefore, we rather think it is likely that the collecting distance, belonging to new moon and full moon will moderate or totally disappear because of the light pollution (Nowinszky 2006).

Data provided by Vaishampayan and Verma (1982) make it clear that there was a catch maximum at a new moon and a minimum at a full moon. In Hungary, however, one can observe no maximum at a new moon or minimum at a full moon, only smaller, still significant maxima in the first and the last quarter. We found that the degree of light pollution was smaller in India 30 years ago, than in Hungary in recent years.

Here, the difference between the catch at a full moon and a new moon practically disappeared. Consequently, there is no difference between the catch in this two quarters, but there is a maximum in the first and the last quarter.

Examining the relationship between polarized moonlight and collecting has gained special significance since studies by Dacke *et al*. (2003) had proved that certain insects can find their bearing with the help of polarized moonlight. Our current findings also show a growth of light trap catch when the polarized part of moonlight is higher.

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Sonderdruck aus Bd. 88 (1979), H. 4, S. 337–353

Zeitschrift für angewandte Entomologie
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The effect of the moon phases and of the intensity of polarized moonlight on the light-trap catches

By L. Nowinszky, S. Szabó, G. Tóth, I. Ekk and M. Kiss

Abstract

The authors worked up a material collected during 14 years at 20 sites of the Hungarian forestry and agricultural light-trap network system. In this study they examined the effect of the polarization and intensity of the reflected moonlight on the abundance of 5 lepidopteran and 2 coleopteran species in the trap catches. The material consisted of 55,003 specimen.

The relative abundances of the insects in catches per day were calculated for each swarming time, and these were arranged by species and flights according to moon phases and the catches of the corresponding days of lunations were meaned. In this way, the mean relative abundances (MRA) vs. moon phase, characteristic for the species, were calculated. Then these daily MRAs of the 7 species were meaned, these general MRAs (GMRAs) served as a basis of the further analysis.

In the next step, from the GMRAs power spectra were calculated; the period times belonging to their extreme values were 14.5, 30, 10, 7.4, and 3.3 d, respectively.

We calculated the correlation coefficient between the GMRAs and the polarization rate (PR) of the moonlight ($r = +0.87$).

Together with these, the theoretical RAs of insects caught at new moon divided by at full moon, were calculated, by using probability methods and data of the illumination conditions (light emission) of the Jermy-type light-trap, the Moon and the night sky.

It was concluded that the calculated period time of 14.5 d was related to the polarization rate of the moonlight. The highest trap catches coincided with the maximal polarization rates.

From the 30 day's period it was postulated that the intensity has a modificator effect. At new moon and at full moon (both phases emitting unpolarized light) the number of insects caught is influenced by the conditions of light intensity in the surrounding of the trap, which determine also the distance of attractiveness.

So the moonlight effects both the extension of the collecting area and flight activity of the insects by the cyclic changes of light intensity and polarization rate. Therefore the number of the insects caught is influenced by the lunar cycle.

Introduction and review of literature

1.1 The influence of the moonlight intensity on the light-trap catches

Only a few entomologists dealt with the modificator effects of the moonlight on the effectiveness of light-traps. Basic and quantitative results were published by Williams (1936). He stated, that the highest number of noctuid moths were trapped on the 2nd, 4th day after new moon, while the minimal values were observed in the catches during the same period after full moon. The abundance curve shows assymetry by the moon phases, which confirms the fact that the light, reflected by the two hemispheres of the Moon is not identical. Observed at the same place, the moonrise is postponed about 50 min daily, which causes an additional assymetry.

The quantitative relationships gained from the data are very interesting: three times more noctuid moths were caught at new moon than at full moon

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Z. ang. Ent. 88 (1979), 337–353

ISSN 0044-2240 / ASTM-Coden: ZANEAE

on clear nights. During cloudly nights, WILLIAMS found that the catch ratio was 2 : 1 (new moon vs. full moon), while according to moon phase only, the ratio was 2.7 : 1. To explain this phenomenon, WILLIAMS (1936) and WILLIAMS, SINGH and EL-ZIADY (1956) suggested two hypotheses: – the moonlight decreases the insect activity, and/or – the light-trap collects from a smaller area in a brighter environment.

WILLIAMS and EMERY (1935) constructed an equipment for the registration of the moonlight for entomological purposes. This is a simple construction with a planconvex cylindrical lens and as a registrator a daily changed photosensitive paper. It has to be oriented with one axis to the sky pole, and has to roll around its other axis with a period time of about 24 h 50 min., so following the virtual orbit of the Moon. By measuring the darkness of the photopaper, the length and the intensity of the moonlight can be established.

In subsequent years, the examinations were extended to other insect orders (WILLIAMS 1940). The highest number of insects was caught in light-traps on the 20th d of the moon cycles, while the minimum values on the 1st d (at full moon). Local minima were found on the 5th, 7–8th, 14th and 17th d of the cycle. The curves derived from the numbers caught a smooth trend of increase or decrease.

Later, WILLIAMS and SINGH (1951) corrected these ratios considering the modification effects of weather conditions.

PONGRÁCZ (1933) observed in many cases the appearing of large swarms of *Polymitacris virgo* Oliv. just after full moon.

CSONGOR and MOCZÁR (1954) stated that the mass flight of the mayfly *Palingenia longicauda* Oliv. begins when increases in air pressure, air and water temperature coincide with the moon changes.

The flight activity of *Ephemeroptera* was found to be the highest 2–3 d after full moon (HARTLAND-ROW 1955).

WÉBER (1957) reported a periodicity in the number of insects trapped, which could be brought into correlation with the moon changes. The number of insects trapped at new moon exceeded the full moon catches about for times. He calculated the correlation coefficient between the amount of catches and the moon phases, using data of the period May–September 1956 but found only weak or median correlations.

PROVOST (1959) and BILDINGMAYER (1964) demonstrated that the moonlight influences the number of mosquitoes caught in light-traps. FRYER (1959) reported that the development of the chironomid *Chironomus brevibucca* Kief. is tightly synchronized with the moon cycle. The adults swarm after full moon.

The well-marked difference between the numbers of insects trapped at full moon of the ones caught at new moon was observed by BROWN, BETTS and RAINEY (1969).

NEMEC (1971) while studying the moth *Heliothis zea* Boddie in Texas, 1964–1966, caught the fewest at full moon while maximum numbers at the first or last quarters. To explain this phenomenon, he reared the moths in bioclimatic chambers, in total darkness. He found the adults to become inactive over illumination levels of 0.01 foot-candles. He concluded that the light conditions at full moon minimize the flight activity of this species. So there exists a synchronity between the activity of the moth and the moon phases. Nemec's results agree with the earlier hypothesis of WILLIAMS, SINGH and EL-ZIADY (1965), mentioned above.

SIDDORN and BROWN (1971) reported the maximum catch of *Spodoptera exempta* Walk. in Kenya 2 h after sunset when studied 7 days before full moon but 11 h after sunset, when 7 d after full moon. The peak catches were closely associated with no moonlight.

BROWN and TAYLOR (1971) investigated the vertical dispersion of insects in the heights of 5, 30, and 50 feet, and found a significant correlation with the moon phase. Insects flying at greater heights were more abundant during the first quarter than during the last, while peaks occured both at full and at new moon.

A detailed description of the moon cycles and lunations is given by BOWDEN (1973a). He dealt with the changes of the illumination and of the light absorption of the atmosphere as well as with the effectiveness of light vs. moon phase. In a second publication (BOWDEN and CHURCH 1973) the authors analysed the effects of night illumination on the insect species caught in traps at Uganda and, established regression constants.

Bowden (1973b) treated the decrease of the illumination after sunset from the civil twilight to the astronomical twilight: The light stimulus is different but definite by species, so the Moon at a certain phase can provide them light enough for orientation. He stated that the biological rhythm of *Heliothis zea* Boddie and another species followed the moon cycle.

Bowden and Gibbs (1973) explained similarly the periodic activity of insects by the synchronization of their biorhythm to the moon phases.

On the contrary, Day and Reid (1969) found no significant difference between the numbers of *Conoderus falli* Lane collected during mooney and moonless nights in a 12-year's study. Papp and Vojnits (1976) did not observe disturbing effects of the full moon on the effectiveness of light-trapping in Korea.

1.2 Perception of the polarized light by insects and their orientation by polarized light

The ability of the insects to percept polarized light was reported by Werchowskaya (1940). Several authors have studied the extraocular effects and intraocular mechanisms involved in the perception of polarized light (Autrum and Strumpf 1950; Seletzkaya 1956; Lüdtke 1957; Kuwaraba and Naka 1959; Burkhardt and Wendler 1960; Fernandez-Moran 1961; Giulio 1963; Masochin-Porshnyakov 1965; and Waterman 1974).

The results proved the ability of percepting polarized light by insects and revealed the physiological processes involved.

Frisch reported orientation by polarized light in honey bees (1948, 1949, 1950, 1951, 1954, 1956), Birukow (1956) in the corixid *Velia currens* F. and Jandler (1957) in ants. However, there are no published results on the effect of polarized light on the orientation of insects attracted by light-traps. Doane and Leonard (1975) reported that *Porthretia dispar* L. larvae orientate themselves according to polarized sunshine but the adults were not dealt with.

It is not the aim of the present paper to investigate the mechanisms of the polarized light reception but, we wanted to give a short review on the subject to better substantiate our hypothesis. We suppose that night flying insects orientate themselves by the polarized moonlight.

The light-trap type being used in the Hungarian network system, the so-called jermy-trap, which is a modified version of the minnesota trap with the difference that the baffles were left away and chloroform serves as a killing agent. The light source is a 100 watt bulb (argon filled) placed at 2 m high (Jermy 1961; Le Berre 1969).

The light-trap network has been working in the Department of Plant-Protection Stations of the Forestry Research Institute since 1961. The large material, which has been collected by this system, has a great importance. We employed a part of this material to investigate the modifying effects of the moonlight on the effectiveness of light-traps under Hungarian geographic and climatic conditions.

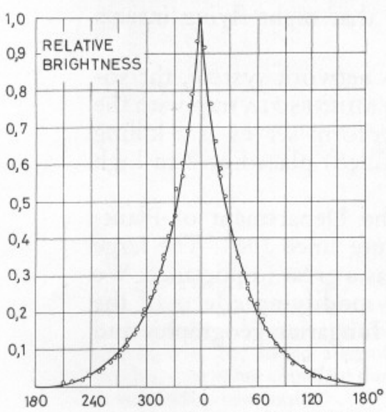
2 Material

2.1 Astronomical data of the Moon

The energy of the sunlight reflected by the Moon is spectroscopically similar to the direct sunlight. The synodic month, the revolution time of the Moon around the Earth takes 29.5306 d. This is the mean period of the Moon's light variations. Due to the excentricity of the Moon's orbit, this value varies in the reality between 29.25 and 29.83 d, so a difference of 13 h arises from the excentric motion.

When the Moon, revolving on its orbit, passes between the Sun and the Earth; it is called as a "new moon", furthermore at "full moon" the sky body has an opposite position to the Sun. This is the time when the Moon has its maximal apparent brightness, because the Sun illuminates the maximum visible surface, while at the new moon the perceivable brightness decreases to zero. Two other moon phases are discerned: the first quarter, 90° from the full moon position, and the last quarter, 90° from new moon position. The moon phases are characterized by the phase angles. This means the angle at the Moon in a Sun-Moon-Earth triangle. To calculate the phase angle the methods of spherical astronomy are used. The data we need are the actual coordinates of the Sun, the ones of the Earth and the Moon; these are published in astronomical yearbooks. The phase angle is at full moon 0°, in the last quarter 90°, at new moon 180°, and at the first quarter is 270°.

For entomological purposes it is more convenient to use estimates of the moon phases only. The light-traps work all the night, but the synodic days do not correspond exactly to solar mean days. We used an approximation of 30 d for the moon cycle which caused a calculated error of 1.6 %. We regarded the elliptical moon orbit as a circle (furthermore + 0.8 % error), with a linear phase angle shift of 12° per d (30 d × 12° = 360° = 1 synodic month). The pooled 2.4 % of error was compensated by the decreased computer time and by the more simple calculus.



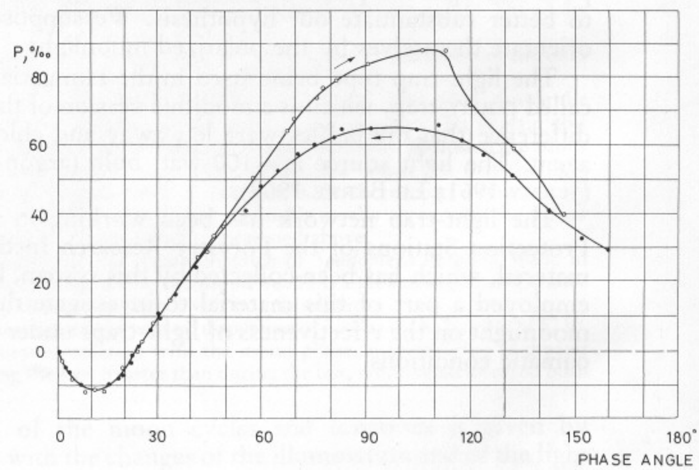


Fig. 1 (left). The phase function of the Moon *Fig. 2 (right).* The polarization of the reflected moonlight

The illumination arriving at full moon to the Earth equals to 0.25 lux located at the zenith under ideal atmospheric transparency conditions. The brightness changes considerably with the phase angle. At the new moon ± 2 d (in the interval of 160–220°), it is very difficult to measure the brightness belonging to a certain phase angle value (fig. 1.). During this period the night sky illumination reaches 0.0009 luxes only.

Table 1. The relative brightness and polarization of the Moon in approximation of lunar days as a function of its phase angle

Approx. lunar days	Phase angle	Rel. brightness	Rel. polarization	Note
0^d	0^o	1.000	0.0000	full moon
1	12	0.724	− 0.0111	
1.9	23.5		0.0000	
2	24	0.533	+ 0.0015	
3	36	0.391	0.0191	
4	48	0.288	0.0418	
5	60	0.211	0.0541	
6	72	0.147	0.0708	
7	84	0.100	0.0812	
7.5	90	0.078	0.0878	last quarter
8	96	0.066	0.0859	
9	108	0.044	0.0875	
10	120	0.026	0.0721	
11	132	0.014	0.0585	
12	144	0.006	0.0436	
12.2	146.5		0.0400	
12.5	150	0.005		
13	156	0.002	0.0240	
14	168	0.001	0,0090	
15	180	0.000	0.0000	new moon
16	192	0.001	0.0120	
17	204	0.003	0.0270	
17.5	210		0.0356	
18	216	0.007	0.0408	
19	228	0.009	0.0518	
20	240	0.025	0.0600	
21	252	0.041	0.0637	
22	264	0.067	0.0654	
22.5	270	0.082	0.0649	first quarter
23	276	0.105	0.0637	
24	288	0.155	0.0589	
25	300	0.211	0.0495	
26	312	0.292	0.0343	
27	324	0.395	0.0184	
28	336	0.535	+ 0.0008	
28.1	336.5		0.0000	
29	348	0.740	− 0.0100	
30	360	1.000	0.0000	full moon

If the Moon is at a z° zenith distance position above the horizon, the illumination reflected is lower compared to the zenith distance of the same moon phase (see Appendix, eq. 8.).

The declination of the Moon (one of the time-dependent spherical geocentric coordinates) may amount to ± 29° in extreme position, so the Moon can take a zenith position only to the equatorial band between 29° N–29° S.

At any geographic site, different from the above, a correlation factor dependent on the distance from the zenith should be used, considering also the light absorption of the Earth's atmosphere. Data of the relative brightness measured at the zenith, are given by ROUGER (1933). Recently, van DIGGELEN (1959) published methods for calculating corrections.

The relative brightness values on the ground level as a functions of the phase angle and approximated lunar month (of 30 d), respectively, are given in fig. 1.

It may be mentioned that very complicated equations describe the dependence existing between the relative brightness of the zenith-positioned Moon and the moon phase, containing trigonometric-exponential and natural logarithm-trigonometric components. For further details, see HAPKE (1971) and BAKULIN (1973).

Examining the light-trap catches of the selected insect species, we found consequent alterations of the abundance curve, which seemed to show higher correlation to the polarization rate of the moonlight rather than to the light intensity. So it is following we examined more thoroughly the polarization relations of the moonlight.

ARAGO (1811) had described the moonlight to be partly polarized. The first quantitative measurements were made by LYOT (1929), and corrected by DOLLFUS (1961), (see table 1).

The moonlight is linearly polarized. The maximum polarization rate (PR) 7.5 ‰ is reached during ± 2 d of the first and the last quarter. It is impossible to measure the PR at new moon ± 3 d. At full moon, the moonlight is not polarized, but in an interval of ± 2.5 d, the polarization plane turns over. The situation vs. moon phase, is pictured in fig. 2.

2.2 Light-trap catches

The light-trap network system includes 20 sites in Hungary (fig. 3.). different both geographically and climatically. We aimed to damp by this diversity the differences in the height above sea level, the relief, the location, the soil, and the weather.

The vegetation surrounding the trap effects considerably the catch. So we used the data of some polyphagous species and that of the forestry network, where the traps are surrounded by a vegetation of similar quality, differing only by its age. 92.37 ‰ of the flight data and 87.66 ‰ of the total material had been collected by the forestry light-trap system (tables 2 and 3). The numbers of swarmings per species and the yearly catches are summarized in table 4.

Fig. 3. The locations of light-traps generating the data used projected into Hungary's map

Table 2. The locations of forestry network stations associated with their data series and number of individuals

Measuring station	Data series	Number of individuals
1. Budakeszi	6	1927
2. Farkasgyepü	8	2284
3. Felsötárkány	5	1296
4. Gerla	44	6421
5. Kúnfehértó	24	2408
6. Mátraháza	4	282
7. Répáshuta	7	886
8. Sopron	10	7763
9. Szentpéterfölde	6	1199
10. Szombathely	1	44
11. Tolna	55	4730
12. Tompa	48	13330
13. Várgesztes	20	5705
Sum of all	218	48275
in %	92.37	87.66

Table 3. The locations of agricultural network stations associated with their data series and number of individuals

Measuring station	Data series	Number of individuals
1. Celldömölk	9	5339
2. Fácánkert	1	40
3. Kaposvár	1	134
4. Kecskemét	1	95
5. Mikepércs	1	887
6. Tanakajd	4	1460
7. Vasvár	1	641
Sum of all	18	6976
in %	7.63	12.34

Table 4. The number of swarming investigated (A) per species (listed down), and the number of individuals (B) in the years 1963–1976

Year	1		2		3		4		5		6		7		Sum of all	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1963					3	410	6	523							9	873
1964					4	448	6	1588							10	2036
1965					3	362	7	1054							10	1416
1966	1	1044			3	277	5	539					4	554	13	2414
1967	7	1296			6	489	6	441					1	196	20	2422
1968					13	3787	7	2769					3	350	23	6906
1969	1	295	4	1516	3	199	7	1914							15	3924
1970	1	76	4	4342	8	649	9	4232							22	9299
1971	3	222	4	905	3	366	8	2041							18	3533
1972	4	226	3	329			2	203			1	131			10	889
1973	1.	64	4	1214	5	637	9	1099			1	2117			20	5131
1974			2	233	5	331	1	104			1	3818			9	4486
1975	7	1109					5	1562	5	333	5	1932	9	2807	31	7743
1976					5	726	5	1380	7	359	3	222	6	1183	26	3870
Sum	25	4332	21	8539	61	6881	83	19449	12	692	11	8220	23	5090	236	55003

1 – *Melolontha melolontha* L., 2 – *Serica brunnea* L., 3 – *Scotia segetum* Schiff., 4 – *Hyphantria cunea* Drury, 5 – *Orthosia gotica* L., 6 – *Orthosia cruda* Den et Schiff., 7 – *Operophtera brumata* L.

We used the data of 14 years (1963–1976) of the following 7 species:
European cockhafer, *Melolontha melolontha* L.
Grape colaspis, *Serica brunnea* L.
Cutworms, *Scotia segetum Schiff.*
Cutworms, *Orthosia gotica* L.
Cutworms, *Orthosia cruda* Den. et Schiff.
Winter moth, *Operophtera brumata* L.
Fall webworm moth, *Hyphantria Drury.*

By processing the material we strived to totality and all series of swarming data were used, where
- generations were well separable
- the light-trap has been operated during the whole swarming period
- the specimens caught from single generations were numerous.

The data included all individuals but the ones caught several days before or after the species' main swarming period (less than 0.05 % of the total).

3 Methods and results

We calculated the relative frequencies of the adults per day. These abundances were arranged according to the moon phases and the daily arithmetical means were calculated. So we had the Mean Relative Abundances (MRA) by species vs. moon phase. Then the daily MRAs of the 7 species were meaned, obtaining thus the General MRAs (GMRA) vs. moon phase (fig. 4., table 5).

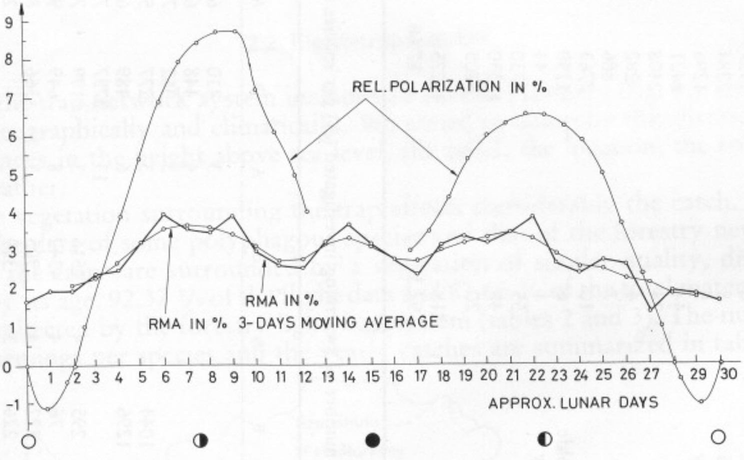


Fig. 4. The relative mean abundance (RMA) as a function of lunar days

We used the relative abundances instead of the actual trapping results which were more suitable for comparison of different years and sites.

The power spectra (periodograms) of the GMRAs were calculated by using the computer of the Gothard Astrophysical Observatory of R. Eötvös University at Szombathely. The period times belonging to their extreme values were 14.5, 30, 10, 7.4 and 3.3 d, respectively.

The correlation coefficient between the GMRAs and PR of moonlight is $r = 0.87$ proved to be significant ($p < 0.05$).

The majority of the species studied swarmed in April-May and July-August (fig. 5). The night period of this season extends to about 10 hours and can be treated as nearly equal in these months. We calculated as an example, the

Table 5. Summarized relative abundances arranged in order of approximated lunar days

Lunar d	RA in %	Lunar d	RA in %	Lunar d	RA in %
1	1.94	11	2.63	21	3.45
2	1.96	12	2.55	22	3.85
3	2.38	13	3.23	23	2.66
4	2.50	14	3.66	24	2.38
5	3.22	15	3.19	25	2.72
6	3.96	16	2.73	26	2.66
7	3.58	17	2.40	27	1.83
8	3.50	18	3.18	28	1.95
9	3.90	19	3.57	29	1.85
10	2.99	20	3.19	30	1.67

Table 6. The duration of nights in a sample 'lunar month' in summer, Juli–August, 1977, in Hungary

Date month/d		Approx. lunar d	Duration of nights h.m.	Exposition time of the Moon above horizon h.m.	below horizon h.m.
July	29	30	8.57	8.57	0.00
	30	1	8.59	8.59	0.00
	31	2	9.02	8.46	0.16
August	1	3	9.04	8.15	0.49
	2	4	9.07	7.48	1.19
	3	5	9.09	7.20	1.49
	4	6	9.13	6.55	2.18
	5	7	9.15	6.27	2.48
	6	8	9.18	5.57	3.21
	7	9	9.21	5.25	3.56
	8	10	9.24	4.47	4.37
	9	11	9.26	3.55	5.31
	10	12	9.29	3.17	6.12
	11	13	9.33	2.26	7.07
	12	14	9.35	1.28	8.07
	13	15	9.38	0.27	9.11
	14	16	9.42	0.00	9.42
	15	17	9.44	0.00	9.44
	16	18	9.47	0.08	9.39
	17	19	9.51	0.59	8.52
	18	20	9.54	1.31	8.23
	19	21	9.56	2.04	7.52
	20	22	10.00	2.41	7.19
	21	23	10.03	3.23	6.40
	22	24	10.06	4.13	5.53
	23	25	10.10	5.10	5.10
	24	26	10.13	6.14	3.59
	25	27	10.15	7.22	2.53
	26	28	10.19	8.36	1.43
	27	29	10.22	9.49	0.33
	28	30	10.25	10.25	0.00
	29	1			

lenghts of the night periods and of those when the Moon was above the horizon for a lunation in August 1977 (table 6, fig. 6).

The optical characteristics of the Jermy-type light-trap are given in fig. 7. The light conditions of the Moon and of the night sky as a function of the distance from the trap are given in fig. 8. For calculating the illumination intensity (eq. 1.) – see Appendix – was used.

According to our calculations, the light of the trap surpasses the Moon + night sky illumination at full moon in a circle of a radius of about 20 and 300 m

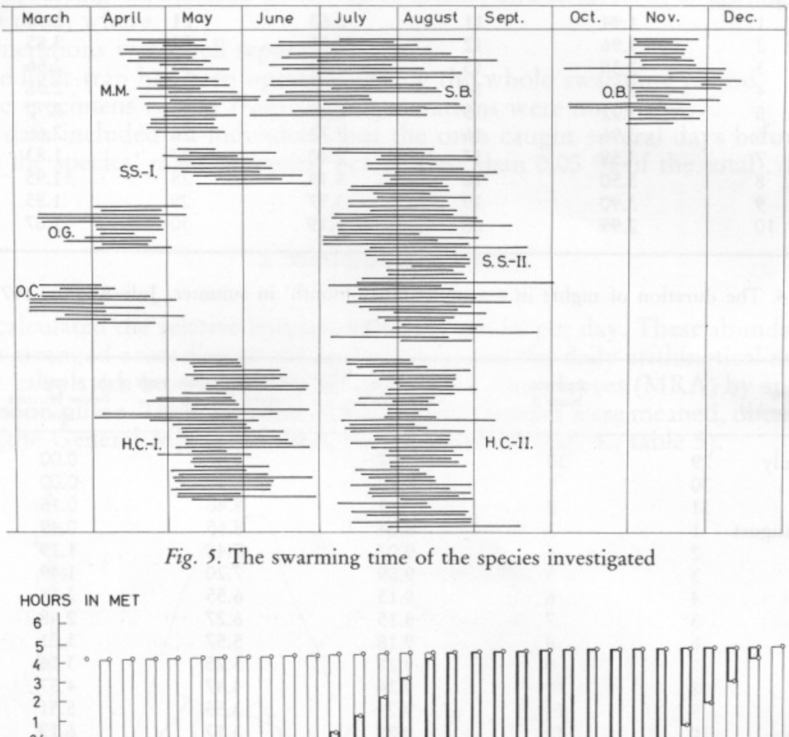


Fig. 5. The swarming time of the species investigated

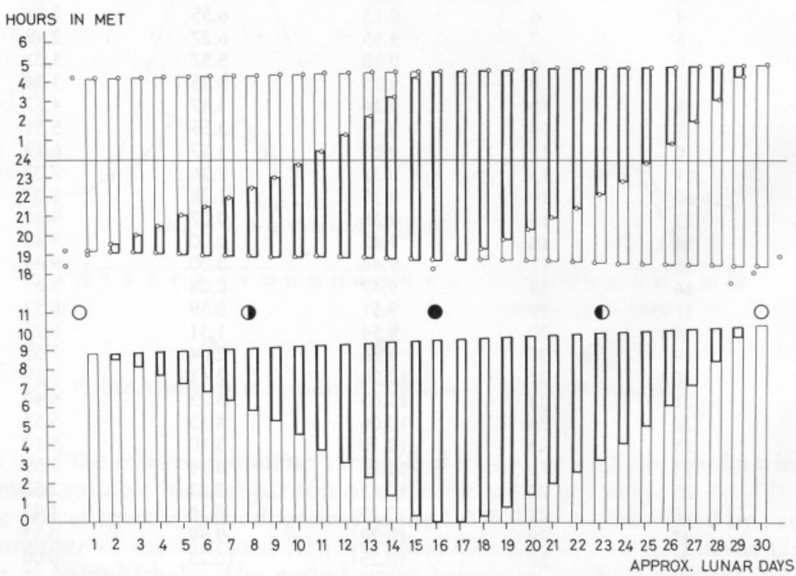


Fig. 6. The duration of nights and times during a night, when the Moon is above horizon

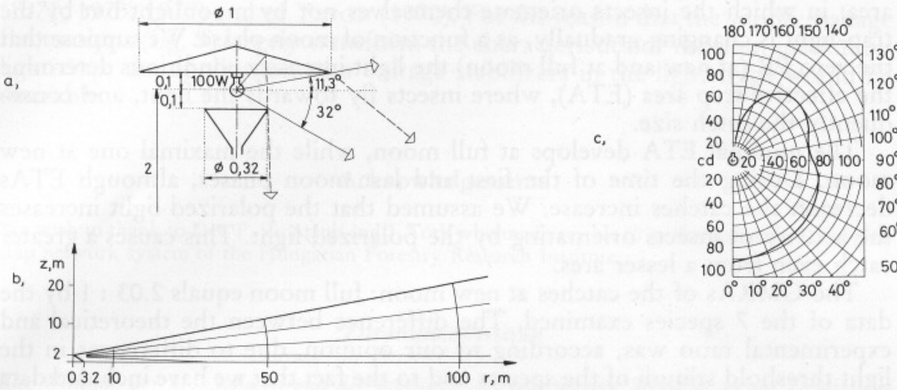


Fig. 7. The optical behavior of a Jermy-type light-trap. a = the beam of direct and reflected light; b = the direct illuminated space; c = the light-distribution curve of an argon-filled 100 watt incandescent lamp

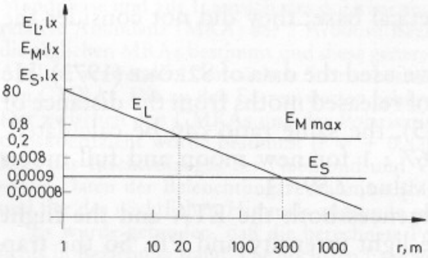


Fig. 8. The components of illumination in the neighbourhood of a light-trap

respectively at new moon, altering between these extremes during the moon cycle (Appendix, equs. 2–4).

According to equs. (5), (6) and (7) of Appendix, the ratio of the GMRAs of the insects caught at new moon to that of at full moon equals 2.60 : 1, supposing the Moon to be at zenith.

If we take into account the latitude of Hungary and the month, (in our example: August, 1977), this has to be modified, and equals 2.26 : 1. Our empirical data based on the 7 species mentioned, showed a ratio of 2.03 : 1.

4 Discussion

The period time of 14.5 d derived from the power spectra data was related to the PR of the moonlight. The light-traps caught indeed the highest numbers at the first and at the last quarter of the Moon when the PR was the highest. The correlation we assumed proved to be strong ($r = +0.87$) and significant ($p < 0.05$). Our results agree with that of NEMEC (1971). Although the author mentioned did not take into account the effects of the moonlight polarization but from his figures it could be seen that the highest catches have been observed at new moon as well as during the first and the last quarters.

From the period time of 30 d we conclude that the light intensity has a modifying effect on the catches. During consecutive nights, the diameter of the area, in which the insects orientate themselves not by moonlight but by the trap-light is changing gradually, as a function of moon phase. We suppose that the zero PR (at new and at full moon) the light intensity conditions determine the effective trap area (ETA), where insects fly towards the light, and consequently the catch size.

The minimal ETA develops at full moon, while the maximal one at new moon. During the time of the first and last moon phases, although ETAs decrease, the catches increase. We assumed that the polarized light increases the activity of insects orientating by the polarized light. This causes a greater catch even from a lesser ares.

The GMRAs of the catches at new moon: full moon equals 2.03 : 1 by the data of the 7 species examined. The difference between the theoretical and experimental ratio was, according to our opinion, due to differences in the light threshold stimuli of the species and to the fact that we have included data also from other months than August, i.e. the base period of our theoretical considerations.

Harstack, Hollingsworth, Ridgway and Hunt (1971) calculated the probability of recapture of released moths vs. distance. Their results were similar to ours, albeit on different theoretical base; they did not consider the effects of moonlight.

For testing our eq. (5) in the practice we used the data of Szeöke (1973). He reported a ratio of 3 : 1 for the recapture of released moths from the distance of 50 and 100 m apart. If we use the eq. (5), the same ratio can be calculated. Williams (1940) reported a ratio of 2.67 : 1 for new moon and full moon trapping conditions. This is near to our value, 2.59 : 1.

We conclude that the moonlight influences both the ETA and the flight activity of the insects by changes in the light intensity and PR. So the trap catches vary as a function of the moon phase. It seems to be demonstrated, further, that the insects flying at night utilize the polarized moonlight for orientation.

To improve the knowledge of the modifying effect of the light intensity conditions near the trap, the light threshold stimuli for the most important pest species should be determined. For this we suggest to use the methods of Agee

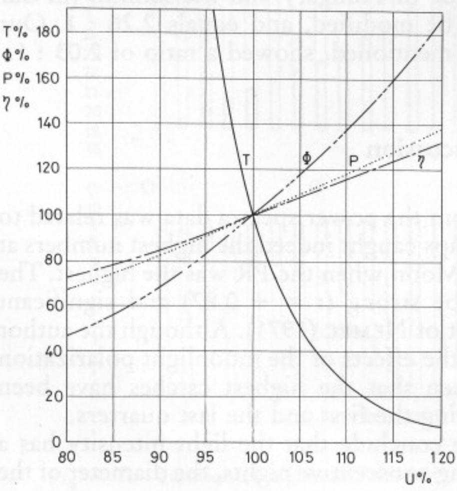


Fig. 9. The changes of some characteristics of an incandescent lamp as a function of the supply voltage. T = average life time, Φ = luminous flux, P = power required, η = luminous efficiency, U = working voltage

(1971, 1973, 1977) and of YINON (1970). For the reason that the supply voltage fluctuations (fig. 9) largely transform the characteristics of the illumination by light-trap, the application of a voltage stabilizers in the light-traps would be desirable.

Acknowledgements

We wish to thank to Drs. P. Szontágh and J. Tóth who made avaible to us the material of the light-trap network system of the Hungarian Forestry Research Institute.

Zusammenfassung

Zur Wirkung der Mondphasen und der Intensität des polarisierten Mondlichtes auf Lichtfallen-Fänge

Fünf Lepidopteren- und zwei Coleopteren-Arten mit insgesamt 55 003 Individuen, die während 14 Jahren in 20 auf forst- und landwirtschaftlichen Flächen in Ungarn verteilten Lichtfallen gefangen worden waren, wurden daraufhin untersucht, ob ihr Auftreten Beziehungen zur Mondphase und zur Intensität des polarisierten Mondlichtes erkennen läßt. Es wurde die mittlere relative Abundanz (MRA) der 7 Arten in Beziehung zur Mondphase berechnet. Sodann wurden die täglichen MRAs bestimmt und diese generellen MRAs (GMRAs) als Grundlage für die weitere Analyse verwendet. Der nächste Schritt bestand in der Berechnung der Mächtigkeitsspektren aus den GMRAs. Die zu den Extremwerten gehörenden Perioden betrugen 30, 14,5, 10, 7,4 und 3,3 d. Der zwischen den GMRAs und der Polarisationsrate (PR) des Mondlichtes bestehende Korrelationskoeffizient wurde bestimmt ($r = +0{,}87$). Zusammen mit diesen wurden die theoretischen RAs des Insektenfanges bei Neumond und Vollmond berechnet, wobei Probabilitätsmethoden sowie Daten der Beleuchtungsverhältnisse (Lichtemission) der JERMY-Lichtfallen des Mondes und der des nächtlichen Himmels zugrunde gelegt wurden.

Es wurde gefunden, daß die berechnete Periode von 14,5 d zur Polarisationsrate des Mondlichts in Beziehung stand. Die höchsten Fangwerte entsprachen den maximalen Polarisationsraten. Aus der 30-Tagesperiode wurde abgeleitet, daß die Lichtintensität modifizierende Wirkung besitzt. Bei Neumond und Vollmond (beide Phasen emittieren unpolarisiertes Licht) wurde die Zahl der gefangenen Insekten von den Lichtverhältnissen in der Fallenumgebung beeinflußt, die außerdem auch die Entfernung der Fallenwirkung bestimmten. Nach alledem beeinflußt das Mondlicht die Ausdehnung sowohl des Fangareals als auch der Flugaktivität der Insekten auf Grund der zyklischen Veränderungen der Intensität und Polarisationsrate. Somit wird die Zahl der gefangenen Insekten vom Mondzyklus beeinflußt.

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Appendix

At a distance of r from the light-trap, the resulting illumination E will be:

$$E = E_L + E_M + E_S = I.r^{-2} + L_o.L_z + 0.0009 \text{ luxes} \tag{1}$$

where
- E_L is the illumination originating from the light-trap,
- E_M is the illumination originating from the Moon,
- E_S is the illumination originating from the night sky,
- I is the illuminating intensity in candelas of the light-trap's lamp,
- r is the distance from the light-trap in meters,
- L_o is the relative brightness of the Moon (see table 1.) at the zenith in units of 0.25 luxes, as a function of moon phases,
- L_z is a smoothing factor, associated with the Moon's zenith distance at the observer.

N. B. The full moon generates 0.25 luxes illumination at the zenith. The night sky without moonlight and any artifical 'man made' illumination reaches the Earth's surface an amount of 0.0009 luxes as a sum in clear conditions.
A 100 watts argon filled bulb emits 80 candelas of illuminating intensity.

Denoting the radius of a circle with r_o, the points located around the circumference of this circle correspond to the condition that illumination originating from light-trap equals to the illumination generated by the actually moonlight itself, that is (fig. 10):

$$E_L = E_M + E_S \tag{2}$$

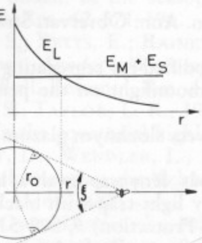

Fig. 10. To understand the probability meditations

At new moon in the zenith $L_o = L_z = O$, hence from eq. (2) yields:

$$r_o = r_{o\,max} = \sqrt{\frac{I}{0.0009}} = \sqrt{\frac{80}{0.0009}} = 298.14 \approx 300 \text{ m} \tag{3}$$

At full moon in the zenith $L_o = 0.25$ and $L_z = 1$, hence from eq. (2):

$$r_o = r_{o\,min} = \sqrt{\frac{I}{0.25 \cdot 0.0009}} = \sqrt{\frac{80}{0.25 \cdot 0.0009}} = 17.86 \approx 20 \tag{4}$$

It is supposed that the insect located at a distance r, will fly in each direction of plane range with equal probability, if $r \geq r_o$. The probability that the insect will fly to ξ plane range determined by the tangents of a circle r_o, equals:

$$P(A) = \frac{\xi}{2\pi} = \frac{2 \text{ arc sin } (r_o/r)}{2\pi} = \frac{1}{\pi} \text{ arc sin } (r_o/r) \tag{5}$$

For an insect located at circumference of circle of $r = r_o$ radius, applying the eq. (5), it is obtained that one will fly into direction of light-trap with a probability of 0.5. The r_o is a function of time, furthermore at a time moment $r_o \leq r \leq r_{o\,max}$.

Introducing a new variable $x = (r_o/r)$, and we calculate for a defined time moment the average probability for a plane range of which are from $r = r_o < r_{o\,max}$ to $r = r_{o\,max}$:

$$\hat{P}(A) = \frac{1}{1 - \frac{r_o}{r_{o\,max}}} \cdot \frac{1}{\pi} \cdot \int_{\frac{r_o}{r_{o\,max}}}^{1} \text{arc sin } x \, dx =$$

$$= \frac{1}{1 - \frac{r_o}{r_{o\,max}}} \cdot \frac{1}{\pi} \cdot \Big[x \cdot \text{arc sin } x + \sqrt{1 - x^2} \Big]_{\frac{r_o}{r_{o\,max}}}^{1} \tag{6}$$

At full moon $r_o = r_{o\,min}$, this taking into eq. (6) furthermore, considering eqs. (3) and (4), $\hat{P}(A) = 0.1926$ is obtained. In such a way, we can have a proportion of probalities, i.e. the mean abundances related to new moon and full moon:

$$\frac{P(A)}{\hat{P}(A)} = \frac{0.5}{0.1926} = 2.59 \approx 2.6 \tag{7}$$

For the astronomical calculation of relative brightness of the Moon as a function of zenith distance, are used the following auxiliary equations:

$$L_z = L_o \cdot e^{-\left(\frac{1}{\cos z} - 1\right)} \tag{8}$$

$$\cos z = \sin \varphi \cdot \sin \delta + \cos \varphi \cdot \cos \delta \cdot \cos t \tag{9}$$

$$t = T_{UT} \cdot k + s_o + \lambda - \alpha \tag{10}$$

where z is the zenith distance of the Moon at moment and site of observation,
L_o is the relative birghtness of the Moon (see table 1) at the zenith in units of 0.25 luxes, as a function of moon phases, at time of observation,
φ and λ are the geographic latitude and longitude of measuring site respectively,
δ and α are the declination and right ascension of the Moon respectively at the observation time,
T_{UT} is the Universal Time (= Greenwich Mean Time) of the oberservation,
t is the hour angle of the Moon by eq. (10),
k is a conversion factor of mean time into sideral one,
s_o is the sideral time at $T_{UT} = 0^h$ at $\lambda = 0°$ (Greenwich).

The eq. (8) is related only to $0° < z \leq 75°$ interval as a good approximation; for a greater zenith distance as an example the Table of Bemporad (1904) is accepted.

It is to be noted that the values of s_o, α and δ can be taken from Astronomical Yearbooks (for example: The Nautical Almanac), although a method was elaborated by one of us (G. T.) the above values with the aid of electronic computers to be calculated economically without any Almanacs by knowing only of calender date of the observations (to be published elsewhere). By this point of view, ist is suitable to use for the evaluations of eqs. (8) to (10) with computers.

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Eur. J. Entomol. **109**: 29–34, 2012
http://www.eje.cz/scripts/viewabstract.php?abstract=1677
ISSN 1210-5759 (print), 1802-8829 (online)

The influence of polarized moonlight and collecting distance on the catches of winter moth *Operophthera brumata* (Lepidoptera: Geometridae) by light traps

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Key words. Lepidoptera, Geometridae, winter moth, *Operophthera brumata*, light trap, polarized moonlight, collecting distance

Abstract. In this study we examine the relationship between the Lunar Phases and the efficiency of light traps in catching winter moth (*Operophthera brumata* Linnaeus, 1758). Our calculations are based on data collected by the Hungarian Forestry Light Trap Network at four sites from 1961 to 2008. We also tried to estimate the influence of polarized moonlight and collecting distance, which also depends on moonlight. Our investigations revealed that the catches were the greatest in the First and the Last Quarters, and the lowest at Full Moon. The reason for this is that the proportion of polarized moonlight in the different lunar quarters varies, with the catches highest when the proportion is greatest. Collecting distance has only a minor role.

INTRODUCTION

It has been known for a long time that nocturnal insects orientate by means of moonlight. As noted by ancient observations ever since Aristotle, nocturnal insects are also attracted to artificial light. Scientists took advantage of this and constructed light traps. Among many other uses, light trap catches are useful in plant protection prognostics.

The majority of scientists working with light traps record a drop in the efficiency of the traps when there is a Full Moon, as against other lunar phases. Williams published fundamental studies in this field. According to Williams (1936), the following reasons might explain the smaller catches when there is a Full Moon: (1) Light from a lamp attracts moths from a smaller distance in a moonlit environment, or (2) Moths are less active in moonlit environments and so the active population available for a light trap to attract is smaller.

It is important to define and distinguish between the concepts of a theoretical and a true collecting distance (Nowinszky, 2008).

The theoretical collecting distance is the mean radius of the circle in the centre of which the trap is located and along the perimeter of which the illuminance caused by the artificial light source equals the illuminance of the environment.

The theoretical collecting distance depends on the luminous intensity of the artificial light source (candela), on the illuminance due to the Sun at dusk or dawn (the timing and length of twilights) and, over and above the illuminance caused by the nocturnal sky, on the periodically changing phase of the Moon. In recent decades, light pollution has had to be taken into account, the intensity of which may vary depending on the geographical position, season of the year or time of night.

The real collecting distance is influenced by the screening effect of the configuration of the terrain, objects, buildings and vegetation and presence of other light sources within the theoretical collecting distance. The real collecting distance also depends on the vagility (mobility), as well as the sensitivity of the insect species, which defines the maximum distance from which the insect can react to the light stimulus (Nowinszky, 2008).

The following authors explain the lower catches recorded when there is a Full Moon in terms of a shorter collecting distance: Bowden & Curch (1973), Vaishampayan & Shrivastava (1978), Vaishampayan & Verma (1982), Nag & Nath (1991). Shrivastava et al. (1987) also suggest that the lower catches of light traps when there is a Full Moon may be due to the stronger and brighter light of the Moon and a smaller collecting area, which are clearly physical phenomena.

On the other hand, the cited authors were living at a time when they did not have to consider the effect of light pollution. Recently we studied the effect of light pollution on the relationship between light trap catches of the European corn borer (*Ostrinia nubilalis* Hübner, 1796) and moonlight (Nowinszky & Puskás, 2009). In this study we were unable to detect any influence of either collecting distance or flight activity. In accordance with the theory of El-Ziady, however, we assumed that these moths fly at greater heights at Full Moon, although, in the absence of light traps operating at different altitudes, this could not be proved.

According to Edwards (1961), measurements of the activity of insects depend on two factors. One is the proportion of the population that is active and the other is the amount of time spent flying by those that are active.

Similarly, but with greater precision, we define flight activity as follows (Nowinszky, 2008). Flight activity is the ratio of the proportion of specimens actually flying within the real collecting distance and thus available to be caught by a trap and the length of time the insects spend flying compared to the duration of trapping. By available specimens we mean the ones within the real collecting distance that fly when the trap is operational. If we accept this definition, then flight activity can be expressed numerically, namely, as the percentage of the available specimens flying multiplied by the percentage of the time they spend flying. However, the total number of individuals available to be caught by a trap is never known and the length of time they spend flying impossible to measure.

If we intend to estimate the degree of activity by visual observations, we may also encounter difficulties. So it is no surprise that the opinions of scientists on the role of moonlight on flight activity are rather controversial.

According to Rézbányai-Reser (1989), on moonlit nights when the Moon is above the horizon, moths often settle close to a trap before falling into it. However, general conclusions should not be drawn based on this observation. If, for example, we try to record the number of moths resting on vegetation in the vicinity of a trap at a Full Moon with the help of a torch, we also need to do the same thing at the same time of night at a New Moon, when the weather conditions are similar. Only then could we state that moths are less active at a Full than a New Moon.

Győrfi (1948) attributes the much smaller numbers of insects caught by light traps at Full Moon to decreased activity. Nemec (1971) is of the view that moths are inactive at Full Moon. Persson (1974) found that moonlight had a more marked effect in decreasing the flight activity of females than males. The study of Bowden & Morris (1975) confirms the hypothesis, that insects are more active at Full Moon, because the catch is higher than that expected due to the decreased efficiency of the trap. Based on the results of their studies, Baker & Sadovy (1978), Baker (1979) and Sotthibandhu & Baker (1979) believe that moonlight cannot influence the collecting distance. Thus, in their view, light intensity moderates flight activity. On the other hand, the observations of Dufay (1964) contradict the theory that moonlight inhibits activity, as they record that nocturnal moths are attracted by car lights on moonlit nights and at Full Moon and although the numbers attracted to the lights decreases, it is never zero.

The cited authors examined the influence of activity only in the context of illuminance caused by the Moon and did not consider that the polarization of moonlight should be taken into account.

Research on the relationship between the numbers caught and the polarization of moonlight depends on proving that some insects orientate by polarized moonlight. In our earlier studies we pointed out that the high light trap catches in the First and Last Quarters can only be explained by the occurrence then of a higher ratio of polarized moonlight (Nowinszky et al., 1979; Nowinszky, 2008).

There is still no comprehensive answer to the dilemma of Williams (1936).

The winter moth (*Operophthera brumata* Linnaeus, 1758) flies from dusk (Szőcs, 1976) until midnight (Fenyves, 1960). Ambrus (1990) observed winter moths flying to light only from places very close to the light source. During pheromone trap experiments, Ambrus & Csóka (1988, 1989, 1992) found that one-third of marked adult winter moth males stayed within a 10 m radius even on the fourth day after marking. The longest distance they recorded a specimen flying to a trap was 70 m. Based on these results, they think it is highly probable that light traps only catch moths from the immediate vicinity, so predictions of larger distances are not reliable. They hold this view even though aware of the fact that in outbreak years light traps catch tens of thousands of this species.

Because of the great deal of uncertainty in the scientific literature we decided to examine the way moonlight affects the light trap catches of winter moth. To do this we primarily considered the information on the behaviour of the species published in the studies of the above-mentioned authors.

The winter moth *Operophthera brumata* Linnaeus, 1758 (Lepidoptera: Geometridae) is a univoltine, widely distributed Eurosiberian species that was also introduced into North America from Europe, with the first record from Nova Scotia in the 1950s and then the Pacific Northwest in the 1970s. It is a polyphagous species the larvae of which feed on many broadleaved trees and shrubs (*Quercus*, *Fagus*, *Carpinus*, *Populus*, *Salix*, *Acer*, *Prunus*, *Betula*, *Alnus*, *Crataegus*, *Malus*, etc.) and in Scotland they also feed and cause considerable damage to Sitka spruce, *Picea sitchensis* (Csóka, 1995). It is regularly one of the dominant species of the spring defoliator assemblages, and is a major defoliator of oaks in many countries in Europe (Csóka, 1995). In peak years the damage is recorded over tens of thousands of hectares in Hungary and the long term (1961–2009) average of the yearly damage is about 9,000 ha in Hungary (Hirka, 2009).

Cyclic outbreaks of winter moth occur in most of Europe, including Scandinavia. The outbreaks occur at 9–10 year interval (Leskó et al., 1999). Recently its outbreak range, most likely due to the climate change, has expanded to the north-east (Jepsen et al., 2008), therefore its importance will probably increase considerably in the near future. So it is important to monitor winter moth populations both from a theoretical and applied point of view.

Light traps are widely used in population studies of the winter moth. Although the wingless females are not caught, light trap catches can be used to provide damage forecasts (Leskó et al., 2008, 2009), but their reliability is dependent on an awareness of the environmental conditions that influence the catches.

TABLE 1. Theoretical collecting distance and polarized moonlight depending on lunar phase angles.

Lunar phase angles			Theoretical collecting distance (m)	Polarized moonlight %
186–174	±15	180° = New Moon	298.1	
174–162	–14	Waxing Crescent	298.1	
162–150	–13		298.1	3.563
150–138	–12		272.8	4.422
138–126	–11		178.6	5.365
126–114	–10		131.1	6.000
114–102	–9		104.4	6.324
102–90	–8	90° = First Quarter	81.6	6.576
90–78	–7		65.2	6.285
78–66	–6	Waxing Gibbous	53.7	5.788
66–54	–5		46.0	4.950
54–42	–4		39.1	3.687
42–30	–3		33.6	2.412
30–18	–2		28.9	–0.412
18–6	–1		24.6	–0.115
6–354	0	0° or 360° = Full Moon	21.1	0
354–342	1	Waning Gibbous	21.6	–1.115
342–330	2		24.8	–0.041
330–318	3		28.4	2.511
318–306	4		33.8	3.927
306–294	5		39.4	5.412
294–282	6		46.0	6.869
82–270	7	270° = Last Quarter	55.1	7.941
270–258	8		66.8	8.714
269–246	9	Waning Crescent	82.3	8.765
246–234	10		133.7	7.212
234–222	11		222.8	6.083
222–210	12		252.6	4.939
210–198	13		298.0	
198–186	14		298.0	
186–174	±15	180° = New Moon	298.0	

Notes: A few days after a New Moon, the Moon is visible again in the Waxing Crescent phase that lasts until the First Quarter. The Waxing Gibbous Moon occurs between the First Quarter and Full Moon. The Sun illuminates more than half of the Moon's surface during this period. The period between Full Moon and the Last Quarter is called the Waning Gibbous phase. The illuminated portion of the Moon goes down from 100% to 50% during this period. The Waning Crescent phase is the period between the Last Quarter and the next New Moon. The Sun illuminates less than half of the Moon during this period.

MATERIAL AND METHODS

To create lunar phase divisions, we downloaded temporal data on Full Moons from the website of the Astronomical Applications Department of the US Naval Observatory (http://aa.usno.navy.mil/cgi-bin/aap ap.pl). Data on the rising and setting of the Moon and lunar phases were downloaded from: http://aa.usno.navy.mil/cgi-bin/aa_pap.pl. We arranged data on the relative polarization of moonlight into phase angle divisions based on the study by Pellicori (1971).

Data on the illuminance of the environment were calculated using our own software. This software for TI 59 computers was developed by the late astronomer G. Tóth specifically for our joint work at that time (Nowinszky & Tóth, 1987). The software was transcribed for modern computers by M. Kiss. The software calculates the illumination in terms of lux of the Sun at dusk, the light of the Moon and the illuminance of a starry sky for any given geographical location, day and time, separately or summarized. It also considers cloudiness.

All our data on cloud cover were taken from the Annales of the Hungarian Meteorological Service. The data in these books are oktas of cloud cover (eighth part) recorded every 3 h.

In addition, data on light pollution were taken into consideration when calculating theoretical collecting distances. In our earlier work (Nowinszky, 2006, 2008), we estimated light pollution based on the study of Cinzano et al. (2001) and lunar illumination. For this study the average illumination at Full Moon and in the First Quarter were calculated. The theoretical collecting distance can be calculated using the following formula:

$$r_0 = \sqrt{\frac{I}{E_N+E_H+E_{CS}+E_F}}$$

where: r_0 = theoretical collecting distance, I = illuminance from the lamp [candela], E = the illuminance of the environment [lux], which is the light from the setting or rising Sun (E_N), Moon (E_H), starry sky (E_{CS}) and light pollution (E_F).

In the present study we did not include light pollution in our calculations, as of the available data on 28 adult broods only 8 were for years after 1982 and in the years before that light pollution is likely to have been quite moderate. We defined the concept of real collecting distance as the part of the theoretical collecting distance in which the catch is increasing.

As the proportion of polarized moonlight is highest in the First and the Last Quarters, we had to determine whether moths can see the Moon in these lunar phases in order to be able to examine the influence of polarized moonlight (Table 1). In the First Quarter they obviously can, as on these days the Moon is visible in the evening, but in the Last Quarter, in most cases only after midnight. Therefore, based on data on the rising and setting of the Moon in the period close to the Last Quarter, we

TABLE 2. The locality and geographical position of the light traps and the period over which they were operated.

Locality	Latitude	Longitude	Years of operation
Felsőtárkány	47.98N	20.43E	1961–2008
Répáshuta	48.04N	20.52E	1962–2008
Szentpéterfölde	46.61N	16.75E	1968–2008
Várgesztes	47.46N	18.38E	1962–2008

determined whether each flight occurred only if the Moon was above the horizon before midnight, the period when this species is active.

We processed the catches of winter moth in the database of the Forestry Light Trap Network for the period between 1961 and 2008. The 4 observation sites chosen were those where the traps have been working continuously for the longest time, which are: Felsőtárkány, Répáshuta, Szentpéterfölde and Várgesztes (Table 2). There are great differences in the numbers of specimens caught each year even by traps in the same locality. This may distort the results even if the number of specimens caught or derived relative catches are included in the calculations. To avoid this distortion, we only included the catches of traps that caught at least 500 specimens. In this way, we could at least work with specimen numbers of the same order of magnitude when calculating the relative catches.

We had a total of 838 catches of a total of 54 089 specimens from 28 broods available for analysis.

The observation data consists of the mean nightly catches of one trap. Only nights and hours when some winter moths were caught were included in the calculations, as our earlier studies indicated that although the Moon influences the efficiency of trapping, it never makes collecting impossible (Nowinszky, 2003).

For every night of the flight periods (UT = 0 h) we calculated phase angle data of the Moon at midnight. Of the 360 phase angle degrees of the full lunation we established 30 phase angle divisions. The phase angle division including that of a Full Moon (0° or 360°) and values 0 ± 6° was designated 0. Beginning from this group through the First Quarter until a New Moon, divisions were marked as –1, –2, –3, –4, –5, –6, –7, –8, –9, –10, –11, –12, –13 and –14. The next division is ± 15, including the New Moon. From the Full Moon through the Last Quarter in the direction of the New Moon divisions, were designated 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each division consists of 12 degrees (Nowinszky, 2003). These phase angle divisions can be related to the four quarters of lunation as follows: Full Moon (–2 to +2), Last Quarter (3 to 9), New Moon (10 to –10) and First Quarter (–9 to –3). The nights and hours of the periods under examination were all classed in these phase angle divisions.

Based on the number of specimens trapped, we calculated relative catch values by species and by broods. Relative catch (RC) is the ratio of the number of specimens caught in a given sample unit of time (1 h or 1 night) and the average number of specimens caught in the same time unit calculated for the whole brood. If the number of specimens trapped equals the average, the value of relative catch is one. We calculated three-point moving averages from the relative catch data.

The use of moving averages is justified whenever the independent variable is made up of data representing a wide range of values that are to be contracted into classes. This is because the dividing line between these classes is always drawn more or less arbitrarily. Besides, extreme values in two neighbouring classes of the independent variable are always closer to each other than they are to the middle value of their own class. Working with moving averages ensures a degree of continuity between the data of our arbitrarily established classes and, at least partially, eliminates the disturbing influence of other environmental factors not examined in a given context (Nowinszky, 2003).

We have sorted relative catch values into the proper phase angle divisions and averaged them. We depict the results and indicate the regression curve, its parameters and the significance levels in the figures.

Consequently, to examine the influence of polarized moonlight and the theoretical collecting distance on catch results we have divided lunation into two sections, one from New to Full Moon including the First Quarter (waning), and the other from Full to New Moon including the Last Quarter (waxing). This was important because in the First and the Last Quarters the distribution of both moonlight and its polarized proportion are asymmetrical.

We have previously associated the percentage value of the proportion of polarized moonlight with different phase angle divisions (Nowinszky et al., 1979).

With the help of our special software, we calculated environmental illumination values associated with the phase angle divisions and from these generated theoretical collecting distances. For these calculations we assumed an average cloud cover of 5 oktas.

In addition, for the waning and waxing section of each lunar month we analysed the correlation between the 3 point moving average of relative catch values and polarized moonlight. In the same way we examined the relationship between the 3 point moving average of relative catch values and the theoretical collecting distance. In every case we calculated significance levels for the correlation coefficients. The results were plotted on graphs.

RESULTS

In Fig. 1 the 3 point moving average of relative catch values as a function of lunar phases are depicted. The relationship between polarized moonlight and the catch is shown in Figs 2–3, while that of collecting efficiency and theoretical collecting distance in Figs 4–5.

For the sake of interpretation of our results we have calculated correlation coefficients for polarized moonlight and theoretical collecting distance. These are as follows:

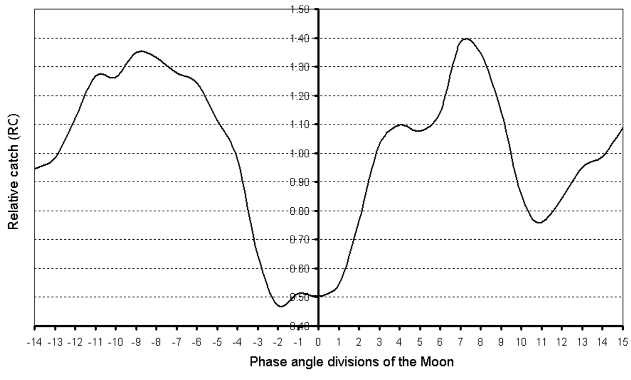

Fig. 1. The light trap catches of winter moth (*Operophthera brumata* L.) depending on the phases of the moon.

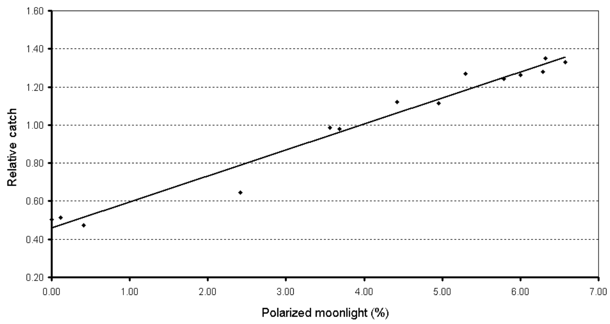

Fig. 2. The light trap catches of winter moth (*Operophthera brumata* L.) depending on polarized moonlight between New and Full Moon.

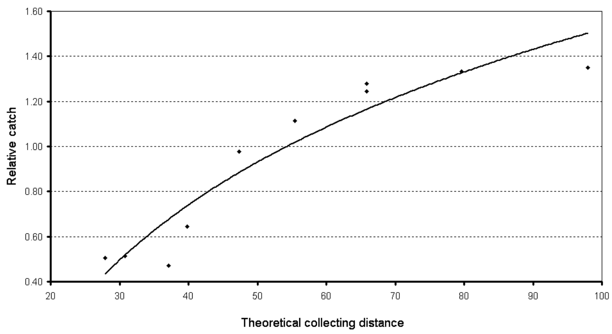

Fig. 4. The light trap catches of winter moth (*Operophthera brumata* L.) depending on the theoretical collecting distance between New and Full Moon.

In the waning section, when the ratio of polarized moonlight is between 0 and 5.788% and the theoretical collecting distance between 27.9 and 98 m, r = 0.9219 and P < 0.001; when the ratio of polarized moonlight is between 0–6.576% and the theoretical collecting distance between 27.9–313 m, r = 0.7708 and P < 0.01.

In the waxing section, polarized moonlight: 0–6083%, theoretical collecting distance: 27.9–124.3 m, r = 0.8307 and P < 0.05; polarized moonlight: 0–8.765%, theoretical collecting distance: 27.9–262.1 m, r = 0.899 and P < 0.001.

DISCUSSION

Fig. 1 shows two peaks in light trap catches of the winter moth (*Operophthera brumata* Linnaeus, 1758) in the vicinity of the First and Last Quarter. According to the studies of Szőcs (1976) and Fenyves (1960), this moth is only active from dusk until about midnight. Therefore, in the First Quarter, specimens can see the Moon every night, but in the Last Quarter, when most nights the Moon rises only after midnight, the catch maximum lacks an explanation. For this reason, we examined the time of the rising and setting of the Moon for each brood. We found that in the case of broods where there was a catch peak in the Last Quarter, the Moon was above the horizon before midnight, so the moths might have sensed polarized moonlight for some time. On the other hand, in the case of broods where there was no catch peak in the Last Quarter, the Moon only rose after midnight. Our results on the influence of polarized moonlight confirm the results of Nowinszky (2008), namely:

The reason for the catch minimum observed during Full Moon may not be a relatively strong illuminance caused by the Moon. Most insects take wing at dusk and the illuminance values recorded during different twilights are higher than those due to moonlight.

Based on the works of Dacke et al. (2003), Gál et al. (2006) and Hegedűs et al. (2006) we can presume that a high ratio of polarized moonlight presents more information for the orientation of insects than a smaller proportion of either positively or negatively polarized moonlight around the time of Full Moon. This may be the reason for the high catches in the First and last Quarters and low ones during a Full Moon.

The illuminance due to moonlight at a Full Moon does not generally decrease the flight activity of insects, as proposed by Williams (1936). The point is rather that at a Full Moon flight activity truly decreases, as compared to that during the First and the Last Quarters. This might be caused by the difference in the volume of polarized moonlight, the highest during the First and the Last Quarters and the lowest at a Full Moon.

Our new results indicate that catches are high when the proportion of polarized moonlight is high (Figs 2–3). Based on our study, we can complete and partially modify the presumption of Williams (1936), that strong moonlight decreases flight activity. Our results indicate that when a high proportion of moonlight is polarized, flight

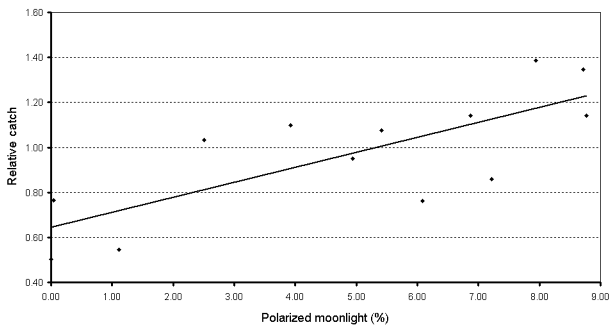

Fig. 3. The light trap catches of winter moth (*Operophthera brumata* L.) depending on polarized moonlight between Full and New Moon.

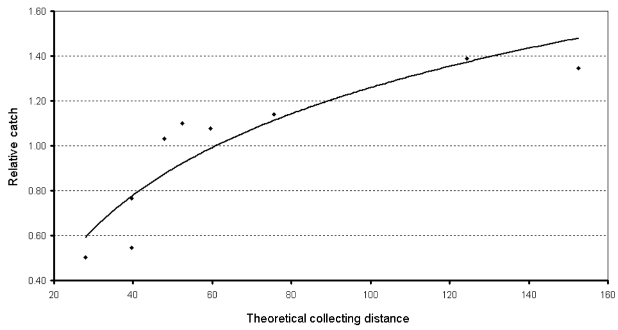

Fig. 5. The light trap catches of winter moth (*Operophthera brumata* L.) depending on the theoretical collecting distance between Full and New Moon.

activity increases but when there is a low level of polarization, as at a Full Moon, flight activity decreases.

Studies by Ambrus (1990) and Ambrus & Csóka (1988, 1992) show that winter moths fly to light traps from only a very short distance. Our results illustrated in Figs 4–5, plotting catch results as a function of theoretical collecting distance, seem to contradict this theory. According to these, an increase of catch may be observed up to 124 m from the trap. Therefore, we should consider this as the real collecting distance. On the other hand, in the chapter on results we have shown polarized moonlight to be closely and significantly related to the theoretical collecting distance. Thus, the contradiction with the results of the above mentioned authors may only be apparent. The increase in the catch might be due to the influence of polarized moonlight rather than collecting distance. This is also indicated by the very low and insignificant correlation ($r = 0.177$) between trap catches and collecting distance for a whole lunation.

In conclusion, light trap catches of winter moth are markedly influenced by changes in the level of polarized moonlight during the course of a lunar cycle.

ACKNOWLEDGEMENT. We thank M. Kiss, who transcribed our software for modern computer.

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Received July 5, 2010; revised and accepted September 2, 2011

Journal of Advanced Laboratory Research in Biology *www.sospublication.co.in*

ISSN 0976-7614

Volume V, Issue IV, August 2014 **Research Article**

Light-Trap Catch of *Lygus* Sp. (Heteroptera: Miridae) in Connection with the Polarized Moonlight, the Collecting Distance and the Staying of the Moon above the Horizon

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Abstract: The paper deals with connections between light trapping of *Lygus* sp. and the polarized moonlight, the collecting distance and the staying of the Moon above the horizon.

Keywords: *Lygus* sp., light-trap, Moon

1. Introduction and Review of literature

The influence of the moonlight on the catches of light-traps has been examined for decades. Williams (1936) has published fundamental studies in this field. Williams found that much fewer insects were collected at Full Moon compared to New Moon. He established two reasons, which may be responsible for lower catch levels at Full Moon periods:

(1) Increased moonlight reduces the flying activity of insects, consequently, a smaller rate of active population will be accessible for the light-trap, or
(2) The artificial light of the trap collects moths from a smaller area in the concurrent moonlit environment.

The past few decades did not come up with a satisfactory answer to that dilemma. The conclusions are contradictory and up to this day a good many questions have remained unclarified.

We refer to the most important studies only from the international literature, but we summarized our results until now, in detail in our two previous books (Nowinszky, 2003 and 2008).

Moonlight reduces the quantity of insects trapped. This view is shared by Mazochin-Porshnyakov (1954), Agee (1972), Bowden (1973b), Southwood (1978), Vaishampayan and Verma (1982), Nag and Nath (1991). The collecting distance as a function of changing moonlight has been calculated by a number of researchers (Dufay, 1964; Bowden, 1973a), Bowden and Church (1973). Bowden (1982) determined, by identical illumination, the collecting radius of three different lamps. Bowden and Morris (1975) always calculated for an identical area the volume of their catch made in the course of the lunar month in areas reduced by the effect of moonlight. The highs of the standardized data occurring in the proximity of the full moon also contradict the theory on the hindering effect of moonlight.

It is important to define and distinguish the concepts of a theoretical and a true collecting distance based on study of Nowinszky (2008). By theoretical collecting distance, we mean the radius of the circle in the centre of which the trap is located and along the perimeter of which the illumination caused by the artificial light source equals the illumination of the environment (Nowinszky *et al.*, 1979). The size of the theoretical collecting distance depends on the luminous intensity of the artificial light source (Candela). It depends on the different days and during the night of the year continuously changing illumination of the environment (time and span of twilights, the periodical changes of the Moon, light pollution) that may be different depending on geographical position, the season of the year or during one night (Nowinszky, 2008; Nowinszky and Puskás, 2013).

The length of a real collecting distance is influenced by the shielding effect of the configuration of the terrain, objects, buildings and vegetation and the presence of disturbing lights within the theoretical collecting distance.

Recently Cinzano and his colleagues discussed the nocturnal state of the sky in several studies. They even

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published a world atlas listing the most important data by countries. In this work, the authors consider artificial illumination above 10% of the natural background illumination as light pollution. Intensive light pollution can be noticed in Europe (Cinzano, 2001). Nowinszky (2006) published a summarizing study about the inhibitory effects of light pollution on light trapping. He noted that the collecting distance, belonging to New Moon and Full Moon, will moderate or totally disappear because of the light pollution. Other researchers are of the view that moonlight slackens the flight activity of insects.

By reason of their studies, Baker and his colleagues (Baker, 1979; Sothibandhu and Baker, 1979; Baker and Sadovy, 1878) believe that moonlight cannot have an influence on the collecting distance. The following observations by Dufay (1964) contradict the theory of moonlight inhibiting activity: Nocturnal moths can be seen in the light of car lights also on moonlit nights; at a Full Moon is collecting decreases, but does not stop; in case of lunar eclipses the catch is high when the Moon is obscured, although closely before and after it is low.
According to Edwards (1961) an estimate of the activity depends on two factors. One is the proportion of the population in an active phase and the other the amount of time spent in flight by these specimens.

We have defined the concept of flight activity as follows. Flight activity is the ratio of the proportion of specimens actually flying in the real collecting distance and thus available for the trap and the length of time the insects spend flying as compared to the duration of trapping. However, it is clear that the proportion of the total population, which currently flying in the air, and they spent time not measured (Nowinszky, 2008).

We published several new results regarding the effect of the Moon based on our own research (Nowinszky 2008; Nowinszky and Puskás, 2010, 2011, 2012 and 2013; Nowinszky *et al*., 2012a; Nowinszky *et al*., 2012b). Due to light pollution the difference between the theoretical and actual collecting distance has become basically balanced out. Consequently, the catch of certain species is practically equal at a Full Moon and at a New Moon. The actual collecting distance – just like the theoretical one – varies by light-trap types and taxa.

Due to light pollution the difference between the theoretical and actual collecting distance has become basically balanced out. Consequently, the catch of certain species is practically equal at a Full Moon and at a New Moon.

Generally, illumination by the Moon does not hamper the flight activity of insects. Besides the points made by Dufay (1964), the following facts prove this theory. It is a justified fact, that certain insects use polarized moonlight for their orientation. It is unthinkable that the activity of these insects would decrease when polarized moonlight is present in a high ratio. Our investigations have also proved the catch to be higher in case of higher polarization. In moonlit hours we observed a higher catch on more occasions than in hours without moonlight.

The relatively strong illumination by the Moon cannot be the reason for a catch minimum recorded on a Full Moon. Most insects start to fly in some kind of twilight and illumination at twilight is stronger by orders of magnitude than illuminated by moonlight.

Suction trap studies by Danthanarayana (1986) have not justified the decrease observable with light traps at a Full Moon. Observation is claiming that insects spend less time in flight during a Full Moon should be completed with similar observations for a New Moon. High standard scientific investigation is needed to study both periods.

Not even on the basis of the relative brightness of the Moon do we find a correction of the catch data acceptable, as this method does not consider the role of polarized moonlight and it is not effective throughout the whole lunar month (Nowinszky, 2008).

Our hypothesis is the following: In the absence of major light pollution, the reason for the low level of catch at a Full Moon might be the collecting distance that would be the shortest at this time, the fact that the insects rely on other sources of orientation because of the low polarization ration of moonlight, changed flight altitude [3] and, in the case of some species, the timing role of the Moon.

We examined in the current study how affect Moon the light trap catch of the *Lygus* species (Heteroptera: Miridae). Earlier we made similar examination with butterflies (Lepidoptera) and caddisflies (Trichoptera).
The majority of bug (Heteroptera) species can fly well onto the light (Kondorossy, 1997). However, several harmful species cannot be collected with light.

In Hungary till now from the light trap catch of bugs (Benedek and Jászainé, 1968; Jászainé 1964; Jászainé 1964-1966; Jászainé 1998; Rácz and Bernáth, 1993) published results, but these authors selected their topics only according to ecological and faunal viewpoints.

The species richness and abundance of the field bugs (Miridae), collected by the light traps, are important. Among these the most considerable ones are *Lygus rugulipennis* Poppius and *Lygus pratensis* Linnaeus, the individual number is high in both cases (Kondorossy, 1997).

Duviard (1974) investigated the effects of the moonlight among the foreign authors, but not in conjunction with our examined species. He collected the 79% of Belastomatidae species during two weeks around the full moon.

We mention the paper of Önder *et al*., (1984) from the new studies. They collected in large number the *Exolygus pratensis* (L.), *E. rugulspennis* (Popp.), *Adelphocoris lineolatus (Gz.)* és a *Trigonotylus ruficornis* (G.) species of Miridae in Turkey.

2. Material and Methods

The light source of the applied Jermy-type light-traps was a 100W normal white light electric bulb hanged under a metal cover (Ø: 1m) at 200 cm height above the ground. Most traps were operated without baffles and the insect material was led by a funnel under the bulb into a collecting jar. In each case chloroform was used as a killing agent. The traps were operated through every night during the season from April until October. An automatic on/off switching technique guaranteed the capture of both crepuscular and nocturnal insects. Turning on the light trap was 18 o'clock every night and off at 4 am (UT) (Nowinszky, 2003).

Data on the illumination of the environment were calculated using our own software. This software for TI 59 computers was developed by the late astronomer G. Tóth specifically for our joint work at that time (Nowinszky and Tóth, 1987). The software was transcribed for modern computers by M. Kiss. The software calculates the illumination in terms of lux of the Sun at dusk, the light of the Moon and the illumination of a starry sky for any given geographical location, day and time, separately or summarized. It also considers cloudiness.

The data of Moon rise and set were got from astronomical yearbooks. From these we counted the period of Moon stay above the horizon during all the investigated nights. The ratio of the percentage polarization of moonlight was taken over from our earlier work (No-winszy and Tóth, 1987).

All our data on cloud cover were taken from the Annals of the Hungarian Meteorological Service. The data in these books are oktas of cloud cover (eighth part) recorded every 3 h (Nowinszky and Puskás, 2013).

The light trap collection data of *Lygus* Genus, caught in Fejér County (Hungary, Europe) between 1980 and 1995, were processed in conjunction with the collection distance, the polarized moonlight and the length of stay over the horizon of the Moon.

The material of caught species has not been determined, but its deciding majority belonged to individuals of *Lygus rugulipennis* Poppius, 1911 (European Tamished Plant Bug) and *Lygus pratensis* Linnaeus, 1758 (Tamished Plant Bug). Altogether 43758 individuals and 2793 monitoring data were available for the investigation.

The names of light trap catch stations, their geographical coordinates and the years of collecting are shown in Table 1.

We have calculated the relative catch values of the number of specimens trapped by years. Basic data were the number of individuals caught by one trap in one night. The number of basic data exceeded the number of sampling nights because in most collecting years more light-traps operated synchronously. In order to compare the differing sampling data of the Genus, relative catching values were calculated from the number of individuals. For examined Genus the relative catch (RC) data were calculated for each sampling day per site per year. The RC was defined as the quotient of the number of individuals caught during a sampling time unit (1 night) per the average catch (number of individuals) within the same generation relating to the same time unit. For example, when the actual catch was equal to the average individual number captured in the same generation/swarming, the RC value was 1 (Nowinszky, 2003).

Towns and villages	Years	Geographical coordinates	
		Latitudes	Longitudes
Dunaföldvár	1980	46°47'29"N	18°55'45"E
Dunaújváros	1980	46°58'03"N	18°56'13"E
Gánt	1982	47°23'47"N	18°23'26"E
Nadap	1981-1990	47°15'44"N	18°56'13"E
Pusztaegres	1981-1995	46°53'16"N	18°37'01"E
Rácalmás	1984-1985	47°01'51"N	18°56'60"E
Ráckeresztúr	1991	47°16'60"N	18°49'76"E
Sárosd	1982 and 1989	47°02'50"N	18°39'12"E
Seregélyes	1986	47°06'77"N	18°34'80"E
Sukoró	1986	47°14'40"N	18°39'99"E
Székesfehérvár	1980 and 1981	47°17'45"N	18°19'59"E
Velence	1980	47°14'32"N	18°39'28"E
Zámoly	1983-1990	47°19'00"N	18°24'64"E

Table 1: Years of trapping and geographical coordinates of light-trap stations

Following we arranged the data on the catching distance, polarized moonlight and the duration of the Moon staying above the horizon in classes.

The data are plotted and regression equations were calculated for a relative catch of examining Genus and the parameters of the Moon data pairs.

3. Results and Discussion

Our results are shown in Fig. 1-6.

Our results proved that in the examined years, when the light pollution was not high yet, the increase of the collection distance increased the efficiency of the collection from New Moon to Full Moon and also from Full Moon to New Moon. In recent years, we demonstrated in our several studies the collection distance has minimal role, because of the light pollution in the latter decade.

The duration of the Moon staying above the horizon unambiguously causes the increase of the catch from New Moon to Full Moon and also from Full Moon to New Moon.

The proportion of polarized moonlight also leads to the increase in the catch both in the first quarter of the Moon and the last quarter of the Moon. These latter two results justify that the moonlight does not reduce the efficiency of the light trapping again together with the result of our earlier works.

Figure 1 Light-trap catch of the Lygus sp. as a function of the logarithm of the collecting distance, between New Moon and Full Moon (data of light-trap network in Fejér County, 1980-1995)

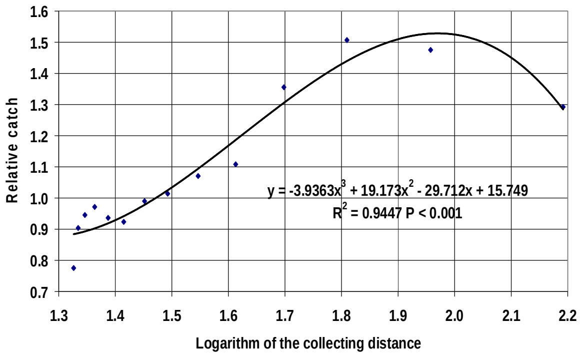


Figure 2 Light-trap catch of the Lygus sp. as a function of the logarithm of the collecting distance, between Full Moon and New Moon (data of light-trap network in Fejér County, 1980-1995)

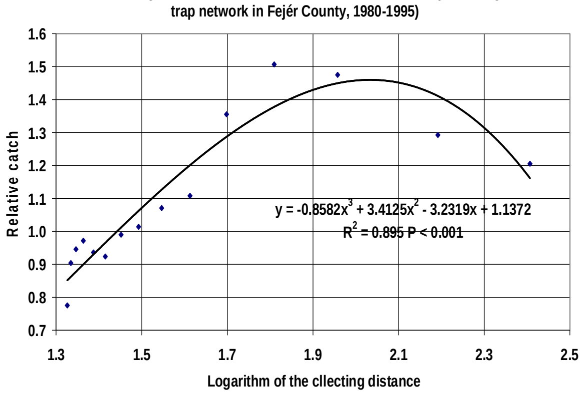


Figure 3 Light-trap catch of the Lygus sp. as a function of polarized moonlight, in the First Quarter (data of light-trap network of Fejér County, 1980-1995)

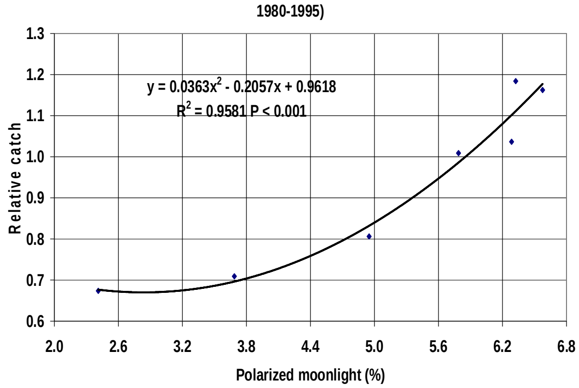


Figure 4 Light-trap catch of the Lygus sp. as a function of polarized moonlight, in the Last Quarter (data of light-trap network of Fejér County, 1980-1995)

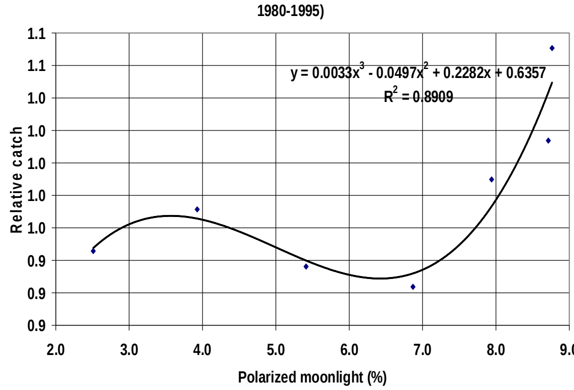


Figure 5 Light-trap catch of the Lygus sp. as a function of the Moon staying above the horizon, between New Moon and Full Moon (data of light-trap network of Fejér County, 1980-1995)

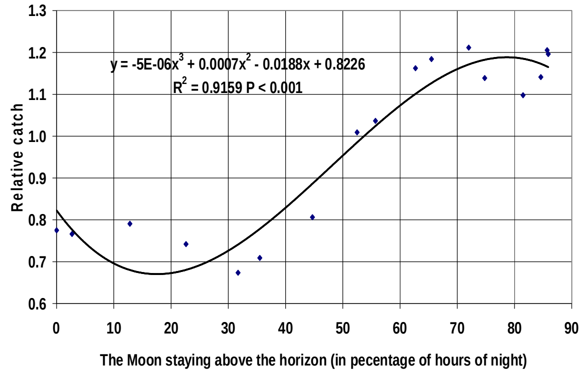
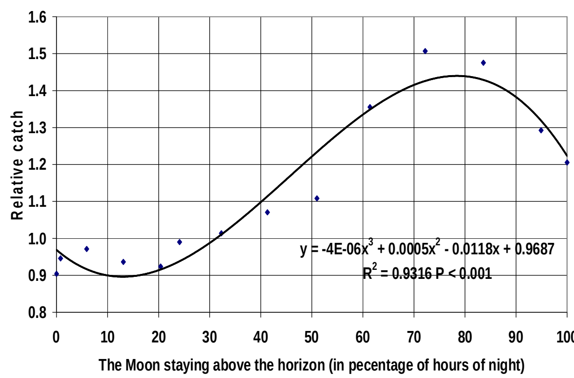


Figure 6 Light-trap catch of the Lygus sp. as a function of the Moon staying above the horizon, between Full Moon and New Moon (data of light-trap network of Fejér County, 1980-1995)



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Annals of Natural Sciences
Vol. 1(1), December 2015: 3-8
Journal's URL: http://www.crsdindia.com/ans.html
Email: crsdindia@gmail.com

e-ISSN: 2455-667X

Annals of Natural Sciences

ORIGINAL ARTICLE

Light-trap Catch of European Corn-borer (*Ostrinia nubilalis* Hübner) in Connection with the Polarized Moonlight and Geomagnetic H-Index

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ABSTRACT

This study deals with the change of light-trap catch of the European Corn-borer (Ostrinia nubilalis Hübner, 1796) in connection with the polarized moonlight and geomagnetic horizontal component (H-index). Our collection data of between 1993-2011 are from the material of Hungarian national light-trap network. These daily relative catch data were assigned to the daily values of geomagnetic field above 21,250 nanotesla (H-index). The numbers of specimens caught by generation were calculated relative catch values. We divided our relative catch data according to the Moon phase angle around the four Moon quarters (New Moon, First Quarter, Full Moon and Last Quarter). The daily relative catch data were assigned to the daily values of geomagnetic H-index in the vicinity of New Moon. We correlated the daily catch results pertaining to the daily values of geometric H-index values in vicinity of New Moon and polarized moonlight in vicinity of First Quarter and Last Quarter. The higher catch belongs to the higher H-index values in the New Moon period. In the vicinity of Full Moon there is no connection with the moonlight or H-index. In the First Quarter and the Last Quarter the increasing catch belongs to the higher polarized moonlight value.

Key words: *polarized moonlight, geomagnetic H-index, light-trap, European Corn-borer*

Received: 20th Nov. 2015, Revised: 28th Nov. 2015, Accepted: 29th Nov. 2015

How to cite this artle:
Nowinszky L. and Puskas J. (2015): Light-trap Catch of European Corn-borer (*Ostrinia nubilalis* Hübner) in Connection with the Polarized Moonlight and Geomagnetic H-Index. Annals of Natural Sciences, Vol. 1[1]: December, 2015: 3-8.

INTRODUCTION

It has been known for decades that various species of insects perceive geomagnetism and actually use it in their spatial orientation. A number of laboratory experiments and comprehensive studies are devoted to the physiological bases of perception and the ways of orientation (Jahn 1986, Wehner 1992).

Becker (1964) has found that certain species of Isotermes, Coleoptera, Diptera, Orthoptera and Hymenoptera are guided in their orientation by the natural magnetic field. Studying the *Heterotermes indicola* Wasmann (Isoptera: Rhinotermitidae), Becker & Gerisch (1973) found a stronger correlation between this activity and the vertical component of geomagnetism (Z) than with the values of the K index. Mletzko (1969) carried out his experiments with *Broscus cephalotes* L., *Carabus nemoralis* Müller and *Pterostichus vulgaris* L. (Coleoptera: Carabidae) on a 100 square meter asphalt coated area in the Moscow botanical garden. He placed the insects in the middle of the area and followed their movement with a compass. After some uncertainty, the insects were flying in a given direction with an accuracy of +5 °C in daylight and +60 °C at night. The author assumes that orientation is guided by geomagnetism. Pristavko and Karasov (1970) studying the few Spotted Ermel (*Yponomeuta rorrella* Hbn. Lepidoptera: Yponomeu-tidae), revealed a correlation between the C and ΣK values and the number of individuals caught. In a later study Pristavko and Karasov (1981) also established that at the time of magnetic storms ΣK had a greater influence on flying activity of the above species. Tshernyshev have discussed the results of laboratory and light trapping experiments with species of different orders of insects to reveal a connection between geomagnetism and certain life phenomena in a series of studies. He found a high positive correlation between the horizontal component and the number of trapped insects. Tshernyshev (1965) found that the number of light-trapped insects significantly rose at the time of magnetic perturbations. Later, however, he reported while light-trap catches of some Coleoptera and Lepidoptera species increased those of other Lepidoptera and Diptera species fell back during magnetic perturbations (Tshernyshev 1972). Tshernyshev (1966) found that the number of light-trapped beetles and bugs rose many times over at the time of geomagnetic storms in Turkmenia.

Iso-Ivari & Koponen (1976) studied the impact of geomagnetism on light trapping in the northernmost part of Finland. In their experiments they used the K index values measured in every three hours, as well as the ΣK and the δH values. A weak but significant correlation was found between the geomagnetic parameters and the number of specimens of the various orders of insects caught.

Tshernyshev and Danthanarayana (1998) used an infrared actograph to research the activity some species of Noctuidae (Scarce Bordered Straw *(Helicoverpa armigera* Hbn.), Native Budworm *(Helicoverpa punctigera* Wallengren) and Ruby Quaker Moth *(Orthosia rubescens* Walker)) in laboratory conditions. Examining the influence of the geomagnetic K index also in the context of the four typical lunar quarters (First Quarter, Full Moon, Last Quarter and New Moon), a significant negative correlation was found in the Last Quarter and a positive correlation in the other three. Moths are also disturbed by geomagnetic perturbations. 30 hours after perturbations the influence was still experienced.

Over the past decade**s** examinations of Baker and Mather (1982) and Baker (1987) have also confirmed that some Lepidoptera species, such as Large Yellow Underwing *(Noctua pronuba* L.) and Heart & Dart (*Agrotis exclamationis* L) are guided by both the Moon and geomagnetism in their orientation and they are even capable of integrating these two sources of information. At cloudy nights, the imagos of Large Yellow Underwing (*Noctua pronuba* L.) orientated with the help of geomagnetism. In this case, too, their preference lay with the direction they had chosen when getting their orientation by the Moon and the stars.

Using hourly data from the material of the Kecskemét fractionating light-trap, we have examined the light trapping of Fall Webworm (*Hyphantria cunea* Drury) in relationship with the horizontal component of the geomagnetic field strength (Kiss et al. 1981).

According to authors of recent publications (Srygley & Oliveira 2001; Samia et al. 2010) the orientation/navigation of moths at night may become not by the Moon or other celestial light sources, but many other phenomena such as geomagnetism.

We had stated before in our earlier work (Kiss et al. 1981) that the impact of geomagnetism on light-trap catches should not be studied without consideration to the prevalent illumination conditions.

In our current work we studied the effectiveness of light-trap catches of the European Corn-borer (*Ostrinia nubilalis* Hübner, 1796) in connection with the Moon phases and the horizontal component (H-index) of geomagnetic field strength.

MATERIAL

The average field strength of the Earth as a magnetic dipole is 33,000γ. [1γ = 10^{-5} Gauss = 10^{-9} Tesla = 1 nanotesla (nT)]. Geophysical literature uses γ as a unit.

The three-hour index ap and the daily indices Ap, Cp and C9 are directly related to the Kp **index**. In order to obtain a linear scale from Kp, **Bartels** **(**1957) gave the following table to derive a three-hour equivalent range, named ap index. This ap index is made in such a way that at a station at about dipole latitude 50 degrees, ap may be regarded as the range of the most disturbed of the two horizontal field components, expressed in the unit of 2nT. The daily index Ap is obtained by averaging the eight values of ap for each day.

In order to replace the somewhat subjective index Ci, the Cp index - the planetary daily character figure - was developed. Cp is a qualitative estimate of overall level of magnetic activity for the day determined from the daily sum of eight ap amplitudes. Cp ranges, in steps of one-tenth, from 0 (quiet) to 2.5 (disturbed).

Another index devised to express geomagnetic activity on the basis of the Cp index is the C9 index. It converts the 0 to 2.5 range of Cp to one digit between 0 and 9.

The simplest local characteristic of magnetic activity is the character number: C_i. The C_p planetary number of characters can be calculated for the total Earth from these numbers based on a few selected observing places, distributed evenly on the Earth.

The three-hour K index shows the activity of the variations created by the solar wind, which is measured in every 3 hours at all observatories. The K index may be a whole number from 0 up to 9 (Völgyesi 2002).

In our earlier study (Kiss et al. 1981) a correlation was found between the summarized values of horizontal component (values of H-index over 21,250 nT) change of the geomagnetic field-strength measured at night, and the amount of light-trap catches of Fall Webworm *(Hyphantria cunea* Drury). It was stated that the change of geomagnetic field strength significantly, but in the various moon phases differently influences the catches.

For our present work we downloaded the earth's magnetic x and y data from the World Data Centre for geomagnetism, Kyoto's website (http://wdc.kugi.kyoto-u.ac.jp/hyplt/). These values were calculated on the horizontal component of the formula, according to the advice of Mr. László Szabados's Tihany Geophysical Observatory):

$$H = \sqrt{x2 + y2}$$

In our study we used the data pertaining to the European Corn-borer (*Ostrinia nubilalis* Hbn.) from the material of the Hungarian national light-trap network in the years 1993-2011.

There are used Jermy-type light-traps in this network (Jermy 1961). The light source of traps was 100 W normal bulbs at 2 m height. We used chloroform as killing material. Between 1993 and 2011 there were successful trapping in 2,945 nights and the 66 traps caught altogether 172,557 specimens. Some of these light-traps were closed down or moved to other villages, while, on the other hand, new light-traps were set up even in recent years. The number of observation data was 28,222 because more traps were in operation during one night. Observing data means the catching of one trap in one night, regardless of the number of insects caught. The number of observing data exceeds the number of the nights because more light-traps have worked on a night. By observation data, we mean the catch of a species on one night at one observation post, regardless of the number of specimens, but now we did not calculate those nights when trapping was unsuccessful.

METHODS

Then the number of individuals of a given species in different places and years of observation is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same in every locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago (Nowinszky 2003).

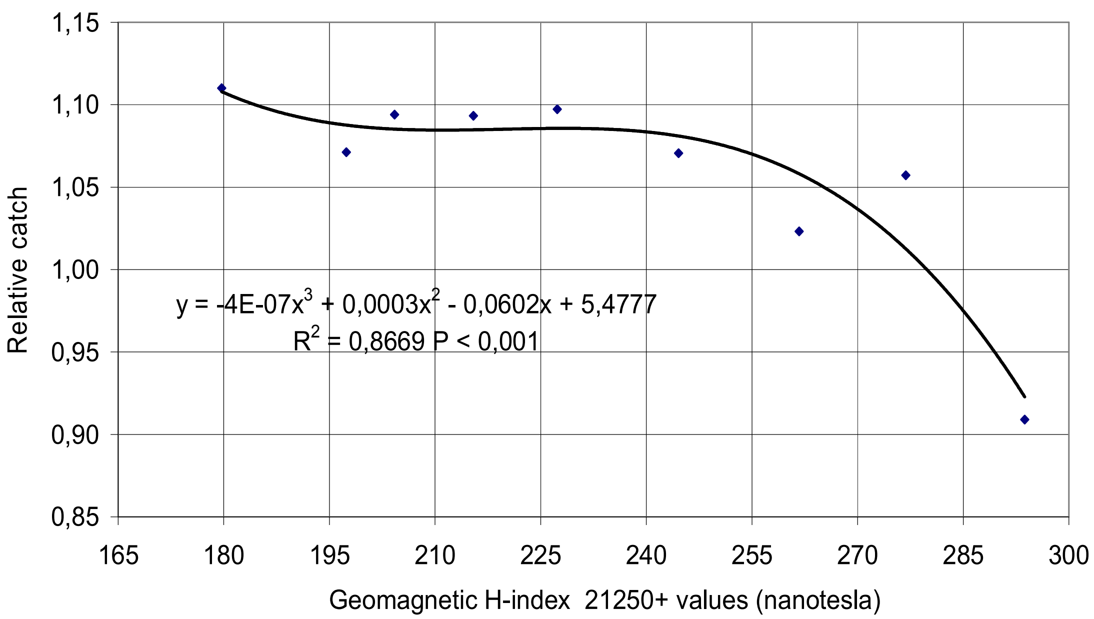
The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number of individuals per unit time of sampling, the number of generations divided by the influence of individuals. If the number of specimens taken from the average of the same, the relative value of catch: 1 (Nowinszky 2003).

We established the Moon phase angle groups according to around the four Moon quarters in the following way: In the swarming periods of the European Corn-borer (*Ostrinia nubilalis* Hbn.) we calculated the value of the Moon phase angle for the 24th hour (UT) of each night. Then we formed 30 groups of phase angles of the 360 phase angle values of the complete lunar month. The group containing the phase angle values found in the vicinity of a Full Moon (0°, or 360°) ± 6° is marked: 0. Proceeding from here through the First Quarter in the direction of the New Moon, the groups are marked as: -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. From the Full Moon through the Last Quarter in the direction of the new Moon the groups are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The group of phases containing the New Moon is marked: ± 15. Each group contains 12-phase angle value. The four typical Moon quarters contain the following phase angle groups: Full Moon (-2 — +2), Last Quarter (+3 — +9), New Moon (+10 — -10) and First Quarter (-9 — -3).
From the collection data pertaining to examined species we calculated relative catch values (RC) by swarming of individuals.
Relative catch values were placed according to the features of the given day, and then RC were summed up and averaged. The data are plotted and regression equations were calculated for relative catch of examined species and polarized moonlight in First Quarter, Full Moon and Last Quarter and H-index in all four Moon phases. We determined the regression equations, the significance levels which were shown in the Figures.
Then we arranged our catching data on the polarized moonlight in groups of First Quarter, Full Moon and Last Quarter and H-index in groups in all four moon phase groups.

RESULTS AND DISCUSSION

There can be found significant positive correlation (Figure 1) only in First Quarter and Last Quarter between the relative catch and the percentile values of polarized moonlight, but we were not able to justify a context in the period of a Full Moon.

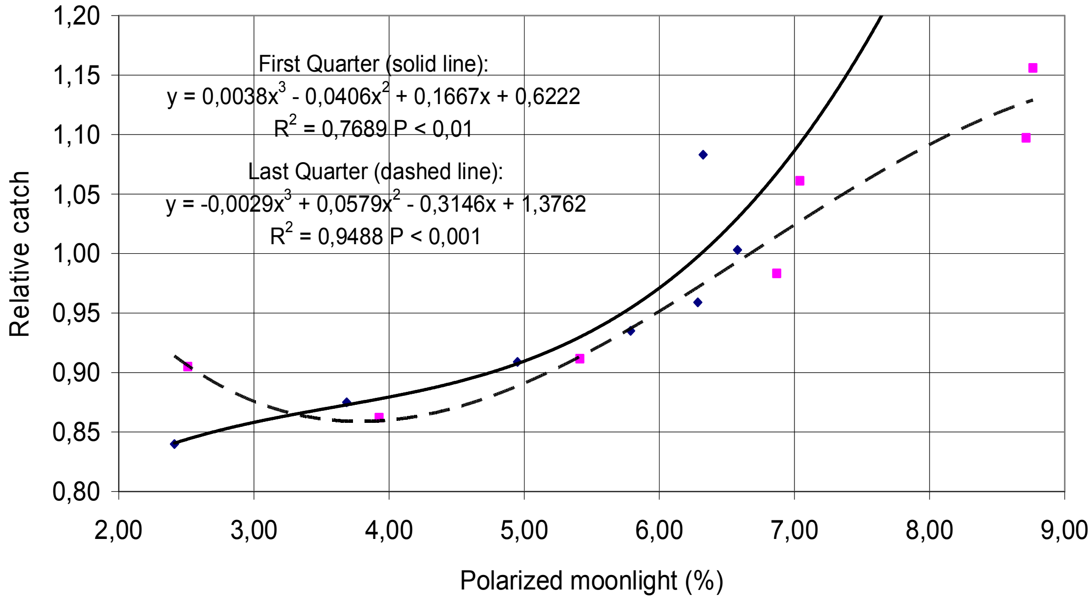
Figure 1 Light-trap catch of European Corn-borer (*Ostrinia nubilalis* Hübner) in connection with the geomagnetic H-index in vicinity of New Moon



This fact in these Moon Quarters attributes to the high polarized moonlight. This confirms the results of previous studies (Nowinszky et al., 1979; Danthanarayana and Dashper 1986; Nowinszky 2004; 2008; Nowinszky and Puskás 2010; 2011; Nowinszky et al., 2010) which have already established that the polarized moonlight helps the orientation of insects.

It appears that in the period of lunar month in which the presence of the Moon provides insects with orientation information at some time of the night, orientation is guided primarily by light stimulus even if the Moon is not over the horizon (Nowinszky, 2008).
At Full Moon, when the Moon stays almost all-night above the horizon, the moonlight is not polarized, but in an interval of ± 2.5 days, the polarization plane turns over from positive to negative (Nowinszky et al. 1979). However, this fact does not explain the behaviour of these moths in the vicinity of a Full Moon. Further researches are necessary to find the reason for this behaviour.
We didn't find any significant context in First Quarter, Last Quarter and at Full Moon between the relative catch and the values of horizontal component (H-index) of geomagnetic space strength. The Moon stays above the horizon in the longer or shorter periods of the night in these moon phases. Thus, it seems that in the presence of moonlight, the corn borer moths do not use the horizontal component of earth's magnetic field for their spatial orientation. However, in the vicinity of New Moon when there is no measurable moonlight, on the growing values of geomagnetic horizontal component, higher catch values can be experienced (Figure 2).

Figure 2 Light-trap catch of European Corn-borer (*Ostrinia nubilalis* Hbn.) in connection with the polarized moonlight at First Quarter and Last Quarter (Hungarian light-trap network, 1993-2011)



Growth of the geomagnetic field strength may generate an intensification of the flying activity of insects, yet, with the role of the light stimulus being of prime importance in orientation, collecting is even more effective. On the other hand, in the vicinity of the New Moon when at no time of the night cannot insects base their orientation on the Moon, it is presumable that intensifying geomagnetic field strength that increases the security of the orientation of insects will, as against light stimuli, receive an increasingly important role in the process of orientation (Nowinszky 2003).
Our results tinged our related knowledge longer with the topic. It was well known that insects use both the moonlight and the Earth's magnetism for their spatial orientation, but the researchers did not experience till now that this was used in different ways in different moon phases. It would be necessary to examine with a similar method the behaviour of other insect species in the future.

ACKNOWLEDGEMENT

We say thanks for Mr. László Szabados for his kind help in taking the earth's magnetic data and calculating the H-index.

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THE HOURLY DISTRIBUTION OF MOTH SPECIES CAUGHT BY A LIGHT-TRAP

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(Received 31th May 2006; accepted 15th Apr 2007)

Abstract. The present study discusses the hourly distributions of Macolepidoptera and Microlepidoptera species caught by a light-trap. The fractional type mercury vapour (125 W) light-trap had been operated by Mészáros, at Julianna-farm of the Plant Protection Institute between 1976 August and 1979 July. This trap was not in operation every night in this period, only periodically. It was in work during 57 nights in total. We summarized all caught specimen of all species hourly. In this way, we examined data of 66 species. We calculated percentages from hourly-totalized specimen number. We made a comparison between nightly distributions in caught species activity and Tshernishev's activity types.
Keywords: *: Lepidoptera, fractional catching, flying activity*

Introduction and survey of literature

The question of the distribution of the catch by light-trap in the course of a night has been a subject of research for several decades. Williams [1] used a fractionating light-trap in four years of examining flight activity as it was changing over the night. A glass-replacing device separated the catch into eight groups. Always adapted to the time of sunset and sunrise, the duration of light trapping varied. Accordingly, the periods of the individual phase of collecting also showed differences, but the fourth period always ended at midnight.

His sum total has revealed that he caught the largest number of insects in the first phase and the smallest in the seventh. Lepidoptera species flew to light in the highest number in the second, fifth and eight phases. However, the time of flight activity of nocturnal insects varies by species (Steward and Lam, [2], Hitchen et al., [3]).

There is significant difference among active flight periods of species even from the same family, according to the results of examinations (Wallner et al., [4]) in the near eastern part of Russia. According to these examinations the highest activity periods of moths are the following: gypsy moth (Lymantria dispar L.) between 11 p.m. and 1 a.m. The black arches (Lymantria monacha L.) between 3 a.m. and 5 a.m. and rosy gypsy moth (Lymantria mathura Moore) between 1 a.m. and 3 a.m. Ambrus and Csóka [5] determined that there is a difference in the light-trap periods of the two sexes of pine moth (Dendrolimus pini L.). The males fly to the light also during late night but females rather in the first part of the night to 22 and 23 hours. There is a relationship between activity and flight to light.

Tshernishev [6] claims that the flight activity of each species follows a special daily rhythm that usually corresponds to the time of flying to light. From this point of view, he establishes four basic types of insects:

- Flight of short duration tied exclusively to twilight, can never be observed by night (most Ephemeroptera, Corixida, Coleoptera, Diptera and Hepialida species),
- Species of a flight of longer duration. They start their flight later, reaching the peak in the evening. Some species fly all night (Trichoptera, Chironomida and a few east-African Ephemeroptera species),
- Intensive flight from sunset to close on sunrise, not letting up during the night (Tripuloidea and Ephemeroptera species),
- Typical night flight with a well discernible nocturnal peak (Ophionina, Lepidoptera, especially the species of Noctuidae and Brown chafer (Serica brunnea L.).

In the same work, the author lays down for a number of insect orders and for some significant species, the values of illumination expressed in lux characterizing the beginning and the peak of the activity. The activity of most Lepidoptera species increases from 0.01 lux to 0.001 lux but decreases by illumination below that value.

Járfás et al. made examinations in Hungary with fractional light-trap to determine the flight to the light of some harmful moths during night. They published the results in different years. We show these published results in Table 1.

In this present study, we show the flight activity of not only the significant harmful moths, but also the flight of those species, which can not be known in any publication in the Hungarian and international literature.

Material and method

A fractional type mercury vapour (125 W) light-trap was in work, operated by Mészáros, at Julianna-farm of the Plant Protection Institute between 1976 August and 1979 July. This trap was not in operation every night, but only periodically. It was in work during 57 nights. The working period was 12 hours in spring, summer and the beginning of autumn from 5 p.m. until 5 a.m., but from the second part of October between 4 p.m. and 4 a.m. (UT). Mészáros identified all Macrolepidoptera species and the harmful Microlepidoptera ones from the caught insect material. We used this data in this study.

We summarized hourly all caught specimen of all species. We did not examine later those species which number was 5 or less. In this way, we examined data of 66 species. We calculated percentages from the total hourly specimen number. We made comparison between nightly distributions in caught species activity and Tshernishev's activity types when the specimen number was high.

Results

The percentages of hourly caught specimen number of examined species are shown in Table 2. For each species, the total trapped individual number and the number of those nights when these species were caught by the light-trap is shown.

Discussion

The nightly activity of Macrolepidoptera species, except one, belongs to the 4th Tshernishev type. Types 1 and 2 do not occur. It is striking, although these species fly to the light during all night, light-traps did not catch before 7 p.m. in none of the months. Generally, the swarming peak can be found between 9 p.m. and midnight.

The activity types of Macrolepidoptera species belong to type 2 and 4. The frequency is almost the same in these types. Type 3 is infrequent, and type 1 can not be found as well.

There are differences between Tshernishev's types and type 3 and 4, because we found 2-2 activity peaks in the first part of the night or rather during the whole night (3a and 4a).

Table 2 shows those species, of which more than 5 individuals were caught, but their number was insufficient to determine nightly distribution. We also publish these results, because they prove that these species are active during the period.

Table 1. *The hourly distribution (%) of harmful moth species caught by light-trap according to Járfás et al.*

Species/hours	**18-19**	**19-20**	**20-21**	**21-22**	**22-23**	**23-24**	**0-1**	**1-2**	**2-3**	**3-4**	**References**
Hyponomeuta spp.	3,3	6,1	15,0	19,0	14,9	17,2	12,4	8,1	2,4	1,6	Járfás [7]
Pandemis dumetana Tr.	5,5	19,3	23,8	16,4	8,9	6,7	5,3	5,1	6,1	2,9	Járfás [7]
Pandemis heparana Schiff.	19,4	14,4	17,1	14,7	14,5	7,2	5,1	3,5	1,6	2,5	Járfás [7]
Pandemis ribeana Hbn.	8,8	6,0	17,6	23,5	6,0	8,8	14,7	8,8	2,9	2,9	Járfás [7]
Adoxophyes reticulana Hbn	8,1	6,4	7,2	5,2	7,8	15,1	17,7	15,7	12,2	4,6	Járfás [7]
Laspeyresia pomonella L.	5,3	8,9	15,6	14,0	14,5	14,2	11,1	8,2	4,6	3,6	Járfás [9]
Ostrinia nubilalis Hbn.	6,3	8,4	14,6	16,3	14,1	11,0	10,3	9,2	6,2	3,6	Járfás [8]
Loxostege sticticalis L.	4,0	8,6	10,0	15,0	10,9	12,2	12,0	10,3	8,0	9,0	Járfás and Viola [12]
Hyphantria cunea Drury	5,4	7,6	9,1	9,4	10,1	10,0	18,1	16,1	8,7	5,5	Járfás and Viola [11]
Scotia segetum Schiff.	10,1	15,9	12,8	12,0	12,0	11,2	11,5	7,9	4,9	1,7	Járfás [9]
Autographa gamma L.	14,6	15,8	13,5	10,8	12,9	9,7	9,0	7,9	4,4	1,4	Járfás et al. [10]

Table 2. *Light-trap catch (in %) of the examined species during night (UT)*

Species	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	0-1	1-2	2-3	3-4	4-5	Indi-viduals	Nights
Plutellidae															
Plutella maculipennis Curt. (4)				15,0	18,0	19,0	25,0	5,0	5,0	6,0	1,0			262	24
Gelechiidae															
Recurvaria nanella Hbn.						17,0	34,0		17,0	34,0				6	
Tortricidae															2
Tortrix viridana L. (4)			0,4	4,5	25,6	23,7	21,1	11,7	7,1	4,5	0,8	0,8		266	10
Pandemis heparana Schiff. (4)			2,2	8,9	28,9	33,3	15,6	6,7	2,2	2,2				45	8
Pandemis ribeana Hbn. (3)			14,3	9,5	14,3	14,3	9,5	14,3	9,5	9,5	4,8			21	7
Hedia nubiferana Haw. (4)			0,6	2,5	15,4	14,8	22,2	11,7	14,2	11,7	4,3	1,2	1,2	162	14
Spilonota ocellana F. (4)				14,3	35,7		28,6	7,1	7,1				7,1	14	2
Laspeyresia pomonella L.			16,7	16,7		16,7	16,7	16,7				16,7		6	4
Pyralidae															
Oncocera semirubella Scop.						16,7	33,3	16,7	16,7	16,7				6	5
Sitochroa verticalis L. (4)				6,7	13,3	6,7	40,0			20,0	6,7	6,7		15	7
Microlepidoptera spec. indet.		0,2	1,3	5,3	12,0	14,0	22,1	12,0	13,0	11,6	6,8	1,7	0,2	2802	39
Drepanidae															
Polyploca ridens Hbn. (2)			7,9	26,3	34,2	0,0	7,9	2,6	7,9	5,3	7,9			38	5
Asphalia ruficollis Schiff. (2)		7,1	50,0	19,0	14,3	2,4	4,8				2,4			42	4
Drepana binaria Hfn. (4)				4,8	14,3	42,9	23,8		9,5		4,8			21	8
Geometridae															
Chiasmia clathrata L. (4)					9,1	22,7	31,8	9,1	9,1	9,1	9,1			22	13
Biston stratarius Hfn. (2)		2,4	18,1	32,1	22,1	5,6	8,0	4,8	0,8	4,0	0,8	1,2		249	21
Apocheima hispidaria Schiff. (2)		4,4	40,0	24,4	22,2	4,4	2,2				2,2			45	8
Lycia hirtaria Cl. (4)		8,9	6,7	4,4		2,2	24,4	11,1	8,9	15,6	13,3	4,4		45	10
Lycia zonaria Schiff.		12,5					62,5		12,5	12,5				8	3
Biston betularia L.						14,3	14,3	28,6	14,3	28,6				7	6
Erannis marginaria Bkh.					33,3		33,3	11,1	11,1		11,1			9	5
Bapta temerata Schiff.					42,9	14,3	14,3	14,3		14,3				7	1

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EDITORIAL COMMUNICATION

In the previous volume of AEER 2007 from the article “Nowinszky-Mészáros-Puskás: The hourly distribution of moth species caught by a light trap” AEER 5(1): 103-107 Table 2 was missing.
We apologize for any inconvenience this may have caused.

Editorial Board

Table 2 *Light-trap catch (in %) of the examined species during night (UT)*

Species	*16-17*	*17-18*	*18-19*	*19-20*	*20-21*	*21-22*	*22-23*	*23-24*	*0-1*	*1-2*	*2-3*	*3-4*	*4-5*	*Individuals*	*Nights*
Plutellidae															
Plutella maculipennis Curt. (4)				15,0	18,0	19,0	25,0	5,0	5,0	6,0	1,0			262	24
Gelechiidae															
Recurvaria nanella Hbn.						17,0	34,0		17,0	34,0				6	
Tortricidae															2
Tortrix viridana L. (4)			0,4	4,5	25,6	23,7	21,1	11,7	7,1	4,5	0,8	0,8		266	10
Pandemis heparana Schiff. (4)			2,2	8,9	28,9	33,3	15,6	6,7	2,2	2,2				45	8
Pandemis ribeana Hbn. (3)			14,3	9,5	14,3	14,3	9,5	14,3	9,5	9,5	4,8			21	7
Hedia nubiferana Haw. (4)			0,6	2,5	15,4	14,8	22,2	11,7	14,2	11,7	4,3	1,2	1,2	162	14
Spilonota ocellana F. (4)				14,3	35,7		28,6	7,1	7,1				7,1	14	2
Laspeyresia pomonella L.			16,7	16,7		16,7	16,7	16,7				16,7		6	4
Pyralidae															
Oncocera semirubella Scop.						16,7	33,3	16,7	16,7	16,7				6	5
Sitochroa verticalis L. (4)				6,7	13,3	6,7	40,0			20,0	6,7	6,7		15	7
Microlepidoptera spec. indet.		0,2	1,3	5,3	12,0	14,0	22,1	12,0	13,0	11,6	6,8	1,7	0,2	2802	39
Drepanidae															
Polyploca ridens Hbn. (2)			7,9	26,3	34,2	0,0	7,9	2,6	7,9	5,3	7,9			38	5
Asphalia ruficollis Schiff. (2)		7,1	50,0	19,0	14,3	2,4	4,8				2,4			42	4
Drepana binaria Hfn. (4)				4,8	14,3	42,9	23,8		9,5		4,8			21	8
Geometridae															
Chiasmia clathrata L. (4)					9,1	22,7	31,8	9,1	9,1	9,1	9,1			22	13
Biston stratarius Hfn. (2)		2,4	18,1	32,1	22,1	5,6	8,0	4,8	0,8	4,0	0,8	1,2		249	21
Apocheima hispidaria Schiff. (2)		4,4	40,0	24,4	22,2	4,4	2,2				2,2			45	8
Lycia hirtaria Cl. (4)		8,9	6,7	4,4		2,2	24,4	11,1	8,9	15,6	13,3	4,4		45	10
Lycia zonaria Schiff.		12,5					62,5		12,5	12,5				8	3
Biston betularia L.						14,3	14,3	28,6	14,3	28,6				7	6
Erannis marginaria Bkh.					33,3		33,3	11,1	11,1		11,1			9	5
Bapta temerata Schiff.					42,9	14,3	14,3	14,3		14,3				7	1

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Table 2 (continuing) *Light-trap catch (in %) of the examined species during night (UT)*

Species	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	0-1	1-2	2-3	3-4	4-5	Individuals	Nights
Campaea margaritata L.			11,1	11,1	11,1	11,1	44,4	11,1						9	3
Siona lineata L.					14,3	14,3	42,9	14,3	14,3					7	4
Alsophila aescularia Schiff. (2)		12,5	22,5	27,5	12,5	5,0	7,5	12,5						40	3
Lygris pyraliata Schiff. (4)					7,1	10,7	32,1	21,4	14,3	7,1		7,1		28	2
Geometridae sp. indet.			0,9	3,5	10,6	15,0	15,9	14,2	13,3	15,9	4,4	5,3	0,9	113	15
Notodontidae															
Dicranura ulmi Schiff.				14,3		14,3		14,3	14,3	28,6	14,3			7	4
Notodonta tritophus Schiff.						30,0		10,0	50,0	10,0				10	1
Drymonia ruficornis Hfn. (4)			4,8	14,3	9,5	23,8	28,6	14,3	4,8					21	8
Noctuidae															
Apatele rumicis L. (4)			7,7	7,7	15,4	23,1	15,4	7,7	7,7	7,7	7,7			13	5
Minucia lunaris Schiff. (4)				7,1	14,2	28,6	35,7	7,1		7,1				14	8
Autographa gamma L. (4)				9,1		36,4	18,2	9,1		27,3				11	9
Brachinochia sphinx Hfn. (4)	3,1	6,3	3,1	0,0	6,3	9,4	15,6	28,1	18,8	3,1	3,1	3,1		32	4
Episema coeruleocephala L. (2)	5,0	30,0	25,0	5,0	5,0	15,0		5,0		5,0	5,0			20	1
Charanyca trigrammica Hfn.							50,0	16,7	16,7	16,7				6	4
Dicycla oo L. (4)						11,1	14,8	40,7	25,9	7,4				27	2
Cosmia trapezina L.							83,3	16,7						6	2
Agrochola lychnidis Schiff.			16,7	16,7	33,3	16,7	16,7							6	2
Amathes c-nigrum L. (4)				6,2	16,9	23,1	26,2	15,4	6,2	3,1	3,1			65	15
Agrochola litura L.		11,1		11,1	33,3	11,1	22,2		11,1					9	4
Eupsilia transversa Hfn. (3a)		5,9	17,6	5,9	5,9	11,8	11,8	5,9	17,6	5,9		11,8		17	3
Conistra vaccinii L. (3a)	2,3	25,6	9,3	11,6	7,0	16,3	20,9	4,7			2,3			43	13
Conistra vaupunctatum Esp.						12,5	25,0	25,0	12,5	25,0				8	5
Conistra erythrocephala Schiff. (3a)		7,1	7,1	28,4	7,1		28,4	14,2	7,1					14	4
Lithophane ornitopus Hfn. (2)		5,0	25,0	20,0	15,0	5,0	10,0	5,0		15,0				20	10
Valeria oleagina Schiff. (2)		5,6	11,2	16,7	28,0	16,7	5,6			5,6		11,2		18	5
Ammoconia caecimacula Schiff. (2)	3,0	36,4	21,2	12,1	6,1	9,1	3,0	3,0	6,1					33	11

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Table 2 (continuing) *Light-trap catch (in %) of the examined species during night (UT)*

Species	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	0-1	1-2	2-3	3-4	4-5	Individuals	Nights
Apamea anceps Schiff. (3)			10,0	13,3	16,7	13,3	10,0	13,3	13,3	6,7	3,3			30	6
Procus (Oligia) Hbn. (4a)					31,8	18,2	18,2	9,1	9,1	4,5	4,5		4,5	22	4
Discestra trifolii Hfn.					33,3		33,3	16,7				16,7		6	4
Harmodia luteago Schiff.					28,4	14,2	28,4	14,2	14,2					7	3
Mamestra brassicae Hfn.						33,3	33,3	16,7	16,7					6	3
Orthosia incerta Hfn. (4)		5,4		10,8	32,4	16,2	18,9	5,4		8,1		2,7		37	14
Orthosia gothica L. (4)		2,9	5,9	5,9	11,8	14,7	14,7	17,6	14,7	11,8				34	17
Orthosia cruda Schiff. (2)		5,7	15,6	18,0	10,7	5,7	10,7	9,8	7,4	11,5	3,3	1,6		122	12
Orthosia stabilis Schiff. (2)		6,9	4,2	18,1	20,8	9,7	12,5	9,7	1,4	8,3	5,6	2,8		72	15
Orthosia munda Schiff.		11,1	11,1	11,1		11,1	22,2			11,1	11,1	11,1		9	4
Xylomania conspicillaris L.				33,3			33,3		16,7	16,7				6	5
Perigrapha i-cinctum Schiff. (2)		7,1	7,1	21,3	21,3	21,3	7,1	7,1				7,1		14	5
Eugnorisma depuncta L. (4a)			13,8	10,3	17,2	3,4	10,3	13,8	17,2	6,9	6,9			29	2
Agrochola humilis Schiff. (4)		5,7	9,4	7,5	17,0	32,1	22,6		5,7					53	4
Cerastis rubricosa Schiff.			15,4	15,4	23,0	15,4		15,4				15,4		13	1
Scotia exclamationis L. (4)				1,9	14,8	5,6	29,6	20,4	14,8	11,1	1,9			54	12
Scotia segetum Schiff. (4)		6,7		13,3		13,3	13,3	26,7	20,0	6,7				15	10
Noctuidae spec. indet.			2,9	7,8	26,2	19,4	12,6	17,5	5,8	2,9	3,9		1,0	103	11
Lymantriidae															
Lymantria dispar L. (2)			12,5	25,0	12,5	18,8		18,8	6,3	6,3				16	3
Arctiidae															
Ocnogyna parasita Hbn.						12,5	50,0	12,5	25,0					8	2
Phragmatobia fuliginosa L.			10,0	10,0	50,0		10,0	10,0	10,0					10	5

Notes: The Tchernishev's activity type number can be seen after the species name in brackets. The 3a and 4a sample differs, there are two activity peaks in the first part of night, or rather during whole night.

THE BEGINNING AND THE END OF THE INSECTS' FLIGHT TOWARDS THE LIGHT ACCORDING TO DIFFERENT ENVIRONMENTAL LIGHTINGS

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(Received 12nd June 2008 ; accepted 23rd September 2008)

Abstract Many news bulletins found in the literature only consent themselves with the description of the night distribution of the trapped species not examining the beginning and the end of the insects' flight towards the light with the measurement of environmental lighting, expressed in lux. For this reason, we had examined the daily appearance of the first and last specimens of the species in the light trap concerning the exact lighting figures. We have used the hourly collection data of the fractionating light trap at the farm of Julianna in Nagykovácsi, belonging to the MTA Crop Protection Research Institute. With the help of our own computer programme we had counted the light coming from the sun, moon and from the starry sky, for every full hour separately and in total. We had given two lighting figures to every trapping data: we had counted the first minute of the first and the next hour of the given hour in lux within which the trapping had happened. Hereby, two lighting figures had become known during which the flight towards lighting had begun and end. The flight of 51 species towards the light happens when the total of the given hour concur in the duration of navigation twilight, of 26 species in the duration of sidereal twilight and of 7 species in the duration of night light. There were 2 species where the first imago was already captured during daylight. In the period of the quick reduction of lighting only the first specimens of the 14 species appear, accordingly: 4 from daylight to civil twilight, 4 from daylight to navigation twilight, 1 from sunset to navigation twilight and 4 species from civil twilight to sidereal twilight. The flight towards light ends in the case of 16 species after midnight during the night light, at 48 species during sidereal twilight and at 28 species at navigation twilight. The flight of only 3 species end when it is clearing up quicker within the given hour, from navigation twilight to daylight. Our results could stop a gap.
Key words: *Lepidoptera, flying threshold, lux*

Introduction and survey of literature

The majority of researchers do not examine the beginning and the end of the insects' flight towards the light with the measurement of environmental lighting, expressed in lux. Most of the authors were satisfied to describe the night distribution of the trapped insects. We only sporadically find records in the literature in reference to at how much lux lighting we can experience the start of certain insects' flight.

According to Mazorchin-Porsnjakov [1] the species of the chestnut cockchafer (Melolontha hippocastani Fabr.) start flying at 14 lux but can only be collected with light trap when lighting is decreased to 7-8 lux.

Tshernyshev [2] had carried out light-trap collectings and visual observations around Moscow. In reference to many insect classes and many important species, he also reported the associated measurement of lighting in lux to the start and maximum of activity.

- Ephemeroptera: *Ordella horaria* L. 4-0.005 lux;
- Homoptera: *Psylla betulae* L. 0.001 lux;
- Heteroptera: *Sigara falleni* Fieb.. *S. striata* L.. *S. praeusta* Fieb. 10 lux;
- Coleoptera: *Amara majuscula* Chd. 1-0.5 lux, *Hybius ater* DeGeer 0.01 lux, *Hydrobius fuscipes* L. 1 lux, *Cercyon quisquillus* L., *C. haemorrhoidalis* Fabr., *C. unipunctatus* L., *C. melanocephalus* L. 5-1 lux, *Serica brunnea* L. 0.001 lux, *Necrophorus vespillo* L. 10-0.1 lux, *Oxytellus rugosus* L. 1 lux, *Bledius opacus* Block. and *Heterocerus hispidulus* Kieff. 100-10 lux, *Aphodius rufus* Müll. *A. distinctus* Müll. 10-1 lux, but these last mentioned species had flew at 10.000 lux as well in May, daytime at 15-17 degrees Celsius.
- Hymenoptera: *Ophion luteus* L. 0.01 lux, *Lasius niger* L. 1000-50 lux;
- Diptera: *Culicoides pulicaris* L. and *C. grisescens* Edw. 10-0.03 lux;
- Trichoptera: *Psychomya pusilla* Fbr., *Leptocerus dissimilis* Steph., *L. nigriversosus* Retz., *Hydropsyche ornatula* McLeach., *Halesus interpunctatus* Zett. 0.1-0.01 lux;
- Lepidoptera: most of the species between 0.01-0.001 lux, but *Hepialus sylvinus* L., H. humuli L. 5-1 lux.

Skuhravý and Zumr [3] had studied the night activities of the black-arches moth (Lymantria monacha L.) in pine tree stand in the Czech Republic. Their flight towards light had began when lighting decreased to 1-3 lux. Through Dreisig's [4] studies in Denmark and Florida he had allocated that the beginning of activities of certain species are specific, usually starts between 1 and 0,003 lux at invariant lighting. If the period of twilight increases, the dispersion of the invariant rate will be higher. This is also influenced by the season besides the geographical latitude. He also gives data about the beginning of the flight of the Macrolepidoptera species related to the environmental lighting. These are the following in Denmark: Plusia gamma L. 1-12 lux, *Agrotis exclamationis* L. 0.4 lux, *Caradrina morpheus* Hfn. 0.15 lux, *Typhena pronuba* L. 0.9 lux, *Monima pulverulenta* Esp. 0.09 lux, *Cerapteryx graminis* L. 0.8 lux, *Deilephia porcellus* L. 1.4 lux, *Malacosoma castrensis* L. 0.5 lux. In Florida: *Plusia gamma* L. 0.8 lux, *Heliothis virescens* Fabr. 0.03 lux, *Spodoptera frugiperda* Smith 0.007 lux, *Anticarsia gemmalis* Hbn. 0.08 lux, *Mocis latipes* Guenee 0.009 lux, *Schinia nubila* Str. 0.15 lux, *Megalopyge opercularis* Abbot & Smith 0.02 lux, *Nystalea* sp. 0.004 lux.

As there are not too many data in literature about the beginning and the end of flight towards the environmental light that is given is lux, we have examined the day-by-day appearance of the first and last specimens of certain species using our domestically collected figures.

Material

At the Crop Protection Research Institute near Budapest, we had operated a fractionating light trap between 1976-1979 at the research plant of Julianna, in Nagykovácsi and the insects collected there had been separated into different flasks. The light trap had operated with a 125-watt HGL bulb. However, this light trap did not operate every night, only periodically, 57 times altogether but that time for 12 hours, in the spring and summer time, early in the autumn from 5 p.m. to 5 a.m. and in the second half of October from 4 p.m. to 4 a.m. (UT). These years the daylight saving time was not applied. Mészáros had defined and journalized from the collected insects the insect pests from all Macrolepidoptera and Microlepidoptera species. We had used the records of 160 Lepidoptera- and 1 Coleoptera species for our work.

The operation had taken part on the following days:

1976: 08. 26-27, 10. 06-07;

1977. 03.10-11, 03.14-15, 03.16-17, 03.17-18, 03.18-19, 03.19-20, 03.21-22, 03.22-23, 03.24-25, 03.28-29, 04.14-15, 04.18-19, 04.19-20, 04.20-21, 04.22-23, 04.26-27, 04.28-29, 05.04-05, 05.09-10, 05.12-13, 05.16-17, 05.19-20, 05.28-29, 05.30-31, 06.02-03, 06.06-07, 06.09-10, 06.13-14, 06.16-17, 06.21-22, 06.24-25, 06.28-29, 07.04-05, 07.12-13, 07.26-27, 07.27-28, 08.08-09, 09.06-07, 09.15-16, 09.22-23, 10.06-07, 10.13-14, 10.20-21, 10.2-28

1978. 09.18-19, 09.26-27, 11.02-03

1979. 03.22-23, 03.28-29, 05.10-11, 05.17-18, 05.25-26, 06.20-21, 06.22-23, 07.23-24.

We had counted the lighting data required for our examinations with the help of our own computer programme. György Tóth, astronomer – who unfortunately cannot be with us any longer – for a TI 59, established this programme. Computer, to be used in our common researches (Nowinszky and Tóth, [5]). This programme was adapted to a modern computer by Miklós Kiss, associate professor, for which hereby we would like to express our thanks.

The programme counts the daytime and twilight lighting from the sun to optional geographical place, day and time separately and in total, the light of the moon if it is over the horizon and the lighting coming from the starry sky, all these data in lux. It also takes the number of clouds into consideration when counting.

We had collected every data concerning all clouds from the yearbooks of the National Meteorological Organization. In these, data is recorded every 3 hours with causal explanation. We had applied the data to the related given hour and to the next 2 hours.

Methods

We have collected the hour of the capture of the first and last specimens of the trapped species from the light trap journal in reference to every night. We have counted the full lighting figures of these time periods. As, of course, the exact trapping time is unknown the lighting figures were counted in reference to a whole hour. We had given two lighting figures to every trapping data: we had counted the first minute of the first and the next hour of the given hour in lux, within which the trapping had happened. Hereby, two lighting figures had become known during which the flight towards lighting had begun and end.

By species, we had put the lux value pairs into order according to the first and last figures of trapping. Our figures were put into a table. We had placed those lighting value pairs into this table, in which the first specimen is already, the last still flew, also separated accordingly whether the trapping had happened before or after midnight.

Results

Table 1. contains the figures of 161 species. We had also aspired to include as many information as possible. To achieve this we had also given to every lux value the period of twilight or night, it belonged to. The abbreviations of these are the following: the numbers in italics show the trappings after midnight, * = only one figure apply to a given specimen, T/N = twilight or night hour, D = daylight, S = sunset, C = civil twilight, A = sidereal twilight, NS = the light of the night sky

Discussion

The beginning of flight towards the light at night happens at distinct lighting conditions in the case of certain species. These do not indicate lawfulness that should be linked to taxonomical rating. The flight of 50 species towards the light happens when the total of the given hour concur in the duration of navigation twilight, of 26 species in the duration of sidereal twilight and of 7 species in the duration of night light. There were 2 species where the first imago was already captured during daylight. In the period of the quick reduction of lighting only the first specimens of the 14 species appear, accordingly: 4 from daylight to civil twilight, 4 from daylight to navigation twilight, 1 from sunset to navigation twilight and 4 species from civil twilight to sidereal twilight.

The flight towards light ends in the case of 16 species after midnight during the night light, at 48 species during sidereal twilight and at 28 species at navigation twilight. The flight of only 3 species end when it is clearing up quicker within the given hour, from navigation twilight to daylight.

Although we only have a few results, many of these are often from one collection figure, we believe it is worth to share with our readers. On the one hand because we could not find any researches like this in the literature, which publish the flight peculiarities of so many species, on the other hand because those are also not from mass collection figures. Of course, our published results will be altered by our continuous observations but until then with their informative nature can stop a gap. We could get interesting informations for example from entomologists who should journalize the exact arrival time of the insects into the capturing sheet and should also measure the lighting related to it. The measuring instrument needed for this is fairly easy to access nowadays and although they are not occupied with, researches like this could help the entomological studies with very important and precise data.

Table 1. . *Beginning and ending of flight of Lepidoptera species before and after midnight in connection with the twilights*

Species	*Beginning and ending of flight (before midnight)*				*Ending of flight (before or after midnight)*			
	between				*between*			
Lepidoptera	*Lux*	*T/N*	*Lux*	*T/N*	*Lux*	*T/N*	*Lux*	*T/N*
Plutellidae								
Plutella maculipennis Curt.	79.22	C	0.1450	N	0.0019	A	0.0071	A
Gelechiidae								
Anarsia lineatella Zeller *	0.0384	N	0.0388	N				

Recurvaria leucatella Clerck.	0.0028	A	0.0031	A	*0.0987*	*N*	*1.821*	*C*
Recurvaria nanella Hbn.	0.0388	N	0.0391	N	0.0039	A	0.0029	A
Sitochroga verticalis L.	0.1450	N	0.1003	N	*0.0203*	*N*	*1.999*	*N*
Tortricidae								
Pandemis heparana Schiff.	1386.2	D	30.338	C	0.0017	A	0.0017	A
Pandemis ribeana Hbn.	1386.20	D	41.614	C	0.0717	N	0.0714	N
Argyrotaenia pulchellana Haw. *					*0.0396*	*N*	*0.0472*	*N*
Adoxophyes reticulana Hbn.	0.0388	N	0.0391	N	*0.0039*	*A*	*1.001*	*N*
Hedya nubiferana Haw.	649.680	D	2.5273	N	*0.0422*	*N*	*90.57*	*C*
Spilonota ocellana F.	12.6161	C	0.0114	N	*0.0019*	*A*	*0.0071*	*A*
Cydia pomonella L.	737.302	D	0.3745	N	*0.0276*	*N*	*186.47*	*C*
Tortrix viridana L. *	0.0604	N	0.0216	N				
Phycitidae								
Oncocera semirubella Scop.	0.0495	N	0.0453	N	*0.0012*	*A*	*0.0039*	*A*
Etiella zinckenella Tr.	0.0195	N	0.0178	N	0.0022	A	0.0031	A
Pyraustidae								
Ostrinia nubilalis Hbn.	0.0021	A	0.0021	A	*0.0045*	*A*	*0.0067*	*A*
Loxostege sticticalis L. *	0.0029	A	0.0028	A				
Evergestis extimalis Scop.	0.0708	N	0.0717	N	*0.0104*	*N*	*0.0086*	*A*
Evergestis frumentalis L.	0.0960	N	0.0495	N	0.0195	N	0.0178	N
Geometridae								
Alsophila aescularia Schiff.	346.480	C	0.0451	N	0.0005	NS	0.0005	NS
Aplocera plagiata L.	0.0101	A	0.0094	A	*0.0012*	*A*	*0.0012*	*A*
Operophthera brumata L.	0.0014	A	0.0014	A	*0.0368*	*N*	*0.0357*	*N*
Philereme vetulata Schiff.	30.3375	C	0.0279	N	0.0363	N	0.0165	N
Lygris pyraliata Schiff.	0.0495	N	0.0453	N	0.0111	N	0.0111	N
Cidaria fulvata L.	0.0165	N	0.0111	N	0.0021	A	0.0021	A
Xanthorrhoe fluctuata L. *	0.0008	NS	0.0004	NS				
Hydrelia flammeolaria Hfn. *	0.0025	A	0.0021	A				
Eupithecia centaureata Schiff. *	0.0717	N	0.0714	N				
Bapta temerata Schiff. *	0.0034	A	0.0008	NS				
Ennomos erosaria Schiff. *	0.1808	N	0.1385	N				
Colotois pennaria L. *					*0.0014*	*A*	*0.0012*	*A*
Crocallis elinguaria L. *	0.0008	NS	0.0008	NS				
Plagodis dolabraria L. *	0.0321	N	0.0346	N				
Macaria alternaria Hbn. *	0.0178	N	0.0164	N				
Chiasmia clathrata L.	0.8153	N	0.0004	NS	*0.8153*	*N*	*611.76*	
Erannis leucophaearia Schiff. *	0.0211	N	0.0026	A				
Erannis marginaria Bkh.	0.0332	N	0.0238	N	0.0005	NS	0.0005	NS
Apocheima hispidaria Schiff.	346.480	C	0.0451	N	0.0006	NS	0.0006	NS
Nyssia zonaria Schiff.	346.480	C	0.0451	N	*0.0010*	*A*	*0.0010*	*A*
Lycia hirtaria Cl.	2853.20	D	17.124	C	*0.0010*	*A*	*0.0010*	*A*
Biston stratarius Hfn.	346.480	C	0.0451	N	0.0008	NS	0.0008	NS
Biston betularius L.	0.0631	N	0.0009	NS	0.0425	N	110.41	C

Boarmia rhomboidaria Schiff.	32.504	C	0.0311	N	*0.0031*	*A*	*0.0048*	*A*
Boarmia cinctaria Schiff. *	0.1389	N	0.1569	N				
Biston arenaria Hfn.	0.0014	A	0.0006	NS	0.0007	NS	0.0007	NS
Ascotis selenaria Schiff. *	0.0128	N	0.0118	N				
Ectropis bistortata Goeze *					*0.0054*	*A*	*0.0063*	*A*
Ematurga atomaria L. *	0.0363	N	0.0040	A				
Siona lineata L.	0.0008	NS	0.0004	NS	0.0717	N	0.0714	N
Noctuidae								
Colocasia coryli L. *					*0.0840*	*N*	*0.0888*	*N*
Apatele rumicis L.	0.5266	N	0.0086	A	0.0006	NS	0.0003	NS
Euxoa temera Hb. *	0.1258	N	0.0228	A				
Euxoa obelisca Schiff.	0.0029	A	0.0028	A	*0.0070*	*A*	*0.0055*	*A*
Agrotis ypsilon Rott.	0.0960	N	0.0495	N	0.0015	A	0.0015	A
Scotia segetum Schiff.	32.5042	C	0.0311	N	*0.0086*	*A*	*0.0088*	*A*
Scotia exclamationis L.	2.5273	N	0.0034	A	*0.0857*	*N*	*0.5864*	*N*
Eugnorisma depuncta L. *	0.0134	N	0.0106	N				
Diarsia rubi View. *	0.0604	N	0.0216	N				
Xestia c-nigrum L.	46.006	C	0.0604	N	0.0007	NS	0.0007	NS
Epipsilia grisescens F. *					*0.0004*	*NS*	*0.0008*	*NS*
Ochropleura plecta L.	0.0063	A	0.0061	A	0.0013	A	0.0007	NS
Diarsia rhomboidea Schiff.	0.0028	A	0.0026	A	0.0009	NS	0.0009	NS
Diarsia xanthographa Schiff. *	0.0057	A	0.0045	A				
Cerastis rubricosa Schiff.	17.1235	C	0.0049	A	*0.0124*	*N*	*1.6583*	*N*
Ammoconia caecimacula Schiff.	18.092	C	0.1921	N	*0.0037*	*A*	*0.0029*	*A*
Noctua pronuba L.	16.6122	C	0.0134	N	0.0009	NS	0.0012	A
Triphaena orbona Hfn.	0.0057	A	0.0045	A	*0.0012*	*A*	*0.0012*	*A*
Mamestra brassicae Hfn.	0.0142	N	0.0128	N	0.0007	NS	0.0007	NS
Mamestra suasa Schiff.	0.0128	N	0.0118	N	*0.0054*	*A*	*0.0063*	*A*
Discestra trifolii Hfn.	0.0279	N	0.0025	A	0.0118	N	0.0104	N
Polia contigua Schiff. *	0.0021	A	0.0021	A				
Harmodia luteago Schiff.	0.0484	N	0.0039	A	0.0216	N	0.0195	N
Tholera decimalis Poda *					*0.0019*	*A*	*0.0012*	*A*
Aplecta advena Schiff.	0.0054	A	0.0045	A	*0.0019*	*A*	*0.0071*	*A*
Xylomania conspicillaris L.	0.1693	N	0.0912	N	*0.0224*	*N*	*0.0257*	N
Perigrapha i-cinctum Schiff.	221.151	C	0.0211	N	0.0089	A	0.0088	A
Orthosia incerta Hfn.	8507.98	D	676.8	D	*0.0010*	*A*	*0.0010*	*A*
Orthosia gothica L.	206.548	C	0.0163	N	*0.0010*	*A*	*0.0010*	*A*
Orthosia munda Schiff.	206.548	C	0.0163	N	0.0018	A	0.0019	A
Orthosia stabilis Schiff.	2853.20	D	17.124	C	0.0207	N	0.0209	N
Orthosia miniosa F. *	0.0005	NS	0.0005	NS				
Orthosia cruda Schiff.	206.548	C	0.0163	N	*0.0084*	*A*	*0.0083*	*A*
Mythimna ferrago F. *	0.0279	N	0.0008	NS				
Mythimna albipuncta Schiff.	0.1450	N	0.1003	N	0.0072	A	0.0080	A
Mythimna l-album Esp.	*0.0070*	*A*	*0.0055*	*A*	*0.0041*	*A*	*0.0062*	*A*

Mythimna pallens L.	0.3745	N	0.0126	N	0.0021	A	0.0021	A
Cucullia argentea Hfn.	0.5654	N	0.0014	A	0.3745	N	0.0126	N
Phlogophora meticulosa L. *	0.0065	A	0.0065	A				
Omphalophana antirrhini Hbn. *	0.0604	N	0.0216	N				
Calophasia lunula Hfn. *	0.0717	N	0.0717	N				
Brachinochia sphinx Hfn.	2.5005	N	0.0024	A	*0.0016*	*A*	*0.0016*	*A*
Lithophane ornitopus Hfn.	221.151	C	0.0211	N	*0.0010*	*A*	*0.0010*	*A*
Meganephria oxyacanthe L. *	0.0015	A	0.0015	A				
Valeria oleagina Schiff.	113.473	C	0.0139	N	*0.0017*	*A*	*0.1383*	*N*
Crino satura Schiff. *	16.6122	C	0.0134	N				
Agriopis convergens F. *	0.0075	A	0.0046	A				
Drybotodes protea Bkh.	0.0075	A	0.0046	A	*0.0302*	*N*	*0.0900*	*N*
Antitype nigrocincta Tr. *	0.1258	N	0.0228	A				
Eupsilia transversa Hfn.	0.0228	N	0.0234	N	*0.0014*	*A*	*0.0012*	*A*
Eupsilia satellitia L.	60.7056	C	0.0073	A	*0.0014*	*A*	*0.0014*	*A*
Conistra erythrocephala F.	0.0234	N	0.0292	N	0.0005	NS	0.0005	NS
Conistra vau-punctatum Esp.	0.0013	A	0.0014	A	*0.0087*	*A*	*0.0089*	*A*
Conistra vaccinii L.	8507.98	D	676.80	D	0.0014	A	0.0014	A
Agrochola humilis Schiff.	0.3661	N	0.0083	A	0.0234	N	0.0260	N
Agrochola lychnidis Schiff. *	0.0134	N	0.0106	N				
Agrochola macilenta Hbn.	0.0228	N	0.0234	N	0.0024	A	0.0014	A
Agrochola helvola L. *	100.105	C	0.0369	N				
Agrochola litura L.	0.0369	N	0.0292	N	0.0105	N	0.0101	N
Cosmia aurago F. *	0.0165	N	0.0017	A				
Amphipyra pyramidea L. *					*0.0076*	*A*	*0.0276*	*N*
Procus strigilis Cl.	0.0960	N	0.0495	N	0.0384	N	0.0388	N
Luperina testacea Schiff.	0.0094	A	0.0083	A	0.0057	A	0.0045	A
Charanyca trigrammica Hfn.	0.0976	N	0.0178	N	0.0029	A	0.0028	A
Cosmia trapezina L.	0.0128	N	0.0118	N	0.0021	A	0.0021	A
Apamea anceps Schiff.	164.304	C	0.0738	N	*0.0203*	*N*	*1.9993*	*N*
Dicycla oo L.	0.0165	N	0.0111	N	0.0021	A	0.0021	A
Heliothis maritima Grasl. *	0.0008	NS	0.0009	NS				
Chariclea delphinii L. *	0.0484	N	0.0039	A				
Lithacodia deceptoria Scop. *					*0.0229*	*N*	*0.0468*	*N*
Erastria trabealis Scop.	649.68	D	2.5273	N	0.0495	N	0.0453	N
Tarache luctuosa Esp.	0.0074	A	0.0057	A	0.0018	A	0.0012	A
Hylophila prasinana L. *	0.0008	NS	0.0009	NS				
Minucia lunaris Schiff.	0.0738	N	0.0065	A	*0.0381*	*N*	*0.1394*	*N*
Plusia chrysitis L.	0.0105	N	0.0101	N	0.0006	NS	0.0003	NS
Abrostola trigemina Wern. *					*0.0207*	*N*	*0.0229*	*N*
Autographa gamma L.	0.0801	N	0.0840	N	*0.0086*	*A*	*0.0126*	*N*
Hadena confusa Hfn. *	16.6122	C	0.0134	N				
Episema coeruleocephala L.	18.0918	C	0.1921	N	*0.0320*	*N*	*0.3020*	*N*
Toxocampa craccae F. *	0.0057	A	0.0045	A				

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Lymantriidae								
Dasychira fascelina L. *					*0.0010*	*A*	*0.0026*	*A*
Dasyhira pudibunda L.	0.0321	N	0.0346	N	*0.0054*	*A*	*0.0063*	*A*
Lymantria dispar L.	15.1900	C	0.0042	A	*0.0048*	*A*	*0.3514*	*N*
Arctiidae								
Gnophria rubricollis L. *	0.0037	A	0.0006	NS				
Ocnogyna parasita Hbn.	0.0017	A	0.0020	A	*0.0005*	*NS*	*0.0005*	*NS*
Phragmatobia fuliginosa L.	15.1900	C	0.0042	A	0.0090	A	0.0074	A
Spilosoma menthastri Esp.	0.0363	N	0.0165	N	0.0034	A	0.0008	NS
Eucharia costa Esp.	0.0072	A	0.0080	A	*0.6542*	*N*	*650.07*	*D*
Hyphantria cunea Drury *	0.0034	A	0.0008	NS				
Arctia villica L.	0.0691	N	0.0681	N	0.0216	N	0.0195	N
Notodontidae								
Stauropus fagi L. *	0.0021	A	0.0023	A				
Dicranura ulmi Schiff.	0.5168	N	0.0016	A	*0.0224*	*N*	*0.0257*	*N*
Drymonia querna Schiff. *					*0.0840*	*N*	*0.0888*	*N*
Drymonia chaonia Hbn.	11.9237	C	0.0037	A	0.0028	A	0.0006	NS
Pheosia tremula Clerck *	0.0237	N	0.0229	N				
Notodonta phoebe Sieb. *	0.0321	N	0.0346	N				
Ptilophora plumigera Esp. *	0.0024	A	0.0014	A				
Phalera bucephala L.	*0.0008*	*NS*	*0.0422*	*N*	*0.8153*	*N*	*611.76*	*D*
Sphingidae								
Marumba quercus Schiff. *	0.0976	N	0.0950					
Mimas tiliae L.	1.3611	C	0.0295	N				
Celerio euphorbiae L. *	0.0018	A	0.0012	A				
Deilephila elpenor L. *	0.0003	NS	0.0004	NS				
Pergesa porcellus L.	0.0476	N	0.0237	N	0.0012	A	0.0019	A
Thyatiridae								
Polyploca diluta F.	0.0075	A	0.0046	A	*0.0076*	*A*	*0.0276*	N
Polyploca flavicornis L. *	0.0067	A	0.0006	NS				
Polyploca ridens Hbn.	0.1693	N	0.0912	N	0.0371	N	0.0381	*N*
Drepanidae								
Cylix glaucata Scop. *	0.0009	NS	0.0009	NS				
Drepana binaria Hfn.	0.0295	N	0.0321	N	0.0010	A	0.0010	A
Asphalia ruficollis Schiff.	500.670	S	0.0652	N	0.0020	A	0.0140	N
Synthomidae								
Amata phegea L. *	0.0165	N	0.0111	N				
Dysauxes ancilla L. *					*0.0012*	*A*	*0.0039*	*A*
Coleoptera								
Melolonthidae	676.8	D	0.4073	N				
Melolontha melolontha L. *	676.8	D	0.4073	N				

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Acta Phytopathologica et Entomologica Hungarica 32 (3–4), pp. 319–332 (1997)

Light Trapping of Turnip Moth (*Scotia segetum* Schiff.) Connected with Continuance Length of Time and Changes of Péczely Type Macrosynoptic Weather Situations

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The light trapping success of turnip moth (*Scotia segetum* Schiff.) connected with continuance length of time and all the possible changes of Péczely type macrosynoptic weather situations was examined in our present paper using the collecting data of Jermy type light-trap network operating in Hungary. The value of relative catch (RC) was calculated for each observing stations and generations using the catching data.

There was made a comparison between the relative catch values and the Péczely type code number belonging to the date. After it the relative catch values were averaged in all the 13 macrosynoptic situations separated daily according to their continuance time. We compared the difference of the averaged relative catch value of each case with the averaged ones of the sum of all other cases. The significance levels were calculated by t-test. The collecting results connected with the changes of macrosynoptic situations also were examined in the same way.

We can conclude from our results, the significant changing of weather increases the flight activity of examined individuals of species.

Introduction and survey of literature

For determining the mass ratio and swarming time of nocturnal insects, the light-trap is the most widely used sampling device. In Hungary the introduction of the light-trap network, unprecedented even at world standards, was started in 1953 by professor Jermy. At the beginning, regular and scientific sampling was done by research institutions, then the initial problems of technology and operation being solved, the installation of a system of uniform Jermy type light-traps was started in 1958 and 1959 in every country plant protection station, and in 1961 the observation sites of the Forestry Research Institution. In the following years the number of observing stations grew suddenly, because the regional light-traps were organized by plant protection stations. The nationwide light-trap network works at present time.

The Hungarian light-trap network has provided priceless scientific material in the last decades for entomology basic research and plant protection prognostication. We have to know the light-trap would collect always the same part individuals of species being in the environment only in that case if it would work always in same circumstances. Certainly we do not know in this ideal case, which distance the imagos of each species arrive from, whether they are members of biocoenosis in the environment or not, and how much the real mass of this population is. The number of caught insects always would

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show the same proportion of those insects which can react to the trap stimulus, because of this more catching of insects would mean more mass of present insects in the environment.

Still, even the same light-trap cannot work under identical circumstances during two different nights, nor at two different times of the same night, as catching insects by light-traps is affected, apart from the biotic factors, by a number of abiotic ones. A part of their keeps changing in space and time, such as weather phenomena, another part changes, first of all, in time, but in space changes only slightly, such as moonlight and geomagnetism. Again others, such as the flora of the location, transform rather slowly in time, but can be extraordinarily different in space. Because of this the great quantity data collected about each species gave not so much practical advantage for plant protecting forecast till now. The situation would be much more favourable if we were able to recognize the factors that influence the resultativeness of trapping, and to reveal their effect. No wonder that a number of researchers are engaged either in Hungary or all around the world in studying the role of different environmental factors, first of all weather and moonlight. Sorry the new informations can be utilized hardly by the plant protecting prognostic in working out of forecast. One of the reasons of it is, the several environmental factors – though the modifying influence of them are well-known better and better – influence the prevailing catching result not only alone, but also with all the other factors simultaneously and in interaction. The primary aim of the large-scale examinations is to know as many effects of abiotic factors modifying the catches as possible. When the role of the majority of the most effective factors has been recognized, we will have the possibility to correct the prevailing trapping results of the species involved. This being done, the corrected catch datum, parallel to our knowledge growing, will approach a value that will proportionately represent the real amount of population in any case.

Insect flight activity – and similarly, the effectiveness of their light-trap collection – are considerably modified by weather, together with a number of abiotic factors. Unfortunately, a decisive majority of the catch results provided by the light-trap network cannot be examined in connection with the particular weather elements, as most observation sights are situated far from meteorological stations, and those operating the traps did not take any meteorological measurements. Therefore, we revealed the connenction between weather and effectiveness of collecting with a light-trap using a different method. For the purposes of our investigations we found those Péczely's macrosynoptic weather situations to be suitable which express complex weather conditions simultaneously existing and pertaining to the whole area of the Carpathian Basin.

The macrosynoptic typifying which can be considered as pertaining to the area of the Carpathian Basin was elaborated by Péczely (1957 and 1983). The daily macrosynoptic weather situations which were determined on the basis of the baric field at ground level were classified into 13 types and characterized by him. Since 1983, typifying has been continued and the daily code numbers are published by Károssy (Károssy, 1987 and 1994).

The data interpretation period for each type is 24 hours belonging to a calendar day. The one single criterium for coding is the definition of the type which pertains for a longer period of time during a day, so the type-shift may as well differ ± 12 hours from the time of the change of the calendar date. The progression of the changes in time, as well as the tendency of particular types to endure and the empiric frequency of the occurrence of situations replacing each other differ significantly.

Following Péczely's work in the field of typifying macrosynoptic weather situations (1957 and 1983), his collaborators elaborated on the particular weather situations with regard to some weather elements and included a detailed data-base. In the following, with the continuity of the typifying ensured, the examinations of the element-sets relating to the macrosynoptic situations were also performed.

In the last few years the examination of the connection between the flight activity of harmful insects and the various macrosynoptic weather situations has become an important and determining trend in the above-mentioned research. During this research we examined the effectiveness of trapping in connection with the macrosynoptic weather situations pertaining to the trapping time of harmful insects flying at dawn or in the first part of night. We extended our investigations to the cockchafer (*Melolontha melolontha* L.), which swarms in spring, to the winter moth (*Operophthera brumata* L.), which flies late in autumn, and to two species of moths, which although insignificant from an economical point of view, are easy to trap in autumn,winter and spring, too, the common chesnut (*Conistra vaccinii* L.) and the satellite moth (*Eupsilia transversa* Hfn.) (Károssy et al., 1994). When investigation species which are active all night, we employed a different method since macrosynoptic situations pertain to one calendar day only, so in those cases when one macrosynoptic type pertained to the date of the evening and another to that of the dawn, we had to examine the formation of the flight activity during the periods when the changes occurred. We contracted the 13 macrosynoptic situations typifield by Péczely on the basis of their characteristic wind patterns into 6 types. The contraction was necessary, although we had great number of observing data, but they would be small to examine all of possible changes. The changes of these types form 36 transitional types, so far uncharacterised even from climatological points of view. We examine the effectiveness of light trapping the turnip moth (*Scotia segetum* Schiff.), the fall webworm moth (*Hyphantria cunea* Drury) and the gipsy moth (*Lymantria dispar* L.) in relation to these 36 types (Károssy et al., 1990 and 1992; Nowinszky et al., 1995). The results of our publications connected with this theme were published in summary study in recent past (Károssy et al., 1994). Recently the collecting results of heart-and-dart moth (*Scotia exclamationis* L.) were examined connected with the determined situations for a smaller territory surrounding Budapest using the data of six observing stations in operation at the mentioned territory (Károssy et al., 1996).

In the literature we have not found publications – except ours – which examine the effectiveness of light trapping in connection with macrosynoptic weather situations. The light trapping success of turnip moth (*Scotia segetum* Schiff.) was examined connected with continuance length of time and the all possible changes of Péczely type macrosynoptic weather situations used the newest numerous collecting data in our present paper.

Materials

A short characterization of the 13 marcrosynoptic weather situations is given in the Appendix. The code-number expressing the marcrosynoptic weather situation for the nights studied are taken from Péczely's catalogues (1957 and 1983).

The Jermy type light-trap is a modified version of the Minnesota type, which the guide-sheets have been removed from. The light source is a 100 W normal light bulb at 2 meters above the ground, colour temperature: 2900 K, the killing material is chloroform. The traps of the plant protection institutions worked from 1st April to 31st October, while the forestry ones all the year round, independently of the time of sunrise and sunset, every night from 6 p.m. to 4 a.m. All time data are given in universal time (UT). The insects trapped during one night were stored in one bottle, so the whole catch of one night at one observational site is interpreted as one observational datum.

The collecting data of turnip moth (*Scotia segetum* Schiff.) were used for examinations getting from 78 observing stations of national agricultural and forestry network operating between 1957–1990. During 4 566 nights 58 159 individuals were caught by the traps. We used 40 858 observing data in our examination. We mean on observing data the catching data at one night at one observing station independently of caught individuals.

We hereby express our gratitude to Dr. Pál Szontágh, for collecting data coming from light-traps of forestry, Dr. András Vojnits, senior research-fellow, Museum of National Sciences and Györgyné Mohai research-fellow at Budapest Phytopathological and Soil Protecting Station for collecting data coming form light-traps of plant protection stations and agricultural ones.

Methods

To know the supposed modifying influence of marcrosynoptic weather situations we had to use all of the collected and available data belonging to each species getting from the data of national light-trap network. We could reach, the effect of not examined factors get on less from the simultaneously existent numerous abiotic factors. There were favourable and also unfavourable values in the examined period according to light trapping, that is why their modifying influence had indifferent effect for the results, because of the gigantic number of data. If we want to use contracted the catching results coming from different observing stations and different generation, we cannot use the real number of caught insects. The quantity of caught insects were modified significantly by biotic and abiotic factors.

The environmental factors are not the same at all places and in all times of trapping, because of this it is sure, catching of the same number of individuals at two different observing stations or in two periods mean other proportion of examined populations. To solve the problem, from the catch data we calculated relative catch (RC) values for

Table 1

The average values of relative catches of the turnip moth (*Scotia segetum* Schiff.) according to the continuance length of time of Péczely type macrosynoptic weather situations

Codes	Continuance length of time of Péczely type marcrosynoptic weather situations									
	1	2	3	4	5	6	7	8	9	10
mCc	0.913	1.082	**0.857**	0.956	**0.807**					
(1)	(732)	(235)	(128)	(67)	(24)					
AB	0.993	**0.925**	**0.900**	1.085	1.136	**1.268**	1.595	0.799	1.112	0
(2)	(837)	(402)	(210)	(144)	(110)	(89)	(14)	(14)	(13)	(1)
CMc	**1.124**	**1.258**	**1.146**	1.002						
(3)	(287)	(104)	(43)	(30)						
mCw	1.030	**0.798**	**0.932**	1.188	0.200					
(4)	(769)	(325)	(122)	(25)	(5)					
Ae	1.027	***0.794***	<u>0.965</u>	***1.389***	1.016	1.126	0	0		
(5)	(799)	(403)	(199)	(96)	(53)	(5)	(3)	(3)		
CMw	0.899	***0.663***	1.096							
(6)	(496)	(89)	(15)							
zC	0.946	***0.728***	***0.405***	***0.381***	**0.890**					
(7)	(418)	(165)	(42)	(21)	(20)					
Aw	0.982	1.026	<u>0.943</u>	***0.821***	0.943	***1.644***	**1.289**			
(8)	(2078)	(879)	(273)	(102)	(45)	(33)	(16)			
As	0.979	**1.218**	0.539	0						
(9)	(278)	(46)	(8)	(3)						
An	0.978	0.972	1.001	**0.914**	***0.809***	***0.715***	***0.587***	***0.675***	1.133	
(10)	(1506)	(701)	(492)	(263)	(152)	(91)	(56)	(49)	(27)	
AF	0.957	**1.238**	**1.126**	***1.410***	***1.360***	**1.336**	0.749			
(11)	(616)	(358)	(210)	(149)	(103)	(53)	(42)			
A	1.084	0.986	1.010	1.116	1.067					
(12)	(1244)	(297)	(194)	(107)	(38)					
C	**1.107**	1.724	0	0						
(13)	(87)	(7)	(2)	(2)						

Significance levels are shown with bold numbers (if more than 95%), italic and bold ones (if more than 99%), normal underscored ones (if there are significant differences, but it does not mean important difference from trade point of view) and normal ones (if there are not significant differences). The number of observing data are given in parentheses.

observation sites, species and generations. RC is the quotient of the number of individuals caught during the sampling interval (1 night or 1 hour), and the mean values of the number of individuals of one generation counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

There was made a comparison between the relative catch values and the Péczely type code number belonging to the date. After it the relative catch values were averaged in all the 13 macrosynoptic situations separated daily according to their continuance time. We compared the difference of the averaged relative catch value of each case with the averaged ones of the sum of all other cases. The significance levels were calculated by t-test. The collecting results connected with the changes of marcrosynoptic situations also were examined in the same way. Because of using very numerous data, there was a danger to show significant differences in those cases, when the differences are relatively small and not very significant from trade point of view. Therefore only those significance difference were accepted as significant ones, when they differ from one another with at least 10%.

Results

The relative catch average values of turnip moth (*Scotia segetum* Schiff.), the number of observing data and the significance levels connected with continuance length of time of Péczely type marcrosynoptic weather situations are shown in Table 1 and according to the changing type of marcrosynoptic situations are given in Table 2.

Discussion

If certain situations remain during some days the collecting is favourable on the first day or from the beginning of the first day only at the cases of CMc (3) and C (13) situations, but it is unfavourable in CMw (6) situation. There are not significant difference between the number of caught individuals and the average (expectable) value in all the other weather situations on the first day. Generally the favourable catching results (As [9], AF [11]) and the unfavourable (mCc [1], AB [2], mCw [4], Ae [5], zC [7]) ones are found only from the second or third day or exceptionally later (An [10]) from the fifth day. There are two situations (Ae [5], Aw [8]) when the unfavourable catching result on previous days later change for favourable. According to our suppose in these cases after the decrease of insect's flight activity during some days, the insects have to conform to the unfavourable conditions. The imago has short life, that is why it cannot interrupt the ripening nourishment, the copulation or the oviposition for a long time, because the absence of these ones would endanger the continuance of species. It is sure the zC (7) situation is unfavourable, but the AF (11) one is favourable for catching from the second day. It is remarkable the central anticyclon (A [12]) have not any influence

Table 2

The average values of relative catches of the turnip moth (*Scotia segetum* Schiff.) in the period of Péczely type macrosynoptic weather situations changes

In the evening	Péczely type macrosynoptic weather situations — At daybreak												
	mCc 1	AB 2	CMc 3	mCw 4	Ae 5	CMw 6	zC 7	Aw 8	As 9	An 10	AF 11	A 12	C 13
mCc 1	– –	***0.785*** (231)	**0.655** (26)	1.062 (238)	0.521 (15)	0.966 (169)	0.987 (84)	0.991 (842)	**0.874** (50)	***1.456*** (113)	***0.319*** (38)	***0.784*** (56)	***1.219*** (67)
AB 2	**0.884** (111)	– –		0.964 (33)	0.989 (1)	**1.138** (58)	1.050 (27)	***0.742*** (292)	**0.657** (26)	1.102 (347)	0.997 (232)	**0.924** (134)	**0.169** (15)
CMc 3	0 (1)	1.097 (176)	– –	***0.693*** (102)	0 (1)	1.032 (140)	***0.542*** (88)	1.099 (231)		0.977 (73)	0.895 (31)	***0.327*** (36)	0.440 (4)
mCw 4	0.961 (996)	**1.304** (77)	0.553 (10)	– –	**1.258** (57)	1.052 (235)	1.008 (198)	**0.923** (626)	**0.422** (25)	1.124 (36)	**0.499** (30)	1.088 (16)	0.876 (109)
Ae 5	***1490*** (92)	**0.856** (94)	***1.707*** (18)	0.998 (504)	– –	**0.870** (283)	**0.810** (69)	1.010 (680)	***0.632*** (56)	***1.248*** (181)	**0.831** (30)	***1.385*** (120)	***2.232*** (19)
CMw 6	1.149 (94)	0.333 (12)	***0.870*** (589)	**1.243** (44)	1.058 (27)	– –	0 (1)	***0.469*** (159)	**1.729** (14)	***0.775*** (166)	**0.807** (34)	***1.330*** (71)	1.067 (320)
zC 7	0.968 (142)	**0.760** (53)		1.063 (150)	1.195 (14)	1.132 (116)	– –	**0.878** (262)	0.921 (65)	**0.904** (36)	***2.533*** (14)	***0.749*** (53)	***0.448*** (34)
Aw 8	0.977 (152)	**0.898** (221)	***0.624*** (42)	**1.157** (358)	1.083 (212)	***1.594*** (180)	**0.926** (281)	– –	***0.829*** (224)	1.097 (719)	1.011 (91)	0.976 (1640)	0.973 (20)
As 9	**0.755** (50)	***0.496*** (37)		1.055 (164)	**1.178** (56)	***1.668*** (30)	***1.487*** (34)	***0.643*** (129)	– –	0.683 (10)	0.400 (5)	**0.923** (142)	0.200 (5)
An 10	***0.682*** (70)	1.092 (135)		**1.136** (392)	1.052 (734)	**0.861** (116)	2.183 (3)	***1.549*** (255)	0.470 (14)	– –	0.940 (291)	1.003 (446)	1.116 (24)
AF 11	0.691 (15)	**0.839** (83)	0.704 (14)	**1.201** (56)	0.929 (118)	***0.612*** (47)		0.929 (55)		1.007 (411)	– –	1.617 (18)	0.161 (11)
A 12	1.097 (69)	1.025 (165)		**1.106** (379)	1.024 (936)	**1.265** (81)	**1.200** (91)	***1.182*** (456)	**1.184** (176)	1.093 (331)	***1.828*** (34)	– –	**1.488** (13)
C 13	***0.859*** (164)	**0.838** (39)	0.922 (150)	***1.321*** (58)		***1.216*** (101)	**0.756** (20)	***1.270*** (68)	0.479 (8)	1.036 (42)		**1.212** (28)	– –

Significance levels are shown with bold numbers (if more than 95%), italic and bold ones (if more than 99%), normal underscored ones (if there are significant differences, but it does not mean important difference from trade point of view) and normal ones (if there are not significant differences). The number of observing data are given is parentheses.

for success of collecting during the whole continuance. If this situation changes at dawn, the number of caught insects will also increase in seven cases. We can conclude the quiet situation is not favourable according to the collecting success, but the changes are favourable for it.

High and low catching results also belong to changing weather situations. After examining these situations we cannot declare clear regularity, although it is remarkable at changing the meridional northern situations there are more small catching results, than high ones. This establishment is also true, if the meridional northern situations change to any other ones, but it is mainly true, if any other weather situations change to meridional northern ones. It is typical of the meridional northern directions situations, their appearance often belong to passing of cold weather fronts. At that time the weather is cool, windy, cloudy and frequently there is a rainfall. After these circumstances the low flight activity of insects can be understood. We could often find high collecting result if there were those changing situations when any other situations changed for meridional southern one. There were some cases when the zonal western situation changed for meridional southern one, or the central anticyclon changed for meridional southern situation, the cloudless, dry weather was followed by cloudy and rainy one. Probably the increase of collecting is caused by prefrontal influence.

Relatively the number of those changing situations are less when the catching results do not differ significantly from the expectable values. This is a proof for that fact, mainly the number of caught moths increase in weather changings. Sometimes when significant low or high catching results do not belong to the changing situations, seeing the high number of observing data we can be sure in this time the flight activity neither increases, nor decreases. Probably in other cases the modifying influence cannot be proved, because of the relatively less collecting results. Sometimes we found strong significant differences at that case when the number of observing data were less then 20. May be such kinds of changing weather situations modify significantly the catching results, we think the practical importance is very small, because it is very infrequent.

We can conclude from our results, the significant changing of weather increases the flight activity of examined individuals of species. This fact does not mean favourable weather conditions for the flying of insects. The low values of relative catch mean those weather situations in all cases, when the flight activity of insects decreased, but the meaning of high values are not so equivalent. The significant environmental changes cause physiological changes in the organism of insects. The life of imago is short, the unfavourable weather endangers not only the continuance of individual but also the continuance of the total species. According to our supposition the individuals can use two kinds of strategies to prevent the hindering influences of normal function in phenomenon of life. First is the increased activity. It means the growing of intensity in flying, copulation and oviposition. The second strategy is to hide and ride out in passivity the unfavourable situation. Seeing the above-mentioned facts, according to our present knowledge high light trapping results can belong to both favourable and unfavourable situations.

Seeing that the Péczely's marcrosynoptic situations are valid simultaneously in the whole Carpathian Basin, our results can be utilized not only in Hungary, but also in one part of territory in neighbouring countries for the purpose of making plant protecting prognosis. We can declare is spite of that case we cannot give the correct explanation of high or low catching results in all the changing situations according to our knowledge. Further agrometeorological researches are necessary to find how can be modified the insect's comfort feeling and flight activity by different type changing situations.

Using the Péczely's marcrosynoptic weather situations offers a possibility for investigating the insect's life-phenomena in connection with weather also in those cases where the measuring of certain elements for some reasons comes up against difficulties. The collecting data of the national light-trap network, which is invaluable for science, has also become employable to insect ecological and etological investigations. On the basis of our work it is also proved that Péczely's macrosynoptic situations are reliable not only from the point of view of climatological typization, but also with regard to agrometeorological research. We think it essential to elaborate a similar typization for other geographical regions, and other harmful species of insects as well.

Appendix

A short characterization of the 13 marcrosynoptic weather situations is given in the following:

MERIDIONAL, NORTHERLY ORIENTED SITUATIONS

mCc (1) Cold front from the meridional situations

A situation with meridional direction and northern stream. Hungary belongs to the rear cold front current system of the cyclone, which stays east or nort-east of it, over the Balticum or the Ukraine. This situation causes changeable, windy and wet weather in the Carpathian Basin. In summer a version without a cold front may also arise, when a termic depression effect from South-West Asia spreads over South-East Europe. In summer, this situation is favourable for forming local showers, thunderstorms, in winter snowstorms are frequent. In summer the temperature is above average, in winter it is below average, in spring the deviation is not significant. Cloudiness surpasses the average level, visibility is good, in winter the tendency for fog is smaller. Air pollution is usually insignificant. Typically, the northerly and the north-westerly winds are strong while the westerly and south-westerly winds are strong beyond the Tisza river. There is more precipitation in the eastern half of the country. Atmospheric temperature layers are stabile, the lower layers are warmer. The daily temperature fluctuation is small and aperiodic.

AB (2) Anticyclone over the British Isles

This is a meridionally directed situation with northerly current. Partly because of the Azores cyclone moving to the north, partly because of the anticyclones moving from the arctic basins to the south, high-pressure air masses develop over the British Isles or the North Sea. Its appearance in the Carpathian Basin is usually connected to the passing of a cold front, and results in intensive north-, north-westerly air currents in our region.

When the above situation stabilizes in summer, the baric gradient is a lot lower over Central Europe; on such occasions dry, prolonged warm weather evolves in the Carpathian Basin. It is a misty situation in autumn, winter and spring as well. During the greater part of the year it is characterized by colder air masses of arctic origin and average cloudiness, with higher degrees of cloudiness in summer. There is a strong tendency for fog in winter. There is a north-westerly, westerly wind; over the Tisza river it is westerly, south-westerly, and relatively strong. The temperature-stratification of the air is stabile.

CMc (3) Cold front arising from a Mediterranean cyclone

A situation with meridional direction and northern current. It is the current-system of the back-side of the cyclone. The situation emerges by way of a Mediterranean cyclone moving towards the Balcan peninsula or the region of the Black Sea, so the Carpathian Basin falls in the rear, cold front current system of the cyclone. The movement of air is in a northern, north-west direction. Its speed – mainly in the Transdanubia – may even reach storm intensity. Especially in summer, precipitation may increase, in different amounts at various locations. Snow showers are frequent in winter, storms in spring. Cloudiness is definitely extensive, especially in the summer half of the year. Air pollution is low, the tendency for fog is also low in winter. The temperature is lower in spring and autumn, and higher in winter than on the days preceding this weather situation. The daily fluctuation of the temperature is aperiodic.

MERIDIONAL SITUATIONS WITH A SOUTHERN DIRECTION

mCw (4) Warm front arising from a meridional cyclone

This is a situation of meridional direction, with flow toward the south; it is the frontal current system of the cyclone. The current over the Carpathian Basin is directed by a cyclone with its centre either in the region of North-Western Europe or in Western Europe. Hungary's territory is under the effect of the cyclone's warm front, or falls into its warm sector. In autumn it is cooler, in winter and spring milder than the average temperature of the given season. Cloudiness is more extensive, mainly in spring and autumn. Prolonged, slow rains and snowfalls are equally frequent from autumn to spring. Visibility is bad, the frequency of fog is high in winter. In summer it is characterized by sultriness and high degree of air pollution. The southern air current brings considerable precipitation, especially in the winter half of the year.

Ae (5) Anticyclone located east of the Carpathian Basin

A meridional situation with southern current. A dry, southerly, or south-westerly air current dominates in an anticyclone located east of Hungary with its center over the Ukraine. The weather fronts range west of the Carpathian Basin. This situation is characterized by dry, warm, bright weather in summer, and in winter, after snowy days by bitter cold, frequent rime and fog. In autumn and spring, temperature fluctuation is large with a strong rise in temperature. In the cold season the range of the Eastern Carpathians often modifies the direction of the izobars, and in this way the cold, surface level air masses invade the territory of the country passing round the Southern Carpathians (Kossava effect). It is characterized by a temperature surpassing the average prevalent during the greater part of the year. Cloudiness, mainly in summer, is smaller and dry, droughty weather is frequent at this time. In accordance with the weak, southerly current, the amount of precipitation is small, visibility is bad, and air pollution is considerable. The air shows inverse temperature stratification.

CMw (6) Warm front arising from a Mediterranean cyclone

This situation has a meridional direction and southerly current. The cyclone's frontal system of current asserts itself in Hungary. The system is defined by a cyclone which arises over the central part of the Mediterranean Sea and moves toward the Adriatic region. Its warm front passes over the Carpathian Basin causing substantial rains in the winter and spring months, as well as snowfalls in winter. In summer its temperature is lower than the national average temperature. Visibility is low, cloudiness strong, and the fluctuation of the temperature is aperiodic.

ZONAL SITUATIONS WITH WESTERN DIRECTION

zC (7) Zonal cyclone

There is a zonal, westerly flow. While it prevails the European stretch of the frontal zone ranges near the 50° latitude. The air flow is westerly. Northern Europe is affected by fast moving cyclones. The weather is windy and changeable. The temperature, characteristically, is cool in autumn, mild in winter, and in summer it is colder than the average for that season. In spring the fluctuation in temperature is low. Cloudiness is strong, especially in the spring and autumn months. The yield of precipitation is larger at the beginning of autumn and in winter. The lower air strata are warmer. Colder, arctic air strata flow in the higher layers.

Aw (8) Anticyclone located west of the Carpathian Basin

It has zonal current with a western direction. When the Azores cyclone travels north (mainly in summer), its protrusion advances as far as the Central-European region. Its formation usually takes place in connection with a cold front which passes through and results in an intense westerly or north-westerly current in the Carpathian Basin. It is characterized by pleasant, warm and bright weather which however, is misty in autumn and spring, and mild, misty and foggy in winter. In winter it is colder than the temperature typical for that season. Its cloudiness is average, yet it is overcast in summer. Visibility is good, air pollution is low. The lower stratum of air is usually warmer than the one over it, in which there is a cold air current.

As (9) Anticyclone located south of the Carpathian Basin

This situation has a zonal, western current. The northern fringe of the anticyclone situated over the basin of the Mediterranean Sea protrudes into the Carpathian Basin. The northern edge of the frontal zone moves upward, so the cyclone moves along a more northern trajectory, and their frontal system does not effect Hungary. During the greater part of the year this situation-type is warmer than the average and is characterized by a lower degree of cloudiness. In winter, autumn and spring the bright, warm days are followed by mild nights. In winter cloudiness is somewhat stronger, and the frequency of fog is higher. In summer it brings about sultry weather. The air flow is weak, and precipitation is low. The lower stratum of air is colder than the upper, however the opposite may also occur.

ZONAL SITUATION EASTERN DIRECTION

An (10) Anticyclone located north of the Carpathian Basin

This situation has an eastern, zonal current. The anticyclone stays north of Hungary over the Balticum or Poland, and forms a high-pressure ridge from the British Isles as far as Eastern Europe. In summer it is warmer than the temperature typical for that season. It causes a strong fall in temperature in autumn and in spring, but after the cold night a rise in temperature follows about midday. It is characterized by clean air and northern winds. In winter it is connected with the invasion of very cold air masses. On such occasions it is easy to observe how the Carpathian ranges modify the movement of ground level cold air masses and their passage through mountain passes. Many times characteristic, embracing izobars develop along the Carpathians, and the cold invasion from either side sometimes may result in and occlusion front inside the Basin. The weather is windy and foggy even in winter with average cloudiness, and a sky which is a bit more overcast in the spring and autumn months. Sometimes air pollution is high. The air-flow is typically of north-eastern direction. The stratification of air characterized by warmer lower and colder higher strata.

AF (11) Anticyclone located over the Scandinavian peninsula

This situation has a zonal eastern air-flow. The characteristic orientation of the longitudinal axis of the anticyclone which stays in the Fenno-Scandinavian region has a north-easterly diretion. This weather situation brings about a northern or north-eastern flow in Hungary. During it s existence, the weather, especially in autumn, winter and spring is bright and clear, but the air is very cold. It is characterized by northerly winds, wide fluctuation in temperature, average cloudiness, and little precipitation. The Icemen (the three chilly days in May) are usually connected to this marcrosynoptic type.

CENTRAL ANTICYCLONE

A (12) Anticyclone located over the Carpathian Basin

The whole region of Central Europe is dominated by a centrally situated anticyclone which rises above the Carpathian Basin. It can be of smaller size, even just a few hundred kilometres in diameter, but it can also be a so-called intermediate anticyclone, which moves fast separating other cyclone systems. In most cases, however, it remains for a longer period over the Carpathian Basin. Its duration gets prolonged in winter by a cold air-cushion stuck on the bottom of the Basin (inversion). Its prolonged existence ensures undisturbed radiation weather. In winter it is accompanied by a strong fall in the temperature, and considerable inversions of temperature, and in summer by a great rise in temperature, heat waves and thunderstorms. One frequent feature is an air-flow in diverse directions which originates from the centre. During the greater part of the year it can be characterized by a temperature of radiation effect – i.e. warm during the day and in summer, cold during the night and in winter. The weather is warm and pleasant either in spring or in autumn, while it is foggy, frosty and rimy in winter. Temperature fluctuation is great. Cloudiness is slight. It is a bit more overcast in winter, and brighter in summer. Precipitation is small, showing large regional variability. Visibility is bad. There is a high frequency of fog, and air pollution may be strong. The air is usually dry. The wind has no uniform or characteristic direction.

CENTRAL CYCLONE

C (13) Cyclone located above the Carpathian Basin

The centre of the cyclone is located over the Carpathian Basin. In a great majority of cases, Mediterranean cyclones which pass over Hungary from this type. There may, however, be cases when a cyclone develops having local, orographic causes along a front that has grown stagnant. A sharp contrast in temperature evolves in Hungary. The north-western parts of the country fall in the rear flow system of the cyclone, so the temperature there is much lower than in the eastern part of the country, which fall into the frontal flow system. In the western, north-western and south-western regions of the country, because of what was said above, the frequency of fronts is higher than in the rest of the country. When this type is present, in winter the temperature is higher, in summer it is lower than during the preceding days. In autumn this type is characterized by cold, windy, overcast and rainy weather, and in winter by stormy weather. In spring it is characterized by rainy weather. In all three seasons temperature fluctuation is small. Cloudiness is greater in summer, smaller in winter. Visibility is bad, and air pollution is low. A strong field of flow is characteristic, although its direction is not homogeneous. Precipitation is markedly large.

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IDŐJÁRÁS

Quarterly Journal of the Hungarian Meteorological Service
Vol. 97, No. 2, April-June 1993

The flying activity of turnip moth (Scotia segetum Schiff.) in different Hess-Brezowsky's macrosynoptic situations

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(Manuscript received 15 October 1992; in final form 8 June 1993)

Abstract—The collection of insects by light-trap is a wide-spread sampling method of plant-protection, but its efficency is influenced by many environmental factors especially the weather. Knowing these influencing parameters, one can elaborate more reliable prognoses.

The authors pointed out in their earlier paper that the macrosynoptic weather types of *Péczely* are very useful for investigation of insect ecology in territory of Carpathian-Basin.

The present paper deals with macrosynoptic situations of *Hess-Brezowsky* extended for the whole Europe in connection with the flying activity of a harmful insect, the turnip moth (Scotia segetum Schiff.) being represented by the number of collected individuals.

The authors have established that from the various 29 types of macrosynoptic weather situations, if they are continuous, which are favourable or unfavourable from the point of view of collecting the moths, moreover how the species investigated react to the change of the weather situations.

Key-words: Hess-Brezowsky's macrosynoptic situations, turnip moth, light trap.

1. Introduction

The principal condition of effective and economical plant-protection taking care of the environment is the reliable prognosis of harmful insects. In order to elaborate a suitable prognosis it is necessary to make simultaneous observations of the time of appearence and the number of individuals, using adequate methods and sampling devices. The light-trap is a wide-spread tool for catch of insects flying at night which kills the insects flown to the artifical light source.

There has been a uniform light-trap network of *Jermy* type in Hungary for about thirty years which has collected a great amount of valuable data for scientific research. The data representing the activity of insects are influenced by several factors, including the weather. It is easy, therefore, to understand that many entomologists deal with the investigations of the effect of meteorological parameters all over the world. Unfortunately, most of the Hungarian light-trap stations did not observe the meteorological elements. These stations were in general situated remote from meteorological observing stations. We published the effectiveness of catching the most harmful insects by light-traps in earlier papers (*Károssy* and *Nowinszky*, 1987a; *Nowinszky* and *Károssy*, 1986) associated with the *Péczely*'s macrosynoptic weather situations existing in the Carpathian Basin.

In some papers the results of light-trap catches were demonstrated at the time of change of *Péczely*'s type (*Nowinszky* and *Károssy*, 1988; *Károssy* and *Nowinszky*, 1987b). In these publications we searched for the connection between the catching data and the change of 13 types of *Péczely*. The types which seldom occured were eliminated. This method gave much information, but its application was complicated for plant-protecting forecast. In the recent paper a simple method is presented which is easily applicable for plant-protecting forecast. Based on the air flow the 13 situations had been contracted into 6 types and after that the time of their change was investigated (*Károssy et al.*, 1990, 1992).

In the present paper the authors analyse the light-trap catches of turnip moth (*Scotia segetum Schiff.*) in connection with the macrosynoptic weather types of *Hess-Brezowsky* (1977) extended to whole Europe.

2. Material

The determination of macrosynoptic types of *Hess-Brezowsky* had been similarly and subjectively worked out as *Péczely*'s ones, taking into account the circulation conditions of the continent (Europe). The catalogue of *Hess-Brezowsky* (1977) based on baric circumstances of Central Europe, distinguishes 4 zonal, 18 meridional and 7 mixed types of weather situations, maintaining one type for unclassified baric areas. *Bartholy* and *Kaba* (1987) interpreted the *Hess-Brezowsky*'s situations for the whole Atlantic-European area. They analysed a great amount of data processed from 8 Hungarian meteorological stations of 60 years and 18 daily values and determined the *Hess-Brezowsky*'s weather picture for Hungary. The characteristics of these types can be found in literature cited. The codes which were necessary for this investigation, are similarly taken from publication of *Hess-Brezowsky* (1977).

The Hungarian light-trap network is supported by the Forestry Research Institute, the plant-protecting stations and other research organisations. The uniform light-trap device consists of a 100 W incandescent lamp situated at 2 m above the ground surface and the killing material is chloroform.

During the interval between 1957 and 1976, i.e. through 20 years, 32,100 individuals of turnip moth (*Scotia segetum Schiff.*) were caught by the 61 traps of the network from 20,508 observations and 249 swarmings at 2,647 nights. In our terms, swarming is the time-span of one generation and an observational datum is denoted as the result collected at a single station during one night.

The turnip moth (*Scotia segetum Schiff.*) has two generations yearly and is characterized as a polyphag harmful insect. The first generation in most cases occurs from the beginning of May to the middle of June, while the second one from middle of July to September. This moth is equally dangerous for vegetables, root crops, industrial plants, cereals, leguminouses and ornamental plants.

3. Method

We calculated relative catches (RC) from the obtained data belonging to each collecting stations and generations. This procedure gives us a possibility to compare the results taken at various light-trap stations to each other. The RC is defined as a quotient of the number of individuals caught during a sampling time (a night) and the mean number of a given generation.

The catching data belonging to the same *Hess-Brezowsky*'s 29 types in the evening and morning, have been averaged. After this the significance levels have been computed between them using the *Welch*-test (i.e. an approximate t-test). In cases, if we did not take the macrosynoptic types into account, we applied 1 (the unity) as relative catch value (RC).

In so far as during a two days period the weather types changed, the original 29 situations were sorted into zonal, mixed, meridional, cyclonic or anticyclonic groups on the basis of their circulation characteristics. On this basis we accepted 6 groups, containing the original situations too, as follows:

- Zonal anticyclone: Wa (1), Ws (3), and Ww (4),
- Zonal cyclone: Wz (2),
- Mixed anticyclone: SWa (7), NWa (13), HM (17) and BM (30),
- Mixed cyclone: SWz (8), NWz (14) and TM (25),
- Meridional anticyclone: Sa (5), SEa (9), Na (11), NEa (15), HB (18), HNa (19), HFa (21) and HNFa (23),
- Meridional cyclone: Sz (6), SEz (10), Nz (12), NEz (16), HNz (20), HFz (22), HNFz (24), TB (26), TRM (27) and TRW (28).

The above listed 6 groups can change into 36 possible categories. Continuing the procedure, we have averaged the RC belonging to each variable situation and after this the confidence level was calculated related to the expected value, using the *Welch*-test.

4. *Results and discussion*

Table 1 contains the averages of RC of the turnip moth (*Scotia segetum Schiff.*) with the number of observations, the confidence levels of the *Hess-Brezowsky* situations which have the same characters in the evening and morning. *Table 2* shows the same data of the changing situations.

The data of Table 1 show that in most case of northern, northwestern and western situations, when the macrosynoptic situations remained unchanged in the evening and in the morning, the number of moths significantly decreased. This phenomenon may be explained by windy and cool weather, which characterizes the night hours generally in these cases. It is conspicuous that high catch can be associated only with four situations, of which three belong to southern or southwestern types. It seems that the continuously existing weather situations are unfavourable for the activity of insects. We obtained similar results earlier in connection with *Péczely*'s situations. From the varying situations in general, the anticyclones are unfavourable, because the character of circulation changes, moreover an anticyclone is followed by a cyclone or a cyclone by anticyclone, respectively.

We have high catch, if a cyclone is succeeded by a cyclone and if a meridional anticyclone is followed by an other one or a meridional cyclone.

The low values of RC are referring in all cases to such a weather situation which cause decresed flying activity of insects. The high values cannot be interpreted unambiguously. The significant changes in environment induce some physiological variations in organism of insects. The life of an imago is short, therefore the unfavourable weather is dangerous as well for individuals as for remaining of whole species. We suggest that an individual, in order to avoid the bad circumstances hindering his normal life, can apply two strategies. The insect shows increased activity which consists of expanded flying, copulation and laying eggs, or passively, hide themself through the unfavourable times. Based on facts discussed above, high RC belongs both to good and bad weather situations.

The present paper is a first one of those investigations, which are associated with the connection between the macrosynoptic situations of *Hess-Brezowsky* and the life circumstances of insects. To the further work, we think it necessary to reveal the characteristics of the behaviours connected with the times of variations of the weather situations. We hope, based on our new results, that a reliable forecast can be established using *Hess-Brezowsky*'s classification all over Europe. In Hungary the *Péczely*'s situations give also good approximation to plant-protection service.

Acknowledgements–The insects caught by light-traps were identified by a team at the Hungarian Museum for Natural Science under the direction of *Lajos Kovács*. The note-books were kindly disposed to us by *András Vojnits*, to whom we express our sincere acknowledgements hereby.

Table 1. The RC of turnip moth (*Scotia segetum Schiff.*) in situations when the *Hess-Brezowsky's* macrosynoptic type has the same character both in the evening and in the morning

Code	H-B situations	Mean of RC	Number of data	Confidence level
	Northern macrosynoptic types			
11	Na	0.757	97	94.45
12	Nz	0.922	463	91.68
19	HNa	0.930	248	-
20	HNz	0.772	376	99.84
18	HB	0.861	384	97.16
	Northwestern macrosynoptic types			
13	NWa	0.972	123	-
14	NWz	0.938	1139	92.68
27	TRM	0.733	240	99.25
	Western macrosynoptic types			
1	Wa	0.948	869	90.05
2	Wz	0.945	2512	96.16
3	Ws	1.020	483	-
	Southwestern macrosynoptic types			
7	SWa	1.295	661	99.90
8	SWz	0.960	471	-
28	TRW	1.210	1084	99.83
4	Ww	1.127	274	-
	Southern macrosynoptic types			
5	Sa	0.746	49	92.70
6	Sz	1.321	18	-
26	TB	1.200	446	96.30
	Southeastern macrosynoptic types			
9	SEa	0.775	66	-
10	SEz	0.812	6	-
	Eastern macrosynoptic types			
21	HFa	0.868	758	98.98
22	HFz	0.969	409	-
23	HNFa	0.895	249	-
24	HNFz	1.061	505	-
	Northeastern macrosynoptic types			
15	NEa	0.999	430	-
16	NEz	1.328	274	98.90
	Types with its center situated above Central-Europe			
17	HM	1.001	1032	-
30	BM	1.104	1055	90.34
25	TM	0.734	142	96.75

Note: The codes are obtained from the paper of *Bartholy* and *Kaba* (1987).

Table 2. The RC of turnip moth (*Scotia segetum Schiff.*) when the *Hess-Brezowsky*'s macrosynoptic types has been changed

Variable situations	RC	Number of data	Confidence level
FROM ZONAL ANTICYCLONE TO			
-zonal anticyclone	-	-	-
-zonal cyclone	0.757	123	97.71
-mixed anticyclone	0.892	188	-
-mixed cyclone	0.813	71	-
-meridional anticyclone	0.714	105	98.67
-meridional cyclone	1.231	103	-
FROM ZONAL CYCLONE TO			
-zonal anticyclone	0.567	106	99.99
-zonal cyclone	-	-	-
-mixed anticyclone	1.031	208	-
-mixed cyclone	1.240	122	90.57
-meridional anticyclone	1.126	24	-
-meridional cyclone	0.916	201	-
FROM MIXED ANTICYCLONE TO			
-zonal anticyclone	1.054	102	-
-zonal cyclone	1.359	276	99.34
-mixed anticyclone	1.058	124	-
-mixed cyclone	1.254	113	-
-meridional anticyclone	0.844	164	93.28
-meridional cyclone	0.976	326	-
FROM MIXED CYCLONE TO			
-zonal anticyclone	1.015	178	-
-zonal cyclone	1.450	72	90.54
-mixed anticyclone	1.073	171	-
-mixed cyclone	1.440	122	-
-meridional anticyclone	1.030	241	-
-meridional cyclone	0.783	120	97.36
FROM MERIDIONAL ANTICYCLONE TO			
-zonal anticyclone	0.543	72	99.75
-zonal cyclone	0.666	12	-
-mixed anticyclone	0.745	179	99.69
-mixed cyclone	1.132	53	-
-meridional anticyclone	1.245	225	94.38
-meridional cyclone	1.267	222	95.70
FROM MERIDIONAL CYCLONE TO			
-zonal anticyclone	1.102	115	-
-zonal cyclone	0.912	219	-
-mixed anticyclone	0.901	222	-
-mixed cyclone	1.182	176	-
-meridional anticyclone	0.833	247	96.59
-meridional cyclone	1.112	491	-

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VERSITA

Cent. Eur. J. Biol. • 8(8) • 2013 • 756-764
DOI: 10.2478/s11535-013-0195-0

Central European Journal of **Biology**

The growing abundance of *Helicoverpa armigera* in Hungary and its areal shift estimation

Research Article

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Received 11 January 2013; Accepted 18 April 2013

Abstract: The invasive Cotton Bollworm (*Helicoverpa armigera* Hübner, Lepidoptera: Noctuidae) has become a serious pest of several agricultural plants since its first mass occurrence in Hungary (1993). During the decades of the species' presence in the Carpathian Basin, a remarkable fluctuation was detected in its abundance and flight phenology. We analysed long term light trap records and meteorological data to identify the possible factors behind these fluctuations. This study presents an overview of the areal dispersion and the rate of accumulation and flight phenology of this invasive pest, from its first Hungarian mass occurrence until the present, focusing on the influence of climatic factors on the Hungarian distribution of *H. armigera*. According to our estimation, this pest occupied 94% of the area of Hungary within eight years. There were significant differences in pest pressure by regions, corroborated by the average number of trapped specimens and the regression coefficients. Fluctuations of specimen numbers in the different years are clearly visible in the flight phenology diagrams, which depend on the rate of the growing abundance. The results indicate that abiotic elements may also play a significant role in the areal dispersion of this important invasive insect.

Keywords: *Cotton Bollworm • Direction of distribution • Area reservation • Flight phenology • Climatic factors*

1. Introduction

The Cotton Bollworm, *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) is one of the most detrimental insect pests in the world. In Europe it causes substantial losses to maize, legume, fibre, cereal oilseed and vegetable crops [1]. Its original distribution area covers tropical and subtropical regions [2-5]. The species used to be recorded in Central Europe and also in Hungary, cycling in even larger numbers every 16th or 17th year, due to a possible major outbreak in its primary distribution area. In the past, this pest was unable to overwinter in Hungary due to cold winter temperatures and frost [6,7]. An unexpected presence in larger numbers has been observed all over the country since 1993 [8]. Its Hungarian accumulation can be considered continuous from this time. This phenomenon was reported by more cautionary publications [9-11], which suggested the possibility of Hungarian overwintering too [12,13]. Naturally, the strong correlation was proven between the mass accumulation and the agricultural damage caused by the larval stage of this pest in certain years (e.g. 1997, 2003) [8,14,15].

H. armigera is considered to be a facultative migrant, emigrating in response to a deterioration of its local environmental conditions to improve chances of adult survival and larval development elsewhere. The effects of temperature, vapour-pressure deficit and the availability of sugar solution over the pre-reproductive period have been investigated by Colvin and Gatehouse [16]. Migrant individuals usually appear in the Carpathian Basin at the beginning of the summer [17], with populations arriving in Hungary from south European areas, primarily from Serbia and Croatia. Its occurrence in the former Yugoslavia was reported in the monograph of Čamprag [18]. According to this

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monograph, the moth had two or three generations in Serbia, Bosnia-Herzegovina and Macedonia. The extreme accumulation and areal dispersion of the pest in this region and country was studied in detail and reported [18-21]. Meanwhile, a constant increase of the Hungarian population of the Cotton Bollworm was experienced by the years of millennium (2000-2013), a fact that might only be explained by the successful overwintering and subsequent local breeding of the species in the Carpathian Basin.

Climate change may affect both crop production areas and the distribution of their insect pests [22]. Tiedemann [23] predicted a northward shift in the areal border of some cultivated plants. This might result in a parallel northward shift of the distribution of insect pests of xerotherm plant species. By comparing agroecosystem models, Gourdiaan and Zadoks [24] concluded that climatic changes have a great influence on insect pests that follow their host plants. The objective of this study was to gain a deeper knowledge on the trends and pace of dispersion and flight phenology of *H. armigera* adults in Hungary and to evaluate the influence of weather fronts on the Hungarian distribution of this serious agricultural pest.

2. Experimental Procedures

We examined changes in the temporal patterns of CBW by processing imaginal catch data of the Hungarian Light Trap Network (Plant Protection Information System of the National Food Chain Safety Office) and the Hungarian Forestry Light Trap Network (Hungarian Forest Research Institute). Using data from both light trap networks allowed us to cover the whole area of Hungary (Figure 1).

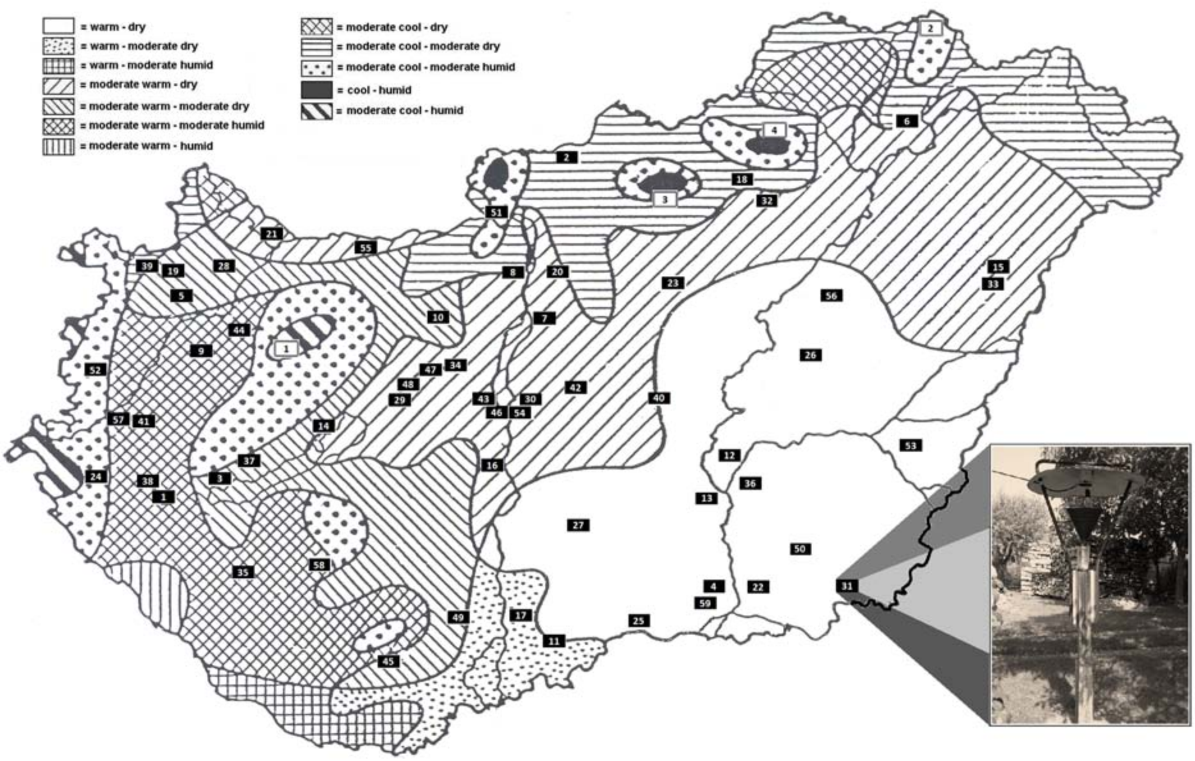

Figure 1. Locations of working light traps during 1993-2011 in Hungary as a function of the Péczely's climate disctricts. Explanation: the working period of the light trap indicated in brackets. *Light traps of the Hungarian plant protection information system*: 1.Andorháza-Pacsa (1959-2002), 2. Balassagyarmat (1968-2011), 3. Balatongyörök (1997-2006), 4. Balástya (1991-2007), 5. Beled (1991-98), 6. Bodrogkisfalud (1993-2007), 7. Budapest-Haraszti str. (1989-2007), 8. Budakalász (1999-2001), 9. Celldömölk (1968-2004), 10. Csákvár (2001-04), 11. Csávoly (1991-2006), 12. Cserkeszőlő (1991-2008), 13. Csongrád (2003-2007), 14. Csopak (1959-2004), 15. Debrecen (1995-2004), 16. Dunaföldvár (2001), 17. Dusnok (1991-2006), 18. Eger (1978-2007), 19. Fertőd (2002-08), 20. Gödöllő (2002-2004), 21. Győr-Bácsa (1991-2008), 22. Hódmezővásárhely (1959-2010), 23. Jászberény (1991-2008), 24. Kálócfa (1991-2006), 25. Kelebia (1993-2006), 26. Kenderes (1960-2008), 27. Kiskőrös (1993-2006), 28. Kóny (1994-2008), 29. Kőszárhegy (2003-10), 30. Kunszentmiklós (1998-2004), 31. Mezőhegyes (1999-2005), 32. Mezőkövesd (1992-2007), 33. Mikepércs (1958-94), 34. Nadap (1987-94), 35. Nagybajom (2000-06), 36. Nagytőke (1991-2008), 37. Nemesgulács (1990-2006), 38. Nemessándorháza (1991-2006), 39. Nyárliget (1997-98), 40. Nyársapát (1980-2007), 41. Oszkó (1999-2011), 42. Örkény (1999-2007), 43. Pálhalma (2004-05), 44. Pápa (1968-2006), 45. Pécs (1977-2006), 46. Rácalmás (1984-2000), 47. Sukoró (1995-2010), 48. Szabadbattyán (1997-2000), 49. Szekszárd (1991-2010), 50. Székkutas (1991-2008), 51. Szob (1999-2003), 52. Tanakajd (1959-2011), 53. Tarhos (1959-2005), 54. Tass (1959-97), 55. Tata (1976-2004), 56. Tiszaigar (1991-2008), 57. Vasvár (1968-1998), 58. Zimány (1992-1998), 59. Zsombó (1991-2008). *Hungarian forestry light traps*: [1.] Bakonybél (1991-2006), [2.] Kishuta (1998-2011), [3.] Mátraalmás (1993-2011), [4.] Répáshuta (1962-2011).

We examined the catch data of traps for the period between 1993 and 2011. The Hungarian dispersion of this pest and its growing distribution area was mapped year by year on the basis of specimen numbers caught by light traps. The estimated growth of the Hungarian distribution area of CBW was determined in absolute (km^2) and percentage (%) values, from its first mass appearance (1993) up to its current Hungarian distribution (2011). These calculations (the pixel numbers of pest dispersion area for different years) were carried out by C++ implementation methods [25].

The effect of climatic factors on the total number of trapped CBW over the years was examined by correlation-regression data analysis using SPSS 11.5, relating the total number of trapped specimens in Hungary to the climatic index (CI): CI=[(yi-Yi)^2/Di^2], i=1,2,3... (where: CI = the value of the difference of the mean; i = the macrosynaptic situations; y = the frequency in the given year; Y= the average frequency relating to reference period; D^2 = variance of the reference period) [26]. According to Major *et al*. [26] the difference of the mean of the years to average value was dependent on its climatic variability. The significance of the calculated correlation coefficient (R) was determined by the following equation: $T=R/\sqrt{(1-R^2)}\times\sqrt{(n-2)}$, at $P\leq 0.05$.

Mean values of the number of trapped CBW specimens (±SE) were calculated for the areas of the different Hungarian counties and were mapped on the basis of total yearly catch values. The intensity of the growing abundance of the Hungarian CBW populations for the different regions of the country was also examined by correlation-regression analysis using SPSS. The differences in the intensity of accumulation, characteristic of the changes in yearly specimen number by counties, are indicated by the of value "b" of the linear regression formula (y=a+bx) [27]. According to this value, five groups were established as follows: b>10: outbreak accumulation; b=2–10: strong accumulation; b=1–2: medium accumulation; b=0–1: moderate accumulation; b=0–-1: moderate decrease. The flight diagrams of three different years (1996, 2003, 2010) observed for Sukoró (Fejér county), as a function of the Walter-Lieth climate diagrams were plotted to illustrate the changing CBW flight phenology. The relevant meteorological data (precipitation, average temperature) originated from Turcsányi's [28] study.

We examined the quantitative distribution of the species in Hungary based on temperature and precipitation conditions. Péczely [29] divided Hungary into 12 climate zones: 1 warm–dry, 2 warm–moderate dry, 3 warm–moderately dry, 4 moderately warm–moderately dry, 5 moderately warm–moderately wet, 6 moderately warm–wet, 7 moderately cool–dry, 8 moderately cool–moderately dry, 9 moderately cool–moderately wet, 10 moderately cool–wet, 11 cool–wet, 12 very cool–wet. We assorted every light trap station into one of the Péczely-type climate zones and calculated mean values of trapped specimen numbers for each night and by climate zones. We established significance levels for each zone compared to the mean of all other zones, using Student's t-test.

3. Results

3.1 Hungarian distribution and areal dispersion of *H. armigera*

One representation of possible progression of invasion by year and potential shift of the area of *H. armigera* in Hungary is shown in Figure 2. As shown, the Central European invasion of this noctuid pest started in 1993 from the southern part of the Great Hungarian Plain. It occupied the central parts of Hungary, approximately 20% of the country, within the same year. After this, the areal dispersion is considered as continuous. The species first conquered the low-lying areas and then the mountainous regions (e.g. Bakony, Northern Hungarian Mountains). The largest Hungarian areal growth was recorded in 2000, and the smallest in 1998. The new light trap location cannot be noticed in 1997 as compared to the previous years. It is interesting to note that the western regions of Hungary, including the whole of Zala county, have not been infected by serious masses of *H. armigera* up to the present day.

Light trap catch data of *H. armigera* for the examined years are summarized in Table 1. The statistical examination unequivocally confirmed a positive linear correlation of the climatic representative index and the number of trapped specimens [R=0.736; $4.510(T)>1.746(T_{critic})$; ($P\leq 0.05$)]. Thus, the rate of the spread may be considered as a function of the climatic characteristics in the examined years. The moderately warm and arid years created excellent conditions for the rapid spread of this pest species. This statement was supported by the catch data of 1999 and 2000. The arid climatic conditions of the year 1999 provided an optimal background for the successful dispersion in the Carpathian Basin, and the subsequent high trapped specimen numbers and outbreaks were immediately observed in the following year. Nonetheless, for Hungary the highest abundance and the swarming peak of CBW occurred in 2003. This might be explained by a number of consecutive dry and warm seasons. The trapping data in this year exceeded any of the values of the previous years, and the number of specimens trapped

Figure 2. One of the theoretical spreading directions and yearly area reservation of *H. armigera* in Hungary based on the catch of light traps.

years	N.L.T.	T.N.I.	E.A.R.	
			(km^2)	(%)
1993	6	69	18760	20.13
1994	11	533	17060	18.34
1995	18	1088	7303	7.85
1996	24	769	9673	10.39
1997	13	102	no new registered area reservation	
1998	12	57	2834	3.04
1999	21	274	6830	7.34
2000	25	1322	22946	24.66
2001	38	79	1655	1.77
2002	36	3418	no new registered area reservation	
2003	41	11594		
2004	40	698		
2005	26	221		
2006	15	184		
2007	21	1319		
2008	15	1360		
2009	17	1186		
2010	12	641		
2011	6	81		

Table 1. The accumulation data and the evaluated area reservation of *H. armigera* from the first Hungarian appearance (1993) until present (2011). Explanation: N.L.T. = number of light traps, which trapped the CBW; T.N.I = total amount of trapped individual number in Hungary; E.A.R. = evaluated area reservations in the given year.

Explanation: N.L.T. = number of light traps, which trapped the CBW; T.N.I = total amount of trapped individual number in Hungary; E.A.R. = evaluated area reservations in the given year.

was nearly four times higher than the same value in the preceding year of 2002. The mass accumulation of the species is also verified by the outstanding number of light traps catching the CBW.

3.2 The rate of the growing of abundance and the phenological changes of *H. armigera* in Hungary

A mean value of the number of trapped specimens (±SE) is shown by Hungarian counties in Figure 3. Representing pest pressure, the trapped specimen numbers show a wide range of differentiation by county. The most significant pressure was recorded by the light traps of Fejér county. Its mean value was double that for Békés, the county ranked second in the row of highest pest pressure counties.

According to the number of trapped specimens, the southern counties of the Great Hungarian Plain (Békés, Csongrád, Bács-Kiskun) and the areas of the Northern Hungarian Mountains (Nógrád, Borsod-Abaúj-Zemplén) are also characterized by a significant presence of the pest. The rate of the growing abundance of *H. armigera* in Hungary is shown by county in Table 2. The differences in the rate of accumulation in the different regions are well described by the value "b" of the regression equation. Ten years after the first Hungarian mass appearance (1993), the rate of accumulation is stronger than what can be experienced in the long-term time series. Outbreak intensity was determined in more than 50% of the counties for the period examined first, and a strong intensity in 30% of the counties. The exceptionally high value of Fejér county is particularly conspicuous. Medium or moderate intensity was recorded only in the western Hungarian regions (Vas, Győr-Mosón-Sopron, Somogy). If we examine the long-term time series (1993-2011), a less intensive rate can be observed, declining strongly in some cases. This decrease is also characteristic in the case of some counties of the Great Hungarian Plain (Csongrád, Bács-Kiskun). Only in Győr-Moson-Sopron could we detect a more significant long-term growth of abundance during the Hungarian colonization.

As mentioned before, 2003 was a year of outbreak and mass accumulation in Hungary (Table 1). Arid climatic conditions during the dry and warm years provided excellent conditions for the mass accumulation of the species in 2003. This phenomenon is clearly demonstrated by the estimated flight phenology diagrams. A good example of this is shown by the flight diagrams of Sukoró (Fejér county), observed in three different years (Figure 4). The dominant arid conditions – shown in the Walter-Lieth climatic diagram

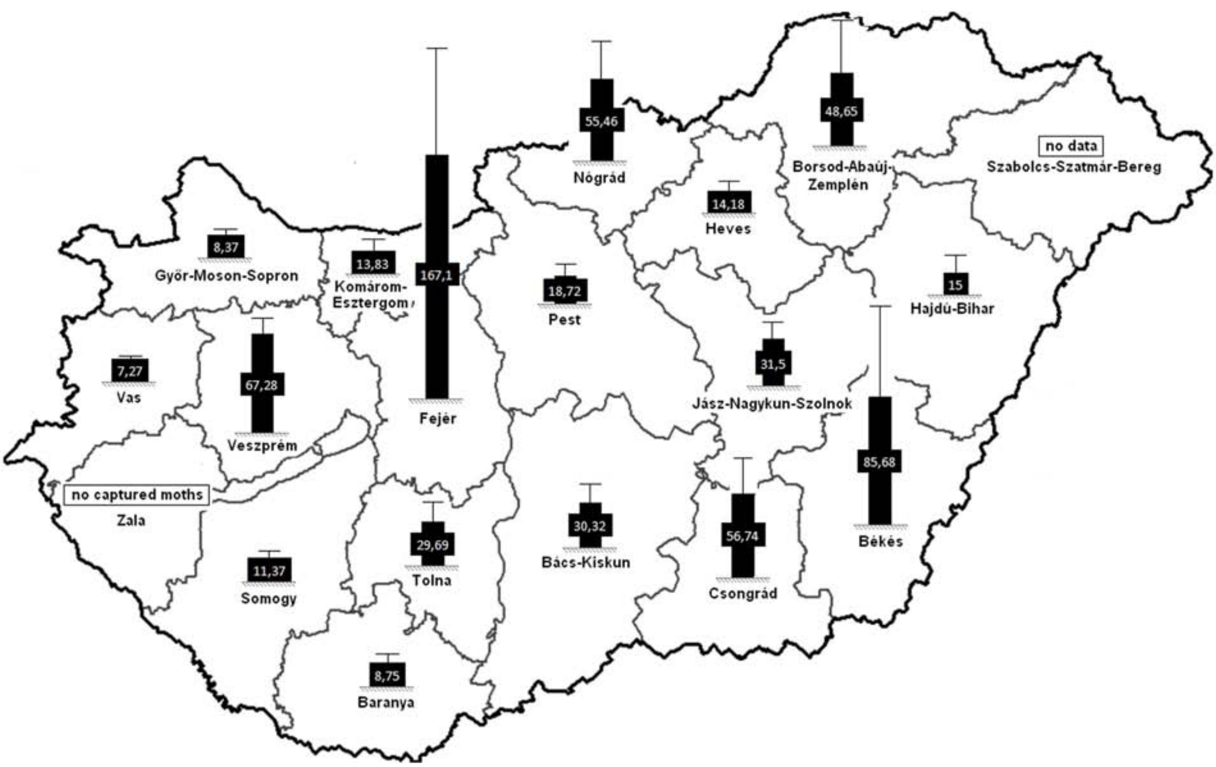

Figure 3. The average trapped individual numbers per years of *H. armigera* by Hungarian county on the basis of all trapped data between 1993-2011.

county	1993-2003 regression formula (y=a+bx)	1993-2003 char. individ. numb. chang.	1993-2011 regression formula (y=a+bx)	1993-2011 char. individ. numb. chang.
Győr-Mosón-Sopron	y=13.75+0.750x	mod.ac.	y=1.673+2.544x	strong ac.
Komárom-Esztergom	y= -16.83+11x	outbreak.ac.	y=7.666+1.187x	medium ac.
Veszprém	y= -21.46+6.899x	strong ac.	y=9.747+1.874x	medium ac.
Vas	y=2.612+1.060x	medium ac.	y=11.230-0.387x	mod.decr.
Zala	no captured moths			
Fejér	y= -120.7+66.81x	outbreak.ac	y=124.400+13.680x	outbreak.ac
Somogy	y=10.123+0.566x	mod.ac.	y= 12.957-0.301x	mod.decr.
Baranya	y=2.333+3.333x	strong ac.	y=0.5+1.833x	medium ac.
Tolna	y= -120+56.82x	outbreak.ac	y=17.143+1.186x	medium ac.
Pest	y=19.40+2.616x	strong ac.	y=30.406-0.099x	mod.decr.
Nógrád	y= -34.23+17.55x	outbreak.ac	y=47.368+0.964x	mod.ac.
Bács-Kiskun	y= -34.28+15.81x	outbreak.ac	y=34.910-0.880x	mod.decr.
Jász-Nagykun-Szolnok	y= -45.70+26.79x	outbreak.ac	y= 18.96+1.418x	medium ac.
Borsod-Abaúj-Zemplén	y= -184.2+51.06x	outbreak.ac	y=58.15+3.681x	strong ac.
Szabolcs-Szatmár-Bereg	no data			
Heves	y= -19.50+5.518x	strong ac.	y= -0.186+1.646x	medium ac.
Hajdú-Bihar	y= 0.702+9.405x	strong ac.	y=23.70-0.965x	mod.decr.
Békés	y= -60.58+24.71x	outbreak.ac	y= -9.307+6.402x	strong ac.
Csongrád	y= -20.74+12.69x	outbreak.ac	y=42.24-0.243x	mod.decr.

Table 2. The comparisons of the rate of growing abundance of *H. armigera* by Hungarian county in two time periods.

Explanation: char. individ. numb. chang. = characteristics of the yearly individual number changing; outbreak.ac. = outbreak accumulation (10-); strong ac. = strong accumulation (2-10); medium ac. = medium accumulation (1-2); mod. ac. =moderated accumulation; (0-1); mod. decr. = moderated decreasing (0- -1).

– intensified the mass appearance of *H. armigera* in 2003. This outbreak exceeded those in both in 1996 and in 2010 if we consider the length of swarming period or the number of specimens trapped.

Cotton Bollworm was caught in the largest numbers in moderately hot and dry and moderately warm areas (Table 3). A significant number of specimens were collected even in moderately warm and moderately humid zones. It is obvious that these zones were most favourable for both the development and the light trapping of the moth. In contrast, dry and wet zones were unfavourable.

4. Discussion

The areal dispersion of the Cotton Bollworm can be considered as continuous in Hungary after the first mass colonization. This adventive and invasive species occupied 94% of the area of Hungary in eight years. The areal penetration, induced by the strong ability of the species for migration and its good vagility, was proved to be influenced also by the climatic characters of the given years [23,30].

There were significant differences in pest pressure by region, corroborated by the average number of trapped specimens and the regression coefficients. It is very likely that a possible spread due to successful overwintering in Hungarian populations [31] and a growing proportion of caterpillars breeding without a diapause were playing an important background role, causing a more significant presence of the pest.

Fluctuations of specimen numbers in the different years are clearly visible in the flight phenology diagrams. The peak, *i.e.* the mass outbreak of *H. armigera* culminated in 2003, following the initial rapid colonization. This phenomenon was also reported by several Hungarian studies [14,15,32,33]. Later, after the years of acclimatisation, a decreased number of specimens were detected and the values stabilized at lower levels. Unfortunately, the early summer generation may not be included in our calculations, because

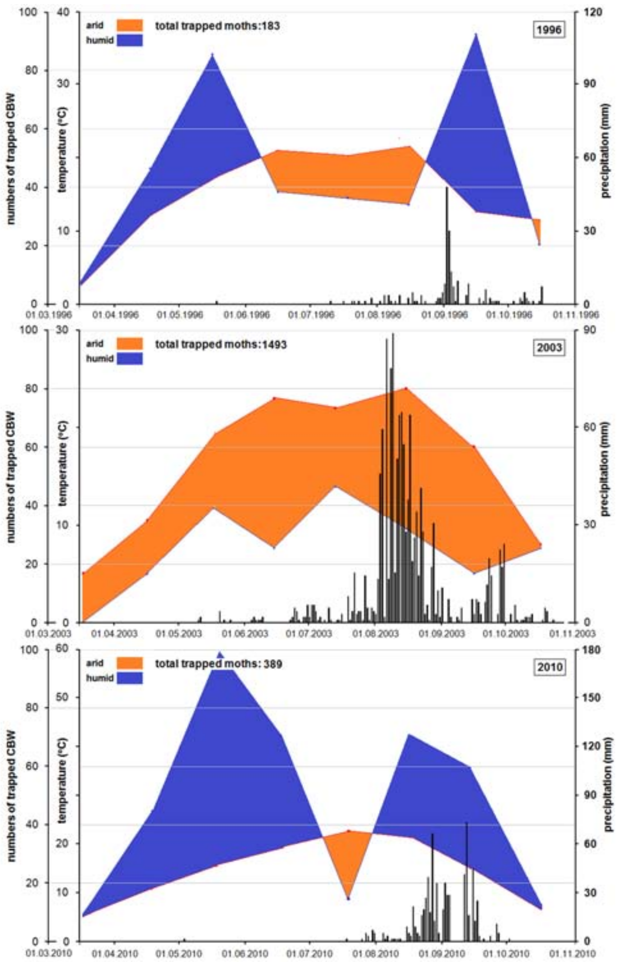

Figure 4. Flight phenology diagrams of *H. armigera* in Sukoró (Fejér county) in 1996, 2003 and 2010 as a function of the climatic features. Explanation: Average temperature and aggregated precipitation were indicated on the vertical axis of Walter-Lieth climate diagram (1:3) according to whether of Central-Europe.

Number	Péczely-type climatic zones	Average number of individuals	P<0.05
1	warm – dry	2.453	0.001
2	warm – moderately dry	9.532	0.001
4	moderately warm – moderately dry	7.877	0.001
5	moderately warm – moderately wet	3.243	-
6	moderately warm –wet	1.679	0.001
9	moderately cool –moderately wet	2.640	0.05
10	very cool – wet	2.389	0.01

Table 3. The average catch and significance of *H. armigera* by Péczely-type climatic zones.

Explanation: The 3, 7, 8, 11 and 12 zones had non-functioning light-traps.

this migrating brood can be detected only by the sex pheromone attractant traps [18,34].

Finally, we have to mention that any climatic warming period may quickly and substantially increase the number of generations as well as the arrival of this adventive insect species [16]. Accordingly, a possible future global warming could provide perfect conditions for the European expansion of this moth species.

Acknowledgements

We are indebted to the workers of National Food Chain Safety Office and Hungarian Forest Research Institute, especial to Dr. Géza Ripka and Dr. György Csóka granting access to data from the national and forestry light trap system. We would also like to thank Dr. Csaba Károssy for providing the climatic representative index and Dr. György Kovács for preparing the objective image pixels analysis.

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Acta Phytopathologica et Entomologica Hungarica 32 (3–4), pp. 333–348 (1997)

Light Trapping Success of Heart-and-Dart Moth (*Scotia exclamationis* L.) Depending on Air Masses and Weather Fronts

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The Jermy type light-trap network – unprecedented even at world standards – has been working all over Hungary since 40 years. The collecting success is influenced by a number of abiotic factors. We examined from these factors the influences of the weather fronts, air masses, the height of tropopause and the microbarographic oscillations to make a useful prognosis by using these gigantic data. We got the meteorological data measuring hourly in Budapest by National Meteorological Service. We categorized the weather fronts, discontinuity surfaces, the surface and upper air masses after Berkes (1961). We determined the upper air masses according to the measuring of radiosondes giving informations about the cross-section in time. We used for our examinations the data of the heart-and-dart moth (*Scotia exclamationis* L.) adults getting from the light-trap network in Hungary. We chose the data taking from 6 observing stations working surroundings Budapest.

For determining the mass ratio and swarming time of nocturnal insects, the light-trap is the most widely used sampling device. In Hungary, the introduction of the light-trap network, unprecedented even at world standards, was started in 1953 by professor Jermy.

The Hungarian light-trap network has provided priceless scientific material in the last decades for entomological basic research and plant protection prognostication. If we want to use the catch data for prognostication, we must accept as basic principle that in so far as the light-trap works under identical circumstances all the time, the number of catches is identically proportionate in any case to the population density in the surroundings. Only on this basis can it be assumed that a larger catch means a larger number of insects present in the surroundings. Still, even the same light-trap cannot work under identical circumstances during two different nights, nor at two different times of the same night, as catching insects by light-trap is affected, apart from the biotic factors, by a number of abiotic ones.

The situation would be much more favourable if we were able to recognize the factors that influence the efficiency of trapping, and to reveal their effect. No wonder that a number of researchers are engaged either in Hungary or all around the world in studying the role of different environmental factors, first of all weather and moonlight. The primary aim of the large-scale studies is to know as many effects of abiotic factors modifying the catches as possible. When the role of the majority of the most effective factors has been recognized, we will have the possibility to correct the prevailing trapping results

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of the species involved. This being done, the corrected catch date, parallel to our increasing knowledge, will approach a value that will proportionately represent the real density of populations in any case.

The frontal passages and changes of air mass cause the sudden and fundamental changes of living creatures' physical environment. The organism of a person or animal answer with front sensitivity symptoms for all the simultaneous changing of weather factors. The behaviour of insects and their flying activity were examined connected with variant front types and air masses by a few researchers in contrast to wide medical meteorological researches. The effect of weather fronts on light trapping of insects was examined by Wéber (1959) in Hungary. In his opinion the research of the front changing effect is hindered by a number of factors (fronts can follow one another with one or two hours differences, weather fronts can pass through without changing of air masses, the intensities of some kinds of fronts can be different). Because of these problems he did not try to determine general regularities in his works. Justed of this he proved the modifying influences for catching of weather fronts with graphic method after the examination of some concrete, typical events. The influences of air masses were also examined by Wéber (1957). He made certain the number of insects caught is significantly the highest at the arrival of subtropic air masses. Járfás (1979) preferred to examine each weather factor instead of weather fronts because of mentioned problems. Kádár and Szentkirályi (1991) showed that the flight activity of ground beetles (Coleoptera, Carabidae) decreases at arrivals of cold fronts, but it increases at arriving warm fronts. They used the front- and air mass calendar issued by the Hungarian National Meteorological Service. These two kinds of front types were determined in this calendar. The light trapping results were examined in New Zealand in relation to cold fronts by Helson and Penman (1970). They experienced ion activity maxima short fly before their arrivals. We did not find fundamental publications in the literature about connections with weather fronts and light trapping.

The great number of collecting data getting from our national light-trap network is suitable to study the influence of weather fronts with mathematical-statistical methods, too. That is why we had to expand our research work in this direction to get suitable results in plant protection forecasting.

Materials

We got the meteorological data from measuring hourly in Budapest by the National Meteorological Service. We used the hourly observations for determination of frontal passages and discontinuity levels. We considered also temperature, atmospheric humidity, wind direction and strength, cloudiness, visibility and air pressure data. We used the categories of weather fronts and discontinuity levels determined by Berkes (1961). The classification of the surface and upper air masses were also made following Berkes (1961). We determined the upper air masses examined the so-called cross-sections in time using the informations of radiosondes that took off at Budapest-

Szentlőrinc. There were two takings off daily. We hereby express our gratitude to the management of the National Meteorological Service for furnishing these data. The taking off were at 0 and 12 o'clock in universal time (UT). The data of temperature, atmospheric humidity, air pressure, wind direction and strength were measured by the ballon radiosonde and relayed on sender to the observing station. The points indicating changes, so-called "marked points" are given in forms of telegraphic code. Several meteorological data can be counted using these informations and a special calculating rule (similar to the slide-rule), for example equipotential temperature. The used method saves "conservative characteristics" of the air. This means whether the temperature or the atmospheric humidity change, the "heat content" of air fragment is shown by the several combinations even at 9 km height.

The values of equipotential temperature drawing one over the other, result in get a curved line, which can change from day to day or even hour by hour according to the weather situations. We determined in the cross-sections characteristic data of "main" air masses using "typehomologs" according to Schinze (1932) from Germany. In this way we got the following types: polar cold, polar warm and subtropical ones. It was clear from the early sixties, that the upper division of air types in Carpathian Basin are different from the "Central European" model. That is why we calculated for every month the basis values of temperature, relative humidity, specific humidity equivalent and equipotential temperature for the 1000, 850, 700, 600, 500, 400 and 300 hPa pressure surfaces using the aerological data measured in Budapest during 6 years. The typehomologs were determined for polar, cold, temperate, warm and subtropical air masses using the informations. The continental and maritime air masses were also separated. If the actual equipotential temperature curved line shows the changings of these air masses, examining the barometric data we can determine the belonging heights. If the boundaries of distinct air currents are registered, thus the air masses being above one another can be separated. Examining the vertical cros-ssection of the tropopause is the apart air current between the lower air masses (troposphere) and the upper air masses (stratosphere) can be determined. The height of troposphere is variable, because at the time of very cold polar air it is only 5 km, but at subtropical air mass it can be even 16 km. Sometimes there are 2–3 tropopauses above one another. In this case we can wait for strong weather changes or we find cloudless, anticyclonic weather situation.

We worked with the following air masses in our examinations: *1. mA* maritime polar air, coming from the area of Greenland and Spitsbergen on polar axis through the North Sea, *2. cA* continental polar air, coming through the European territories of Russia on ultrapolar axis, *3. mK* maritime cool air, coming from the area of Iceland and Scotland on polar axis, *4. rK* returning maritime cool air from SW direction, *5. cK* continental cold air, coming from North Siberia on ultrapolar axis, *6. r'K* returning polar (cK) air from SE direction, *7. mM* maritime air coming from the area of 50° north latitude, *8. m'M* Mediterranean air, *9. m"M* Black Sea air, *10. cM* continental air coming from the area of 50° north latitude, *11. mW* maritime warm air, *12. m'W* Mediterranean warm air from SW direction, *13. m"W* warm air coming from the Black Sea, *14. rW* returning maritime warm air, *15. r'W* returning warm air (m"W or TM) from NE direction, *16. cW* continental warm air, *17. mT* air coming from the Azores with W and WSW direction, *18. m'T* Saharian air coming through the Mediterranean Sea, *19. m″T* Saharian air coming through the Black Sea, *20. TM* subtropical air, *21. cT* continental subtropical air coming from the Near-East with SE direction, *22. S* Saharian (cT) air (observable only at upper levels).

The weather data of fronts and apart air currents exactly fit into the vertical cross-sections, even they show the boundaries of colder or warmer air masses in upper air masses. This is independent of the front types near the surface. The different air masses and apart air currents were also classified following Berkes (1961): *1. W* surface warm front, *2.* W_h upper warm front, *3.* O_w warm occluded front, *4.* W_u unstable warm front, *5.* W_m masked warm front, *6. C* surface cold front, *7.* C_h upper cold front, *8.* O_c cold occluded front, *9.* C_u unstable cold front, *10.* C_m masked cold front, *11.* C_p paradox cold front, *12. O* neutral occlusion, *13.* O_{OR} orographic occlusion, *14.* S_{ww} stationary front that arrives and leaves as warm front, *15.* S_{cc} stationary front that arrives and leaves as cold front, *16.* S_{wc} stationary front that arrives as a warm front and leaves as a cold front, *17.* S_{cw} stationary front that arrives as a cold front and leaves as a warm front, *18. D* subsidence in general, *19. D′* descending motion between two cold fronts, *20. S* destroying high pressure system, accompanied by following falling barometric tendency. The weather fronts were numbered following Berkes (1961), and we used the 0, 1 and 2 exponents for characterization of their power.

We also used the data of microbarographic oscillation for our examinations. The instrument used for this measurement was made in the years before World War II. The air was exhausted from a 30 liter flask jointed to a very sensitive barometer. The time is registered on a 10 minutes graduation, the hourly registrations are about 20 mm and a sinus graph is written on the paper of relative graduation hourly. If there are weather changes or front passages the values change. There are 3 different classes. The class 0 is if the frequency writes one sinus wave and its amplitude is 2 mm. In class 1 the frequency of waves is between 3–5 and the amplitude is 5 mm. In class 2 the frequency is above 5 and the amplitude is above 5 mm. These are in relation to the long-wave electromagnetic radiation according to German literature (Daubert, 1955).

We used for our examinations the data collected by six light-traps operating in the surroundings of Budapest. We worked with the catches of heart-and-dart moth (*Scotia exclamationis* L.). We could not make a comparison between the meteorological data and the collecting results coming from all of the observing stations, because the validity territories of air masses and weather fronts are uncertain, and the territory studied does not extend to the whole country (Csizsinszky, 1964). We chose this species, because it swarms in two generations yearly and it can be caught in great numbers generally between May and September.

The Jermy type light-trap is a modified version of the Minnesota type one, from which the guide-sheets have been removed. The light source is a 100 W normal light bulb at 2 meters above the ground, colour temperature: 2900 K, the killing material is chloroform. The traps of plant protection institutions worked from 1st April to 31st October, while those of the forestry all the year round, independent of the time of sunrise and sunset, every night from 6 p.m. to 4 a.m. The insects trapped during one night were stored in one bottle, so the whole catch of one night at one observational site is interpreted as one observational datum. We got data from the observing stations as below: Budakeszi (1962–1970), Budatétény (1960–1967), Budapest-Rókushegy (1959–1967), Nagytétény (1959–1976), Martonvásár (1960–1961) and Érd (1977–1979). We used altogether the data of 1762 nights, 7239 individuals and 3461 observations. We consider catching data of each night at one observing station independently of caught individuals. We hereby express our gratitude to Dr. Pál Szontágh, Doctor of Agricultural Science for collecting data from forestry light-trap, Dr. András Vojnits (Museum of Natural Science) and Mrs. Gy. Mohai (Budapest Phytopathological and Soil Protecting Station) for collecting data from light-trap of plant protection.

Methods

The number of the individuals trapped at different observation sites and times cannot be compared to each other even in the case of identical species, as each trap works in a different environment, and the environmental factors vary constantly according to time as well. To solve the problem, from the catch data we calculated relative catch (RC) values for observation sites, species and generations. RC is the quotient of the number of individuals caught during the sampling interval (1 night or 1 hour), and the mean values of the number of individuals of one generation counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

The research on influence of air masses were made according to more points of view. We separated those cases at examinations on the influence of air masses near the surface when the same air masses were in the surrounding of the selected light-trap during the night and those ones where air masses changed during the night. The same air mass spends longer time in upper air-layers then in lower ones. Because of this here we could separate the collecting results belonging to the arriving days and following ones. Using this method we could examine whether the influence of arriving air masses and staying for a long time ones on flight activity are the same or not.

We examined separately the success of trapping at those nights when the air masses near the surface and when the air masses in the upper air-layer there are same. We also made an examination for the success of collection in those cases when the air masses were mixed with one another not far from the surface.

We calculated the success of light trapping connected with nocturnal averages of heights of tropopause and also in the cases of multiple tropopause. We worked up separately the catch data of those nights in the examinations for supposed influence of weather fronts and discontinuity levels when there was only one front effect and when the weather fronts changed one another. Finally we compared the successes of light trapping when the microbarographic oscillations changed during the night.

We summarized and averaged the results of relative catches coming from several observing stations for each nights in the flying period of heart-and-dart moth (*Scotia* *exclamationis* L.) connected with the air masses, weather front types, height values of tropopause and microbarographic oscillation. The supposed influence of multiple tropopause in modifying the catch result was examined compared with light trapping results of preceding and following days. We compared the differences of the averaged relative catch values of each case with the averaged ones of the sum of all other cases. The significance levels were calculated by *t*-test.

Results

Our results are shown in Tables 1–9.

Discussion

A few numbers of individuals were caught by the light-trap if the same cold air mass was near the surface (1. mA, 2. cA, 4. rK, 5. cK). This conclusion is also right at that time, when there are 1. mA or 2. cA air masses both near the surface and in upper level. The catch is also small, if 7. mM air mass is near the surface or 10. cM one in upper part. The collecting is successful if there are warm air masses above the surface (9. m″M, 11. mW, 12. m′W, 13. m″W, 14. rW, 15. r′W, 16. cW, 17. mT, 18. m′T, 19. m″T and 21. cT) and if 9. m″M, 13. m″W, 15. r′W and 20. TM air masses are present near the surface and also in the upper air-layer. These results support our knowledge, the flight activity of insects is low in cold air and it is high in warm one. We got interesting results by examining the collecting success of arriving days belonging to different air masses and compared with following days. We found lower collecting in several cases on arriving days and higher light trapping results on following days with the same air masses (1. mA, 11. mW, 19. m″T, 20. TM and 21. cT). We noticed sometimes opposite phenomena (2. cA, 9. m″M, 14. rW, 15. r′W and 22. S). We found the effectiveness of subtropical air masses in increasing flight activity and of course light-trap catching, especially the 17. mT, 18. m′T and 22. S air masses on arriving days, and 20. TM and 21. cT on following days. This three kinds of air masses show strong biological activity in human biometeorology as well. It was suprising that the catch decreased on the arriving day and following ones of 19. m″T air coming from the Black Sea.

The surface 1. mA and 2. cA air are unfavourable for light trapping, but if there is 17. mT above the surface 1. mA, the activity of moths increases. We found the same in the activity when above the Mediterranean warm air (12. m′W) arrives bringing fresh subtropical air from the Azores (17. mT). The 20. TM air mass do not cause development in collecting, but arriving above 17. mT or 18. m’T means increase in the catch. May be because of the strong atmospherical electricity the effectiveness of light trapping is high if Saharian air comes above maritime temperate air (7. mM). This hypothesis is found on results of spherics measuring made by Sulman (1976) in Israel.

Table 1

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest connected with unchangeable air masses during the night

No. and code of air masses		Unchanging during the whole night near the surface		Unchanging during the whole night in upper air layers				Same near the surface and in upper air layers	
				on arriving day		on following days			
		RC	Sign. (%)	RC	Sign. (%)	RC	Sign. (%)	RC	Sign. (%)
1	mA	0.740 (204)	99	*0.922* (154)	95	*1.116* (94)	95	0.863 (72)	95
2	cA	0.659 (41)	95	*0.991* (49)	–	*0.791* (40)	95	0.464 (12)	90
3	mK	0.969 (378)	–	0.851 (167)	99	0.815 (84)	99	0.912 (78)	90
4	rK, m′K	0.727 (29)	95	0.915 (35)	90	0.124 (7)	–	1.322 (6)	–
5	cK	0.470 (15)	95	0.577 (3)	–	–	–	–	–
6	r′K	–	–	0.370 (8)	–	0.540 (3)	–	0.370 (8)	–
7	mM	0.941 (370)	95	0.922 (331)	95	0.934 (179)	90	1.023 (135)	–
8	m′M	0.993 (68)	–	0.965 (84)	90	1.031 (27)	–	0.900 (7)	–
9	m″M	1.544 (34)	99	*1.318* (32)	95	*1.088* (21)	–	1.643 (12)	95
10	cM	1.012 (193)	–	0.976 (196)	–	0.878 (79)	90	0.722 (35)	95
11	mW	1.328 (60)	99	*0.696* (138)	99	*1.279* (59)	99	0.861 (8)	–
12	m′W	1.137 (131)	90	1.116 (195)	90	0.995 (95)	–	1.011 (42)	–
13	m″W	0.907 (30)	90	1.698 (13)	90	–	–	–	–
14	rW	1.834 (35)	99	*1.075* (99)	–	*0.833* (44)	95	–	
15	r′W	0.907 (30)	90	*1.486* (23)	95	*0.916* (19)	–	1.021 (9)	
16	cW	1.207 (55)	95	1.064 (136)	–	1.077 (67)	–	0.927 (9)	
17	mT	1.106 (145)	90	1.140 (221)	95	1.001 (296)	–	0.954 (101)	
18	m′T	1.121 (311)	95	1.114 (143)	95	0.953 (244)	95	0.888 (135)	95
19	m″T	1.512 (60)	99	0.311 (10)	95	0.873 (20)	95	0 (3)	
20	TM	1.033 (65)	–	*1.053* (86)	–	*1.262* (154)	99	1.618 (51)	95
21	cT	1.202 (26)	95	*1.078* (64)	–	*1.530* (63)	99	1.307 (6)	
22	S	–	–	*1.428* (41)	99	*1.068* (111)	–	–	

Notes: The number of observing data are given in parenthesis under values of relative catch. The differences in the averaged relative catch value were compared in each case with the averaged ones of the sum of all other cases. The significance levels were calculated with *t*-test. Significance levels are also shown by italics at upper air layers when the values of relative catch on arriving days and following ones differ more than to 95%.

Table 2

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest when the air masses near the surface and higher are not same

Air masses near the surface	Upper air masses	Relative catches	No. of data	Air masses near the surface	Upper air masses	Relative catches	No. of data
1 mA	3 mK	**0.596**	32	8 m'M	17 mT	*0.847*	13
1 mA	7 mM	**0.657**	31	8 m'M	18 m'T	**1.823**	23
1 mA	10 cM	**0.587**	28	8 m'M	20 TM	*0.878*	17
1 mA	11 mW	**0.746**	22	10 cM	2 cA	**1.646**	24
1 mA	16 cW	**0.475**	16	10 cM	3 mK	**0.839**	22
1 mA	17 mT	**1.477**	24	10 cM	7 mM	1.068	35
2 cA	1 mA	**0.671**	14	10 cM	8 m'M	**1.335**	22
2 cA	10 cM	**0.393**	12	10 cM	11 mW	**1.307**	12
3 mK	1 mA	1.005	46	10 cM	14 rW	**0.394**	16
3 mK	4 rK	1.008	59	10 cM	16 cW	**0.675**	11
3 mK	7 mM	*0.907*	119	10 cM	17 mT	0.991	28
3 mK	10 cM	**0.847**	43	10 cM	18 m'T	**0.607**	19
3 mK	11 mW	**0.305**	21	10 cM	20 TM	**0.884**	14
3 mK	12 m'W	1.066	14	11 mW	17 mT	**0.723**	18
3 mK	14 rW	1.013	20	11 mW	18 m'T	**2.018**	14
3 mK	16 cW	1.041	22	12 m'W	8 m'M	**0.520**	16
3 mK	17 mT	**0.675**	36	12 m'W	10 cm	1.122	12
3 mK	18 m'T	**0.769**	17	12 m'W	17 mT	**2.029**	12
3 mK	20 TM	**0.787**	19	12 m'W	18 m'T	**0.756**	14
7 mM	1 mA	**0.699**	14	16 cW	17 mT	**1.550**	17
7 mM	3 mK	**0.800**	40	16 cW	18 m'T	**1.500**	16
7 mM	8 m'M	**1.242**	38	17 mT	7 mM	**0.577**	24
7 mM	10 cM	0.990	36	17 mT	11 mW	**0.780**	18
7 mM	11 mW	**0.676**	52	17 mT	18 m'T	0.967	14
7 mM	12 m'W	*0.941*	14	17 mT	20 TM	**1.549**	22
7 mM	14 rW	*0.858*	26	17 mT	22 S	0.922	17
7 mM	16 cW	**0.773**	26	18 m'T	7 mM	**0.404**	12
7 mM	17 mT	**1.246**	92	18 m'T	8 m'M	**1.313**	49
7 mM	18 m'T	**0.692**	40	18 m'T	10 cM	0.992	12
7 mM	20 TM	**0.904**	16	18 m'T	12 m'W	1.084	16
7 mM	21 cT	**0.542**	15	18 m'T	17 mT	*1.111*	39
7 mM	22 S	**1.562**	18	18 m'T	20 TM	**1.314**	26
8 m'M	7 mM	**1.758**	14	18 m'T	22 S	1.028	43
8 m'M	10 cM	*0.700*	12	21 cT	10 cM	*1.425*	11
8 m'M	12 m'W	**0.719**	17	21 cT	18 m'T	*0.839*	11

Notes: Only those air masses are shown in the table which were frequent and at the time of simultaneous occurrence the values of relative catch have significant difference compared with the relative catch values of all the other observing data. The significance levels are shown with bold numbers (more than 99%) and italic ones (more than 95%).

Table 3

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest when the air masses near the surface change one another during the night

Previous air masses	Following air masses	Relative catches	No. of data	Previous air masses	Following air masses	Relative catches	No. of data
1 mA	3 mK	*0.826*	24	7 mM	16 cW	*1.509*	11
3 mK	1 mA	**0.715**	70	7 mM	18 m′T	1.134	17
3 mK	7 mM	**0.594**	31	8 m′M	7 mM	**0.596**	17
3 mK	10 cM	**1.514**	32	10 cM	7 mM	**0.494**	23
4 rK	3 mK	**1.848**	11	11 mW	7 mM	**0.708**	23
7 mM	3 mK	**0.718**	100	17 mT	7 mM	1.018	25
7 mM	8 m′M	*1.200*	24	18 m′T	7 mM	**2.598**	14
7 mM	11 mW	*0.396*	12	18 m′T	17 mT	*0.784*	16

Notes: Only those data are shown in the table which are frequent or the values of relative catch have significant difference examined the relative catch values belonging to all the other observing data. The significance levels are shown with bold numbers (more than 99%) and italic ones (more than 95%).

The number of caught individuals is low on those nights when there are different air masses in the surfacial and upper air-layers and we can find 1. mA, 2. cA, 3. mK, 7. mM, 8. m′M, 11. mW, 12. m′W and 17. mT ones near the surface except when there are simultaneously warm air masses high above in the air (17. mT, 18. m′T, 20. TM, and 22. S). We observed hight catch in most cases, if there were warm air masses near the surface (16. cW and 18. m′T). We could find both high and low collecting results connected with surface air masses (10. cM and 21. cT). The catching is very high if on the surface there is continental temperate air (cM) – which has neutral effect in human biometeorology – and continental polar air arrives above it, which used to come with cold fronts.

We found high catch in that cases, when the arriving cold front brings temperate maritime air (7. mM) in place of Saharian air coming through the Mediterranean Sea (18. m’T) which is with the strong activity of spherics (electromagnetic radiation).

During the nights we could determine almost all of the combinations of mixed or very changeable air masses near the surface. High and low light trapping results can also belong to these ones. Although high numbers of trapping data were available no significant differences could be established in the combinations of air masses present. We cannot come therefore to final conclusions based on a number of trapping data.

The explanation of insects’ behaviour is hindered, because the examinations of concrete weather characteristics belonging to the mixed air mass and the mentioned changings are not yet finished.

We found close positive correlation between the height of tropopause and the number of specimen for light trapped moths. Our results getting with the examination of influences of air masses are confirmed by this fact. The low tropopause has a connection

Table 4

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest in the frequent cases of mixed air masses near the surface

First arriving air mass	Later arriving air mass	Relative catches	No. of data	Significance level (%)
1 mA	3 mK	0.675	35	99
2 cA	1 mA	1.327	12	95
3 mK	1 mA	0.804	32	99
3 mK	7 mM	0.888	81	99
3 mK	10 cM	0.746	43	99
7 mM	1 mA	0.483	10	90
7 mM	2 mK	0.783	86	99
7 mM	10 cM	0.667	18	95
7 mM	11 mW	1.399	19	99
7 mM	16 cW	0.865	16	95
7 mM	17 mT	0.723	37	99
7 mM	18 m′T	0.847	73	99
10 cM	1 mA	1.179	16	90
10 cM	3 mK	0.904	65	95
10 cM	7 mM	1.815	24	99
11 mW	7 mM	0.475	26	99
11 mW	17 mT	0.602	12	95
12 m′W	8 m′M	1.619	12	95
12 m′W	18 m′T	0.399	15	95
16 cW	11 mW	1.362	15	95
16 cW	7 mM	1.162	25	90
16 cW	8 m′M	1.978	11	95
16 cW	17 mT	0.544	13	95
17 mT	7 mM	0.689	26	99
18 m′T	12 m′W	0.466	14	95
21 cT	18 m′T	1.796	12	95

Notes: Only those frequent mixed air masses are shown in the table, when the relative catch values differ significantly from the relative catches of all the other observing data.

with presence of cold air masses and high tropopause with warm ones. Depending on in which part of the day the multiple tropopause was observable, we found differences in catching. The multiple tropopause generally anticipates energetic weather changes. If it was noticed during the day time the success of light trapping already decreased significantly during the same night. If the multiple tropopause was observed only in the evening or at night the decrease of collecting was only noticed during the next night. The unfavourable catch result remained still during next nights in all three cases. The height of tropopause above 13 kilometres shows influx of subtropical air mass in great height and it has strong biological effectivity. The above-mentioned weather changes also show in

Table 5

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest connected with the average height of tropopause at night

The average height of tropopause at night (km)	Relative catches	No. of data	Significance levels (%)
8.2	**0.607**	34	99
9.0	**0.775**	83	99
9.5	**0.874**	94	95
10.0	**0.902**	401	95
10.5	**0.880**	355	99
11.0	1.006	960	–
11.5	1.055	484	–
12.0	1.066	802	–
12.5	**1.087**	178	–
13.0	**1.277**	143	99
14.1	**1.250**	81	99

Notes: The differences of the averaged relative catch value of each case were compared with the averaged ones of the sum of all other cases. The significance level is shown with bold number if it is more than 95%. The value of correlation coefficient (0.966) is significant at 99.9% level. This value was calculated using the height of tropopause and the relative catch.

Table 6

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest examined at the nighbourhood of days with plural tropopause

Days	By day		In the evening		At night	
	RC	N	RC	N	RC	N
–2	1.081	69	**0.953**	44	1.039	59
–1	*1.047*	72	**1.115**	43	**0.947**	61
0	***0.705***	68	***1.181***	43	***1.038***	73
1	**0.845**	68	***0.692***	43	***0.639***	59
2	**0.955**	67	***0.910***	41	***0.910***	60
3	**1.153**	65	**1.188**	40	***1.237***	59

Notes: Bold numbers show, if the difference of relative catch from the average of all the other observing data is at least 95%. The same significant difference between the relative catch of two neighbouring nights are shown with italic numbers. N = means the number of observing data.

Table 7

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest connected with the weather fronts and discontinuity levels (there was only 1 kind of front during the night)

		Relative catches	Significance levels (%)	No. of data
Weather fronts				
1.	W^0	*1.587*	99	105
	W^1	*0.713*	95	29
2.	W_h	1.016		61
3.	O_w	1.296	95	69
4.	W_u	–	–	–
5.	W_m	0.600		8
6.	C	0.935	95	423
7.	C_h	1.082		226
8.	O_c	0.854	95	101
9.	C_u^{0-1}	*0.980*		115
	C_u^2	*1.341*	99	39
10.	C_m	0.890	95	51
11.	C_p^{0-1}	*0.676*	99	22
	C_p^2	1.258	95	17
12.	O	0.243		6
13.	O_{OR}	1.623	95	33
14.	S_{ww}	1.006		9
15.	S_{cc}^{0-1}	*0.485*	99	78
	S_{cc}^2	*1.095*		42
16.	S_{wc}	1.045		76
17.	S_{cw}	0.864	90	49
Discontinuity levels				
18.	D^0	*1.027*		189
	D^{1-2}	*0.519*	90	19
19.	D′	0.761	90	30
20.	S	2.319	95	12
Without any front		1.106	95	185

Notes: The difference of the averaged relative catch value of each case were compared with the averaged ones of the sum of all other cases. The significant differences belonging to the same fronts but different in intensity ones are shown with italic numbers.

the catching result noticed after the multiple tropopause took place at different times of the day. The increase of caught moth's number on the third following day can be attributed to the subtropical tropopause. We can conclude from these results, the atmospherical electric factors also have major part, mainly at the time of influx of upper subtropical air. At this time the impulse number of 3 Hz spherics decreases, but the suncosmic radiation shows increase (Örményi, 1984). The atmospherical ions also can have major influence

Table 8

Relative catch (RC) the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest connected with the weather fronts and discontinuity levels changing one another during the night

Previous fronts	Following fronts	Relative catches	No. of data	Previous fronts	Following fronts	Relative catches	No. of data
1 W	7 C_h	1.085	29	8 O_c	18 D	**1.260**	56
1 W	18 D	**1.280**	21	9 C_u	6 C	*1.142*	47
2 W_h	7 C_h	**0.505**	17	9 C_u	7 C_h	**1.335**	28
2 W_h	18 D	1.165	24	9 C_u	10 C_m	*0.504*	10
3 O_w	6 C	1.010	12	9 C_u	15 S_{cc}	1.388	14
3 O_w	7 C_h	1.066	24	9 C_u	18 D	1.229	15
3 O_w	18 D	**0.680**	40	15 S_{cc}	6 C	**0.572**	21
6 C	3 O_w	**0.806**	29	15 S_{cc}	7 C_h	*0.733*	11
6 C	7 C_h	**0.702**	27	15 S_{cc}	18 D	1.056	19
6 C	8 O_c	**0.455**	39	16 S_{wc}	6 C	**0.722**	18
6 C	15 S_{cc}	**1.224**	38	16 S_{wc}	7 C_h	**0.540**	14
6 C	16 S_{wc}	**0.804**	11	16 S_{wc}	8 O_c	1.102	12
6 C	17 S_{cw}	1.040	12	16 S_{wc}	15 S_{cc}	*1.380*	12
6 C	18 D	*1.127*	71	16 S_{wc}	18 D	**0.431**	16
7 C_h	1 W	*0.888*	13	18 D	1 W	**1.345**	42
7 C_h	2 W_h	**0.361**	12	18 D	2 W_h	**0.585**	23
7 C_h	6 C	*0.911*	56	18 D	3 O_w	**0.892**	35
7 C_h	10 C_m	*1.339*	10	18 D	6 C	1.094	42
7 C_h	15 C_{cc}	**1.476**	29	18 D	7 C_h	**1.249**	76
7 C_h	18 D	1.051	35	18 D	8 O_c	**0.534**	21
7 C_h	19 D'	*1.110*	28	18 D	15 S_{cc}	*1.192*	29
7 C_h	20 S	1.024	20	18 D	16 S_{wc}	**0.707**	16
8 O_c	6 C	**0.505**	35	18 D	17 S_{cw}	*0.930*	11

Notes: Relative catches belonging to the frequent front changes are shown in the table. Significance levels are shown with bold numbers (more than 99%) and italic ones (more than 95%).

(Örményi, 1967). The predominance of negatively charged ions measured in the polar air cause decrease in activity, but the predominance of positively charged ions being in subtropical maritime air mass (mT) can be increasing flight activity.

The light warm fronts (W^0), the strong unstable cold fronts (C_u^2), surface cold fronts (C), the strong paradox cold fronts (C_P^2), the warm occluded fronts (O_w), orographic occlusion fronts (O_{OR}) and the apart air current process from discontinuity levels are favourable for light trapping of the examined heart-and-dart moth. The cold front (C), the masked cold fronts (C_M), the light paradox cold fronts (C_P^{0-1}), the stationary fronts that arrive and leave as cold fronts (S_{WW}^{0-1}), the stationary fronts that arrive as cold fronts and leave as warm fronts (S_{cw}), the strong subsidence in general (D^{1-2}) and the descending motion between two cold fronts (D′) are unfavourable. The number of caught individuals

Table 9

Relative catch (RC) of the heart-and-dart moth (*Scotia exclamationis* L.) using the data of light-traps surrounding Budapest connected with the microbarographic oscillations

Unchangable microbarographic codes	Relative catches	Significance levels (%)	No. of observing data
0	0.898	90	323
1	1.039		1334
2	0.986		440
The microbarographic code changes in one direction	**Relative catches**	**Significance levels (%)**	**No. of observing data**
0 → 1	1.218	95	125
1 → 0	1.148	95	316
0 → 2	*0.673*	95	37
2 → 0	*1.330*	95	42
1 → 2	0.904	90	291
2 → 1	0.850	95	301
The microbarographic code changes several times	**Relative catches**	**Significance levels (%)**	**No. of observing data**
0 →← 1 →← 2	0.868	90	29
0 →← 1	1.385	95	57
1 →← 2	1.147		47

Notes: The difference of the averaged relative catch value of each case were compared with the averaged ones of the sum of all other cases. Significance levels are shown with italic numbers (at least 95%) used the data of changes in opposite direction.

was modified oppositely in some cases by the light and the strong fronts. The (W^0) and the (D) increase the catch, but both the strong ones strongly decrease the collecting. We found the opposite influence with the unstable cold fronts (C_u), the paradox cold fronts (C_p) and S_{cc}. There were favourable and also unfavourable collections on those nights when the weather fronts came after one another. The trapping results reflect therefore the effect of the air masses arriving later.

We could observe frequently increases in the number of caught insects connected with different types of cold fronts coming after other cold fronts. This increase means the biological effectiveness in this event. We could find some other effective front changes: subsidence in general (D) comes after the cold or warm fronts (C or W); stationary front, that arrives and leaves as a cold front (S_{cc}) comes after stationary front that arrives as a warm front and leaves as a cold one (S_{wc}), which is often connected with effective cyclon situation; upper cold front (C_h) or stationary front, that arrives and leaves as a cold front (S_{cc}) comes after subsidence in general (D).

After finding that high and low catches can belong to both warm and cold fronts we can conclude that there can be among insects individuals sensitive to cold or warm fronts. The weather front sensitivity symptoms belonging to the insects appear in changes of flying activity. The further examinations of this problem, the proving of above-mentioned hypothesis and determination of ratio of individuals sensitive to cold and warm fronts would be very important both for entomological basic research and plant protection practice.

The number of caught moths is lower, if the microbarographic oscillation can be characterized with level 0 and they are unchanged during the night. It is favourable from the point of view of collecting if the code of oscillations change between 0 and 1 in any direction or it changes from 2 to 0. It is unfavourable if the change is between 1 and 2 in any direction, it increases from 0 to 2 or it is modified in different directions between 0, 1 and 2.

The low values of relative catches indicate in all cases those weather situations when the flying activity of insects decreased, but the interpretation of the high values is not so simple. The significant environmental changes cause physiological changes in the organism of insects. The imaginal life is short, the unfavourable weather endangers not only the life of the individual but also the continuance of the total species. According to our supposition the individuals can use two kinds of strategies to prevent the hindering influences of normal functions in life. First is the increased activity. It means the growing of intensity in flying, copulation and oviposition. The second strategy is to hide and ride out in passivity the unfavourable situation. Seeing the above-mentioned facts, according to our present knowledge high light trapping results can belong to both favourable and unfavourable situations.

Our present work means the beginning of those examinations to study the vital functions of insects connected with air masses, height of tropopause and its changes, the weather fronts and microbarographic oscillations. It is not well known which are the favourable and unfavourable weather influences for the insects at the time of several kinds of weather fronts, air masses and mainly at the time of their changes and combinations. We think to examine more these events to use the results for plant protection prognosis because changes in weather fronts are frequent and the air masses change very often in swarming time of insects.

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Acta Silv. Lign. Hung., Vol. 4 (2008) 49-54

Pre- and Postfrontal Influences on Light Trapping of Winter Moth (*Operophtera brumata* L.)

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Abstract – Light trap catches of the winter moth (*Operophtera brumata L.*) getting from the data of national light-trap network were analysed in connection with weather fronts. It is concluded, that weather fronts modify the catches of light traps according to their specific characters (main types) and according to their successions. It is worthy of attention, however, that even in those cases in which the front reduces the number of insects caught, pre- and post-frontal influences often manifest themselves in an increase of the number of collected specimens. Because of the frequency of weather fronts it would be useful to take their effects into consideration on the quantity of insects captured at light-traps. It is necessary to improve the applied method for this purpose.

weather front / light-trap / insect

Kivonat – Pre- és posztfrontális hatások a kis téliaraszoló (*Operophtera brumata* L.) fénycsapdázására. A szerzők az országos fénycsapda hálózat anyagából megvizsgálták a kis téliaraszoló (*Operophtera brumata* L.) gyűjtési eredményeit. Megállapították, hogy az egyes időjárási frontok típusuknak (közelítő és tartózkodó hideg, meleg, okklúziós, egyidejűleg tartózkodó hideg, meleg és okklúziós) megfelelően és attól függően is mindig azonosan módosítják a fénycsapdázás eredményességét, hogy milyen típus után következnek. Figyelemre méltó, hogy a front hatására csökken a befogott lepkék száma, a pre- és posztfrontális hatások sok esetben a gyűjtött egyedek számának emelkedésében nyilvánulnak meg. Az időjárási frontok gyakorisága miatt célszerű lenne hatásukat a fénycsapdázott rovarok mennyiségi értékelése során figyelembe venni, ehhez azonban az alkalmazott módszer továbbfejlesztése szükséges.

időjárási front / fénycsapda / rovar

1 INTRODUCTION

There were a few studies to examine the activities of insects in relation to several types of weather fronts. This contrasts the intensive researches in medical meteorology. Only some publications can be found in the literature dealing with the relationship of weather fronts to light-trap catches of insects. It would be very important to study this problem, because the frontal passages cause sudden and significant changes in the physical environment of living creatures. The organisms of humans or animals reply with front sensitivity symptoms to

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simultaneous changes of all weather factors. The exact calculation of insect population densities is only possible, if the factors influencing their flying activity are known. We can use it for the purpose of plant protecting monitoring and forecasting. The flying activity can significantly change very often, when different weather fronts come, so the number of caught individuals represents the current mass of population in different rates of their real numbers.

The connection of weather fronts and light-trap catches of insects was studied by Wéber (1959) in Hungary. According to him research on the influences of front changes is difficult for many reasons (the fronts can come after each other in a few hours intervals, fronts can pass through a country without changing the air-masses, the intensity of the same types of fronts can be different). In the course of his examination he did not try to draw general regularities, but he elaborated a graphical method to characterise the modifying influence of weather fronts on light-trap catches based on the analysis of each concrete typical event. Járfás (1979) made studies on the influence of individual weather factors instead of weather fronts, because of the above-mentioned problems. Kádár and Szentkirályi (1982, 1992) made examinations on the flight activity of ground beetles (*Coleoptera: Carabidae*) using the data of monthly Calendar of Weather Phenomena issued by the National Meteorological Service. They found significant differences between the influences of cold and warm weather fronts. We examined the flying activity of harmful insects in relation to macrosynoptic weather situations - which have close connection with weather fronts - in one of our publications (Károssy et al., 1992). No fundamental publications have been found in foreign literature dealing with the connection of weather fronts and light trap catches.

The data - produced by the national light-trap network in Hungary, which is unprecedented even at world standards - are suitable to examine the influences of weather fronts with mathematical-statistical methods.

2 MATERIAL AND METHODS

Weather fronts can be typified according to more points of view. Berkes (1961) determined 21 types of fronts for the territory of Hungary and characterised them. However their validity is questionable in space, and they do not expand to the whole country (Csizsinszky, 1964). That is why we revaluated the situations of weather fronts in Hungary. We could get these information from the synoptic maps of "Daily Weather Reports" of Hungarian National Meteorological Service (Puskás, 2001).

The light trap data of winter moth (*Operophtera brumata* L.) were analysed from the database of the national light-trap network in Hungary. The food plants of these species widespread in whole Europe are well known. The winter moth attacks not only all the deciduous trees in forests, but also the fruit-trees. The most preferred food trees are oaks, hornbeam, beech, horse chestnut, lime and European hazel (Szontagh and Tóth, 1977). The moths fly at sunset and in the evening from early October till mid-December.

Catches were collected at 18 light trap stations between 1961-1976. Total number of daily catches was 3712 representing 46290 specimens from 837 nights. Daily catches mean the collecting result at one station at one night independently of the catch size.

The location of warm-, cold- and occluded fronts were determined for each day between 1st March and 30th November for the years 1961-1976 from Daily Weather Report issued by the Hungarian National Meteorological Service. We classified the fronts on the basis of their quality and location compared to the surface of Hungary (Puskás, 2001). The following front groups were used:

1.	on-coming cold front	OCF
2.	cold front	CF
3.	on-coming warm front	OWF
4.	warm front	WF
5.	on-coming occluded front	OOF
6.	occluded front	OF
7.	on-coming warm and cold fronts	OWCF
8.	warm and cold fronts	WCF
9.	simultaneous warm, cold and occluded fronts	WCOF
10.	without fronts	W

On-coming front means that the front comes close to the border or just enters to the territory of Hungary. The first 6 front types contain only one weather front, but in the last three ones there can be found two or three fronts. The cold and warm front types are well-known, therefore we should like to show the characteristics of the other weather front types. In the case of occlusion the quick cold front will pull up to warm front line, so the two different air masses can be completely combined. There is a previous situation in type 7 and 8, because the cold front does not reach the warm one, only later can form the occlusion. We can see a complete cyclone when type 9 develops and all the different three front types are simultaneously in the Carpathian Basin.

In the course of processing we examined separately all the 9 types of front situations for those days which followed a day with no front effect including those ones when the previous silent day was proceeded a day with a front effect. We could use these front types because the fronts can pass the whole territory of the Carpathian Basin in a few hours. That is why prefrontal and postfrontal effects can follow each other during the same night.

We calculated relative catch values (RC) from daily light-trap catches for all stations, so we could process the values of different localities and dates simultaneously together. Relative catch is the quotient of the number of individuals caught during the sampling interval (1 night), and the mean catch of one generation or flight counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

After this we summarised the values of relative catches coming from different observing stations for each night. We made an average from these values for all the types of fronts. We made a comparison between the values of relative catch belonging to the front types of each day and the average values of catches on the days before and following the front to demonstrate the possible increase or decrease of collection results caused by weather fronts. We examined the days before separately if there were no any front effect and also if there were any other type of front in the territory of Hungary. We made a comparison between values of relative catches belonging to each type of weather fronts and the catches on the previous and the following nights to show the influence of fronts. We separated those previous days when there were no any front effect and those ones when fronts were in the territory of our country. We examined the differences of catches belonging to the front types on those days, which came after frontless days. These differences were compared with the expectable values. Although we examined all the effects of types and changes of weather fronts, but we did not use the results, where we did not find significant differences in catching results. We controlled the significance level of differences with t-test after the analysis of variance.

4 RESULTS

The catching success of light-traps for winter moth (*Operophtera brumata L.*) depending on weather front changes is shown in *Table 1.*

Table 1. Light-trapping of winter moth (Operophthera brumata L.) in connection with weather fronts

Days before and after night of light trapping (0 day)													
– 2			– 1			0			+ 1			+ 2	
RC	N	P	RC	N	P	RC	N	P	RC	N	P	RC	N
			Without			OCF							
1.13	115		1.42	120	**	1.18	122		0.99	125	**	1.34	133
			CF			OCF							
1.24	33	*	2.06	31	**	0.78	34	*	1.44	33		0.99	33
			Without			CF							
1.08	141		1.14	180	**	1.36	178	**	1.07	176		0.87	174
			OCF			CF							
1.28	56	**	0.71	60		0.98	66	*	0.46	60	*	0.98	58
			WF			CF							
0.96	41		1.00	39	**	1.72	47	**	0.89	44		1.16	44
			OF			CF							
1.87	12		0.64	13	**	2.39	13	**	0.62	13	**	1.59	13
			Without			OWF							
0.71	63	**	1.44	64		1.57	74	*	1.25	67		1.51	64
			CF			OWF							
0.47	10	*	1.44	13	*	0.30	14	*	1.09	15		1.59	16
			WF			OWF							
0.77	33	**	0.35	33	**	1.53	33		1.22	32		1.02	28
			Without			WF							
0.72	199		0.66	194	*	0.88	228	**	1.29	193		1.08	185
			OWF			WF							
0.82	35		1.17	37	*	0.64	37	*	1.18	43		1.2	44
			OCF			WF							
0.45	13	*	1.71	12		1.31	24	*	2.66	18		1.69	18
			Without			OF							
1.22	75		1.04	76	**	0.41	78	**	1.17	79		1.00	77
			CWF			OF							
1.32	10		2.27	11	*	0.55	11	*	0.84	11		0.71	13
			Without			OWCF							
1.04	20	*	1.72	21		1.92	22		1.34	21	*	0.92	22
			Without			WCF							
1.00	21		1.19	19	**	0.54	22		0.69	20	**	1.03	20
			CF			WCF							
1.36	23		1.52	22	**	0.71	24	*	1.35	23		1.32	22
			Without			WCOF							
1.25	31		1.13	29	**	1.83	31		2.03	28	**	0.95	25

Notes: RC = relative catches, N = number of data
Significance levels: * = $P < 0.05$, ** = $P < 0.01$

5 DISCUSSION

The on-coming cold front (OCF) is unfavourable for the catches, if it comes after a cold front (CF) or a day without front effect. The catching increase on the following and second day after it. The on-coming warm front (OWF) is also unfavourable if it comes after cold front (CF). The warm front (WF) and specially the occluded front (OC) are unfavourable, but in both cases the number of caught specimens increases on the following days. The cold front (CF) is favourable for catching, if it comes after a warm front (WF), an occluded front (OF) or a day exempt from any front effect, but the numbers of specimens caught decreases on the following night. The catching is strikingly high on those nights, when simultaneous warm-, cold- and occluded front (WCOF) effects arrive at the Carpathian Basin. The favourable effect is noticed also at the following night at that case. The number of moths caught increased, when there was a cold front (CF) or a day without front before the on-coming warm front (OWF). In this last case the catching is already high at the night before. The on-coming cold- and warm fronts (OCWF) cause also a strong rise in the number of specimens caught.

Practical utilisation of our results seem to be difficult at this moment, because the effect of front types can not unified as favourable or as unfavourable for the success of light trapping, but they are variable according to the front type on the day before. Our examinations did not justify the Wéber's (1959) observation, which experienced prefrontal effects in connection with warm fronts and postfrontal effects in connection with cold fronts. As we think the cold front hardly can mean favourable weather situation for moths. We can explain the observed high flight activity with an idea written in one of our earlier publications (Nowinszky, 1994) the developing of flying activity in cold front (CF) effects. According to our hypothesis the low values of relative catches always refer to those weather situations, when the flying activity of insects is reduced. We can not explain the high values so unanimously. The important environmental changes cause physiological changes in the body of insects. The life of adult is short that is why the unfavourable weather endangers not only the survival of the individual moth, but also the survival of the whole species. In our opinion the moths can use two strategies to prevent these effects, which hinder their normal life functions. One is an increased activity, which is expressed in the rising intensity of the flying, copulation and egg-laying. The other the opposite and the insects try to hide and to tide over the unfavourable weather situations in an inactive mode. So as we see the high catching values equally can belong to favourable and unfavourable weather situations. In those cases, where we did not known the catching results belonging to the front changing in the Table 1, we did not experience significant differences in the number of caught moths. The reason of this can be data belonging to specific front changes, and partly by the fact that some of front changes do not cause significant differences in the flying activity of moths. On the basis of the present results we can demonstrate that weather fronts and especially some types of them modify the success of light trapping. It is worthy of attention, however, that even in those cases in which the front reduces the number of insects caught, pre- and post-frontal influences often manifest themselves in an increase of the number of collected specimens. If we could explore the effects of weather fronts on the flight activity of each species we would be able to work out more exact plant protecting prognoses. For this reason we feel it very necessary to continue our research.

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Cereal Research Communications 36(4), pp. 647–657 (2008)
DOI: 10.1556/CRC.36.2008.4.14

Changing of Flight Phenology and Ecotype Expansion of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in Hungary

Part 1. Biomathematical evaluation

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(Received 15 June 2007; accepted 14 July 2008)

The studies aimed to acquire the widest possible information on the annual flight in Hungary of the European corn borer (ECB), *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae). The investigations used biomathematical (Part 1) and graphical (Part 2) evaluation to document changes in the individual population number.

The study was conducted in Hungary using ECB moth capture records from the Plant Protection Information System black light trap system (1991–2004). We have drawn conclusions on the appearance of annual flights and the tendency of alterations in flight direction by means of light trap results in four different areas in Hungary. We calculated the flight peak quotients, the individual population numbers of the second flight peak, the distinctions of individual numbers of two flight peaks in this part.

As previously published, alterations in flight direction of ECB flights began at different times in Hungary. In the current study, a gradual disappearance of the univoltine ecotype and gradual appearance of the bivoltine ecotype ECB in Hungary is confirmed by the data obtained between 1991–2004. Flight peak quotients and data concerning the second flight peak have confirmed change this process, too: the appearance of a second flight peak in Northwestern Hungary from 1995–1996 (FP = 1.27), the more significant appearance of flights in August in Western Hungary (FP = 1.05) and Northeastern Hungary (FP = 1.45), and a three and four times more individual number of the second flight peak in Southeastern Hungary (FP = 3.44). Flight peak quotients, individual population numbers of the second flight peak, the tendency towards a difference in population number of the two peaks, and size of increase of these values demonstrates the southeastern-northwestern presence of the bivoltine ecotype in Hungary.

Keywords: European corn borer, flight

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Introduction

Entomological indicators of climate change

We are currently undergoing a worldwide change of climate, which in the last century resulted in a considerable rise in average temperature in Eastern Europe. The causes of global warming have not yet been adequately established: it might be due to the cyclic nature of the climate history of the Earth, or it may be of anthropogenic origin (Gordon and Davies 1975; Thompson 1975; Jolánkai 2005). Global climate change has a great effect on the elements of the biosphere (Schwartz 1992; Woodward and Lomas 2004), of which one is the distribution and propagation of insect pests (Fuhrer 2003; Strand 2000; Yamamura and Kiritani 1998). The first relevant Hungarian analysis was published by Kozár and Nagy Dávid (1985).

From a comparison of agro-ecosystem models, Gourdiaan and Zadoks (1993) drew the conclusion that climate change has a great influence on insect pests and their host plants.

The first climatological studies concerning the distribution of the ECB are linked to the work of Porter et al. (1991) and Stollár et al. (1993) who found the northern limit of the distribution of the species to shift northward by more than 100 km with a 1 ºC rise in the average temperature. A significant increase of 1.1 ºC in the average winter temperature can be seen to have occurred over the last 110 years in Hungary (Stollár et al. 1993; Jolánkai 2005). The rise of average temperature was especially high in the last decades (Fig. 1).

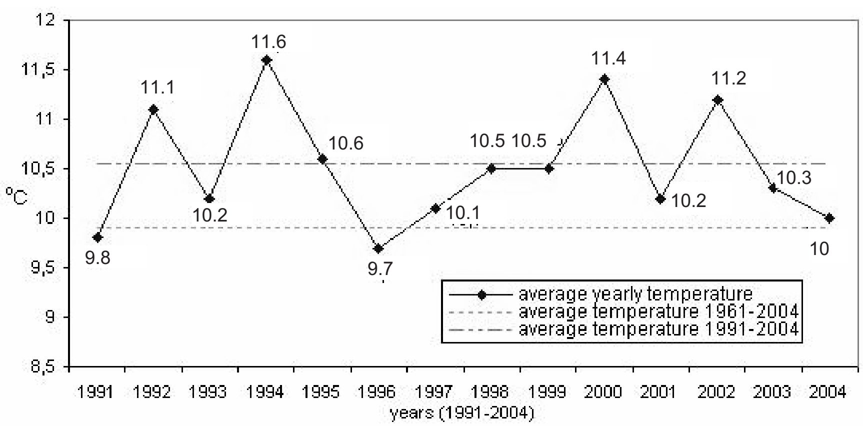

Figure 1. Average yearly temperature in Hungary in 1991–2004
[by Hungarian Meteorological Service (HMS); www.met.hu]

Besides global warming, the meteorological extremities also have a great influence on the spread of insects (Kozár 1995). In recent decades, periods that were cooler and warmer than average alternated in the summers (Stollár et al. 1993; Kozár 1997), which has largely contributed to the more frequent regional fluctuation of insect species (Székács et al. 2005).

Materials and Methods

We examined changes in the temporal patterns of ECB moth flights by processing the data from the Hungarian light trap system [Plant Protection Information System (NIR) of the Hungarian Central Plant Protection and Soil Conservation Service].

The examination was carried out between 1991 and 2004. The choice of the period was justified by two factors. (1) Since the 1990s an ever growing number of publications have been dealing with the effects of global climate change on Hungary (Székács et al. 2005), which reflects the importance of this phenomenon, and (2) it is for that time interval that a more or less uniform series of ECB trap data were available from various parts of the country. Unfortunately, the data were available only from 1995 in District 1, because of the light traps were out of order in Northwestern Hungary between 1991–1994.

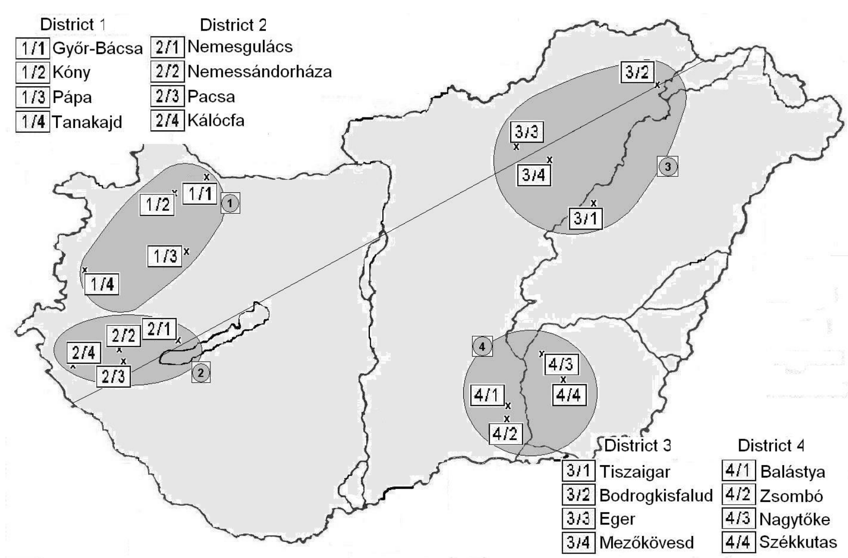

Figure 2. Location of light traps of four districts in Hungary. Explanation: The stripe is the borderline between uni- and bivoltine ecotype of ECB by Mészáros (1969)

We have processed ECB light trap catches originating from 4 sites in each of four different districts of Hungary. Moths were recovered from trap daily, and the representation of catches happened on traps every fifth day. The different districts determined by us and the location of light traps can be seen in Figure 2.

Climatic features of the four districts examined (Péczely 1979) and their annual generation numbers of ECB (Mészáros 1969) are the following:

District 1: Northwestern Hungary. The climate "moderately warm, moderately dry" in the northern part, and "moderately warm, moderately humid" in the southern part of the district. The precipitation is higher than the national average, and half of it falls during the growing season in the northern part. The mean water shortage in summer is 10–30 mm in northern part of district (climatic features of the southern part of district can be seen in District 2). The distribution of ECB univoltine ecotype shown is based on earlier data.

District 2: Western Hungary. A "moderately warm, moderately dry" climate prevails in this district. Precipitation is higher than the national average, and 60% of it falls during the growing season. Despite of this, the mean water shortage is still 15–20 mm in the summer period. The 3200 ºC isotherm dividing the uni- and bivoltine ecotypes is based on earlier data.

District 3: Northern and Northeastern Hungary. Both "moderately warm, dry" and "moderately cool, moderately dry" climatic conditions can be found in this district. Level of precipitation varies throughout this district. It is higher than the national average in the northern part of the district; while in the south it is lower than average. There is significant mean water shortage in summer of about 30–50 mm between May and September. The isotherm of 3200 ºC dividing the uni- and bivoltine ecotypes is in this case, too, based on earlier data.

District 4: Southeastern Hungary. "Warm, dry" climate area, where precipitation is close to the national average and more than half of it falls during the growing season. The mean water shortage is 30–40 mm. This district falls within the distribution area of area of the bivoltine ecotype of ECB.

We drew up diagrams of flight phenology. Based on the generation quotient (Mészáros 1969) [G=B/A; where G = generation quotient, B = individual number of the second generation, A = individual number of the first generation], from the light trap data we were able to calculate the flight peak quotient [FP=B/A; where FP = flight peak quotient, B = individual population number (cumulative moth catch during the period) of the second flight peak, A = individual population number of the first flight peak], and the propagation quotient (E=U/M; where U = individual population number of the year in question, M = individual population number of the preceeding year), and this allowed us to draw conclusions about flight phenology for each of the above districts above. Establishment of the border between first and second peak of flights shown below in results.

We tabulated the flight peak quotients for each year, the individual population numbers of the second flight peaks, and the distinctions of individual numbers of two flight peaks (DFP) (DFP = B–A; where: B = individual population number of the second flight peak, A = individual population number of the first flight peak) in a coordinate system. By means of the linear trends shown we were able to establish the directional tendency from year to year. Annual changes in the aforementioned values were statistically analysed by one-way analysis of variance (ANOVA) by means of SPSS 10.0 software.

Results

In the past 15 years the two peak type of flight appeared in four different areas of Hungary (Table 1). In Northwestern Hungary (District 1), the light traps began to register the appearance of the late summer flight peak of ECB in 1995–1996. A comparison of the peaks indicates that – with the exception of four years (1995, 1998, 2002, and 2004) – the August peak was lower than the first peak with regard to the individual population number.

Table 1. Average flight peak quotients of four districts between 1991–2004

	Average flight peak quotients (FP)						
Years	1991	1992	1993	1994	1995	1996	1997
District 1	–	–	–	–	3.1	0.06	0.09
District 2	1.24	0.35	0.32	0.65	0.19	4.4	0.12
District 3	0.96	0.26	0.14	1.80	0.85	1.99	0.25
District 4	1.84	1.25	1.02	2.43	5.54	1.2	1.52
	Average flight peak quotients (FP)						
Years	1998	1999	2000	2001	2002	2003	2004
District 1	2.31	0.51	0.3	0.86	2.74	0.93	1.85
District 2	1.75	0.43	1.82	0.76	0.77	0.72	1.15
District 3	1.02	1.88	0.29	0.84	6.06	2.2	1.74
District 4	1.67	2.18	5.78	8.36	4.94	4.49	6.02

Average flight peaks quotients (FP) of districts (n = 14)			
District 1	District 2	District 3	District 4
1.27	1.05	1.45	3.44

Explanation: – = one peak of ECB flight in given year

In the case of light traps to the west of Lake Balaton (District 2), the change in flight phenology occurred earlier, before 1991. The western and northwestern expansion of the two-peak flight is demonstrated by the light trap data from Kálócfa, where the August peaks appeared later, only after 1995. The one peak (1991, 1992, 1993) and the two peaks (2003, 2004) flight phenology in Kálócfa can be seen in Figure 3. The emergence of the peaks was the most explicit in these years. Apart from that, 65% of the flight traps of District 2 showed a more significant appearance of the early summer flight.

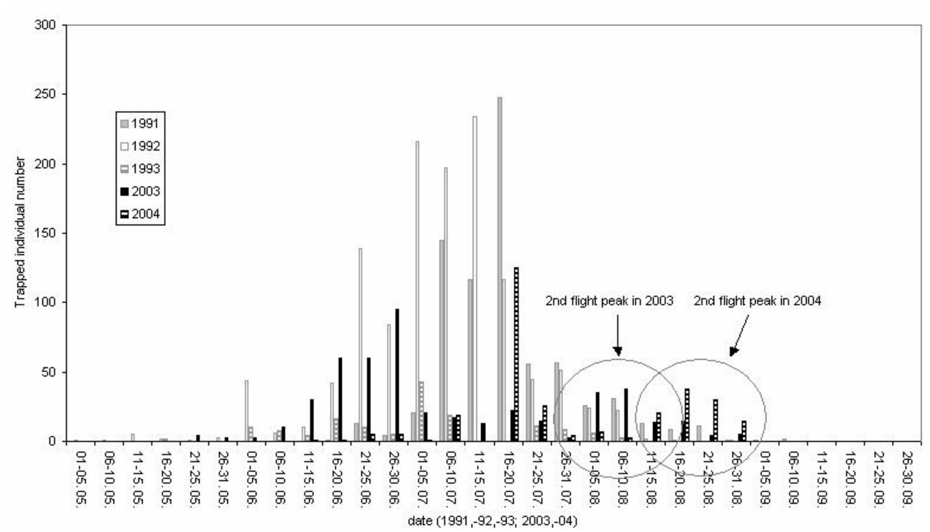

Figure 3. Flight of ECB in Kálócfa in 1991, 1992, 1993 and 2003, 2004

In Northwestern Hungary (District 3), since the turn of the millennium, the second flight peak has become definitive. This phenomenon was particularly remarkable in Mezőkövesd in 2002 (FP = 11.56) and Bodrogkisfalud (FP = 7.68). The pattern of flight observed for the last 4 years has shown increasing similarity to the data from Southeastern Hungary.

The quotients of the average flight peak in District 4 show values above 1 only. A higher measure of increase in the individual population number of the second peak has been especially remarkable since 2000.

Table 2 contains the values for the univoltine populations in comparison to the previous year. It can be seen that in the Northwestern areas of Hungary the two-peak flight appeared later. In the light traps of District 2 in the early 1990s, the univoltine (one-peak flight) ecotype was recorded only in the case of Kálócfa. From the values of the propagation quotients we cannot, however, establish facts concerning the multiplication and ecotype change of the ECB.

Table 2. The propagation quotients of places of occurrence and years of univoltine ecotype between 1992–2002

District 1	Propagation quotients (E)										
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Győr-Bácsa	7.33	0.59	5.11	1.15	1.5	1.59	0.55	0.84	0.93	0.5	**
Kóny	*	*	*	1.31	0.36	1.34	0.53	3.54	0.42	0.33	**
Tanakajd	5.5	0.5	0.45	1.72	0.08	2.8	0.78	2.54	0.61	1.9	**
Kálócfa	1.63	0.11	0.8	**	**	**	**	**	**	**	**

Explanation: * = Trapped result of ECB was not available; ** = Flight of ECB has appeared already in two peaks

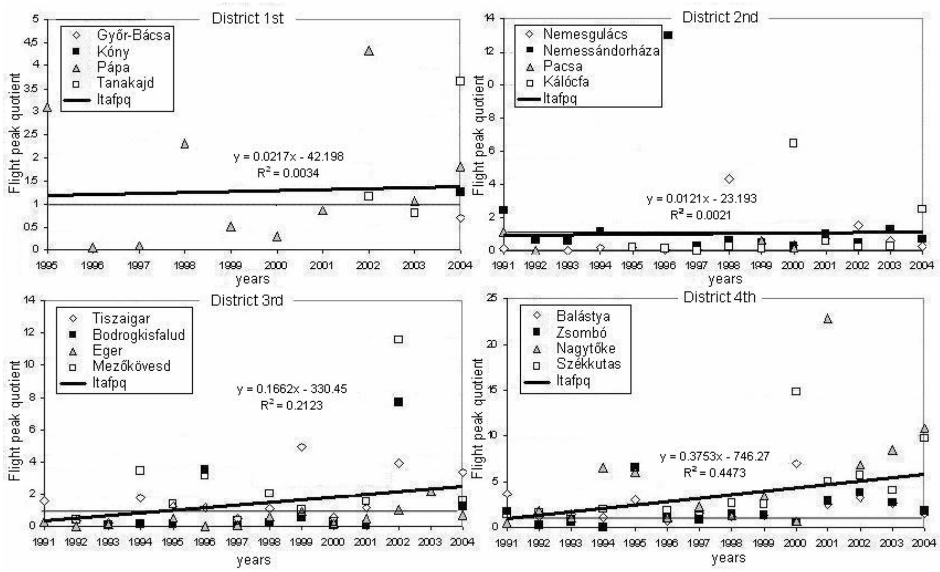

Figure 4. Flight peak quotients of four examined districts between 1991–2004
Explanation: ltafpq = linear trendline of average flight peak quotients; the horizontal line through 1 represents the equality of two peaks' individual number

Figure 4 shows the annual flight peak quotients for the four districts in question. The linear trends indicate the changes in the ratio of the two peaks during the course of successive years. In the areas of southeastern (District 4) and northern Hungary (District 3), a gradual strengthening of the August swarm as compared to the early summer one is remarkable.

From the average individual population number of the second flight peak (Fig. 5) and from the linear trends of changes in individual population number be-

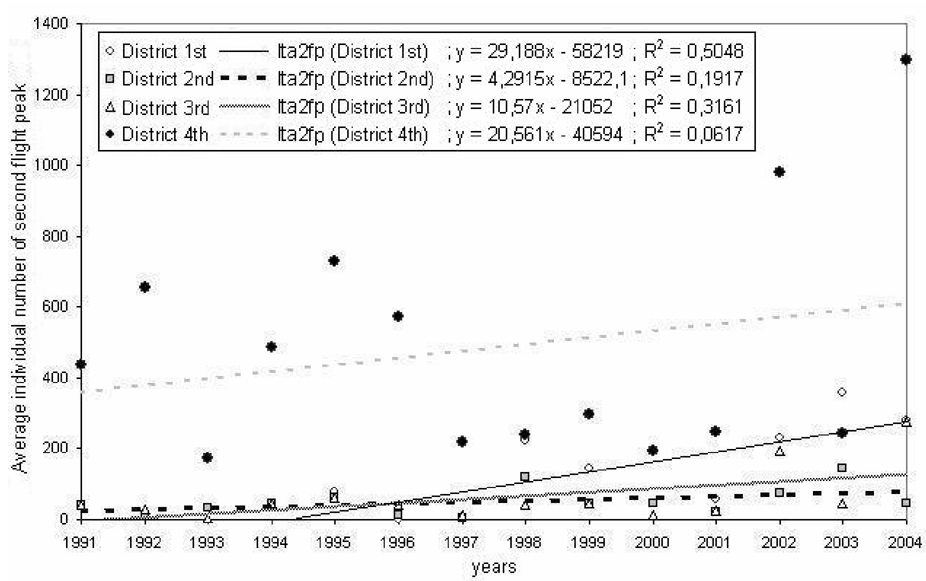

Figure 5. Average trapped individual numbers of second flight peaks in four examined districts between 1991–2004. Explanation: lta2fp = linear trendline of average individual number of 2^{nd} flight peak

tween the two flight peaks (Fig. 6), also the above conclusion can be drawn. In the values of the second flight peak, an increasing tendency can be observed irrespective of the districts (Fig. 5). The year-by-year increase in the number of trapped adults is particularly conspicuous in Southeastern and Northwestern Hungary.

As to the change in individual population number between the two flight peaks (Fig. 6), some increase can be observed though it is a less clear correlation. The light traps of Zala county and Nemesgulács show a moderate increase in the difference between the individual population numbers of the two peaks (most of the data falls below the abscissa).

The three executed variance analysis confirmed a statistically significant correlation ($P < 0.0001$) between procession of the years and the flight characteristics (flight peak quotients of years, individual number of the second flight peak, trapped individual numbers of the two flight peaks).

Discussion

As unequivocally seen from the flight diagrams, in the last years the two-peak flight pattern of the ECB became general in Hungary. Owing to different influencing factors, the rate of flight and ecotype change may vary with the area.

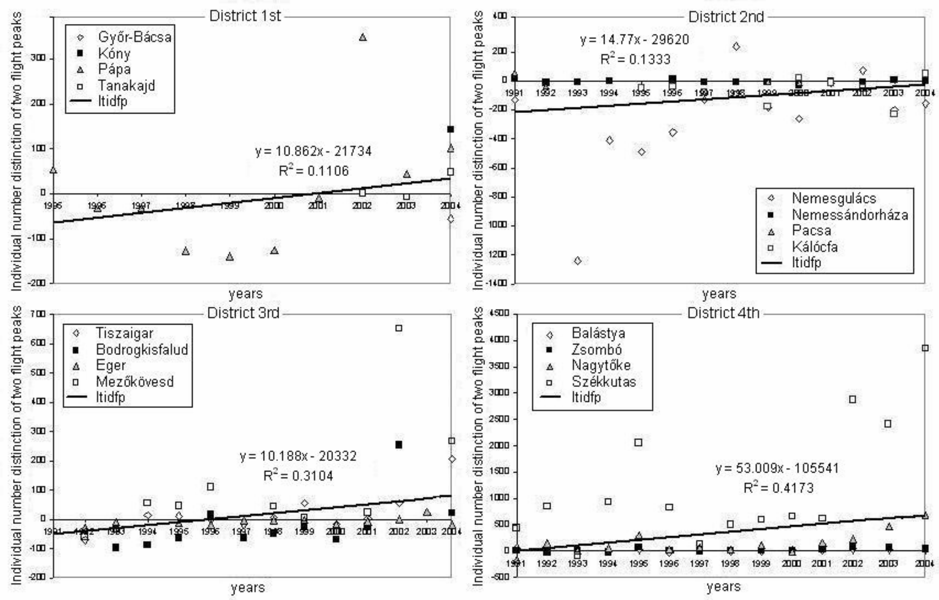

Figure 6. Individual number distinctions of two flight peaks of four examined districts between 1991–2004. Explanation: ltidfp = linear trendline of individual number distinction of two flight peaks

In Northwestern Hungary the sudden appearance and strengthening of the second flight peak observed in the last years can be traced back to a rise in the average annual temperature. In spite of this, the cooler and more rainy climate of this district allowed for a "prolonged conservation" of the univoltine ecotype.

The 3–4-fold dominance of a definite second peak in some places of Northeastern Hungary indicates the presence of the bivoltine ecotype.

The high flight peak quotients obtained for Southeastern Hungary indicates that in this area the ecological conditions necessary for the presence of the bivoltine ecotype, aroused in the preceding decades (Keszthelyi 2004a), had developed even earlier.

From the experiences of preliminary studies (Szeőke et al. 1996; Vörös 2002; Keszthelyi 2004b) we have drawn the conclusion that the change of flight is followed in time by a change of ecotype of the ECB. Therefore, the univoltine ecotype will be gradually displaced from Hungary and replaced by the bivoltine ecotype. This biological trend may cause increasing damage done by the ECB in maize growing areas, as a result of the appearance of a generation developing in summer without diapause.

Acknowledgements

We are indebted to the workers of Hungarian Central Service for Plant Protection and Soil Conservation for granting access to data from the national light trap system.

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THE JOINT INFLUENCE OF METEOROLOGICAL EVENTS FOR LIGHT-TRAP COLLECTING OF HARMFUL INSECTS

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Összefoglalás - Az Országos Meteorológiai Szolgálat 1967 és 1990 közötti "Időjárási események naptára" adataiból az instabilitási vonal, a konvergencia zóna, a ciklogenezis, az országos eső, a hideg- és a meleg frontok, a tengeri- és szárazföldi mérsékelt, sarkvidéki és szubtrópusi légtömegekkel összefüggésben vizsgáltuk meg a vetési bagolylepke (Scotia segetum Schiff.) repülési aktivitást tükröző fénycsapdás fogási eredményeit. A vizsgált időszakban 64 fénycsapda 3232 éjszaka során 29832 példányt gyűjtött. Mivel egy-egy éjszakán több fénycsapda is működött, 25021 megfigyelési adatot dolgozhattunk fel. Megfigyelési adaton 1 állomás 1 éjszakai fogási adatát értjük. Az időjárási eseményekre vonatkozó adatokat annak megfelelően csoportosítottuk, hogy egy-egy napon melyek fordultak elő önmagukban vagy együttesen. Külön csoportba rendeltük azokat a kombinációkat, amelyek időjárási esemény nélküli napot követtek é s azokat is, amelyeket valamilyen időjárási esemény előzött meg. A fogási adatokból állomásonként, nemzedékenként és naponként relatív fogás értékeket számítottunk. Ezeket hozzárendeltük az időjárási események napjaihoz, valamint az azt megelőző és követő 2-2 naphoz is. Ezután naponként összegeztük és átlagoltuk az értékeket. A naponkénti átlagértékek eltérésének szignifikancia szintjét valamennyi csoporton belül t-próbával ellenőriztük. 95%-nál magasabb szignifikáns eltérést összesen 36 csoportban találtunk. Az egyes események gyűjtésre gyakorolt kedvező vagy kedvezőtlen hatása akkor a legerősebb, ha nem egymagukban, hanem más eseménnyel egyidejűleg, esetleg rövid időn belül egymást követően lépnek fel. Eredményeink egyértelműen azt bizonyítják, hogy az egyes időjárási események fénycsapdás gyűjtést befolyásoló hatását nem elég önmagukban vizsgálni. A csapdázás eredményessége ugyanis az egyes időjárási események különböző kombinációitól függően módosul és csak ritkán egyezik meg az önmagában fellépő eseményhez kapcsolódó fogási eredménnyel.

Summary - The light-trap collecting results - showing its flight activity - of turnip moth (Scotia segetum Schiff.) were examined connected with the instability line, the convergence zone, the cyclogenesis, the country-wide rain, the cold- and warm weather fronts, the maritime- and continental moderate, arctic and subtropical air masses used the data published in "Calendar of weather phenomena" between 1967 and 1990 by National Meteorological Service. There were 29 832 moths caught during 3 232 nights by 64 light-trap stations in the examined period. During one night more light-traps operated, therefore 25 021 observing data were worked up. We mean by observing data the catching data at one night at one observing station. The data of meteorological events were collected into groups according to their occurrence on one day alone or together with other ones. They were collected into separated groups according to arriving after a day without any meteorological events or if there were any of them on the previous day. The values of relative catch (RC) were calculated daily for each observing stations and generations used the catching data. There was made a comparison between the relative catch (RC) values and the meteorological events belonging to the date and also on previous and following 2 - 2 days. After it the relative catch values were summarized and averaged daily. The differences of daily average values of significance levels were controlled by a t-test in all the groups. More than 95% significance levels were found in 36 groups. The favourable and unfavourable influence of each events are the strongest at that time, when they have influence not only alone, but also with other effects simultaneously, or they follow one another in a short time. Our results prove clearly, it is not enough to examine alone the modifying influence of each meteorological events for light-trap collecting. The success of light trapping is modified depending on several combinations of each meteorological events and they are not very often the same as the catching result of event to have an influence alone.

Key words: instability line, convergence zone, cyclogenesis, country-wide rain, weather fronts, air masses, insect, light trapping

INTRODUCTION

The insects' phenomenon of life exerting influence of meteorological events are examined generally with the atmospherical process taking to pieces for elements the authors of publications in literature. It is clear that the joint influence of meteorological events has more importance according to the living creature, but publications dealing with these researches are less known. The influences of air masses and weather fronts for light-trap collecting of insects were studied by *Wéber* (1957, 1959) among Hungarian researchers. *Kádár and Szentkirályi* (1991) showed, the number of light-trapped ground beetles (Coleoptera, Carabidae) are the less on the day of arriving convergence zone and on following day of arriving instability line. We could not find fundamental publications on this theme in the foreign literature. The modifying influence of collecting connected with 22 kinds of air masses and 20 kinds of weather fronts and discontinuity levels determined after Berkes (1961) - were examined in our publications (*Puskás et al.*, 1997; *Örményi et al.*, 1997). These papers will be published in the near future. The air masses, the weather fronts and the discontinuity levels were determined for surrounding of Budapest, and unfortunately they are not valid for the whole territory of Hungary (*Csizsinszky*, 1964). We spread our examinations for the joint influence of meteorological events (weather fronts, air masses, instability line, convergence zone, cyclogenesis and country - wide rain). These pieces of information are part of regular meteorological data and they are simultaneously valid for the whole country, or they pass the territory of Hungary at one night.

MATERIAL

The "Calendar of weather phenomena" - published monthly by National Meteorological Service - contains cold and warm weather fronts and 6 kinds of air masses: arctic continental (Ac), arctic maritime (Am), moderate continental (Mc), moderate maritime

(Mm), subtropical continental (Tc) and subtropical maritime (Tm) ones.

We mean on air masses the wide - spread mass of the air, although physical characteristics (mainly the temperature and degree of humidity) change horizontally continuously, but their changes are very small, and their vertical dispersions are almost the same.

The instability lines, the convergence zones, the point of time and length of time belonging to cyclogenesis and the country-wide rain are found in the above-mentioned "Calendar of weather phenomena".

The instability line (squall line) is a convective activity, which moves in a band or line. The short-term intense strengthening of wind speed is the characteristic of its passing and after it violent tempest and thunderstorm come. The convergence develops if two atmospheric motions come from two different directions in the atmosphere. Generally this process takes place along long line, the air accumulates here and one part of it rises up high. It comes often with weather fronts and cyclons. Cyclogenesis is the developing or strengthening of cyclonic circulation.

The catching results of turnip moth (Scotia segetum Schiff.) were analysed connected with these meteorological events. We used the data of light-trap network in Hungary used uniformly the Jermy type light-traps. The light source is a 100 W normal light bulb at 2 meters above the ground, colour temperature: 2900 K, the killing material is chloroform. The traps of the plant protection worked from 1st April to 31st October, while the forestry ones all the year round, independently of the time of sunrise and sunset, every night from 6 p.m. to 4 a.m. All time data are given in universal time (UT). The insects trapped during one night were stored in one bottle, so the whole catch of one night at one observational site is interpreted as one observational datum.

The collecting data of turnip moth (Scotia segetum Schiff.) were used for examinations getting from 64 observing stations of national agricultural and forestry network operated between 1967 and 1990. During 3 232 nights 29 832 individuals were caught by the traps. We used 25 021 observing data in our examination. We mean by observing data the catching data at one night at one observing station independently of caught moth number.

METHODS

The number of individuals trapped at different observation sites and times cannot be compared to each other even in the case of identical species, as each trap works in different environment factors constantly vary according to time as well. To solve the problem, from the catch data we calculated relative catch (RC) values for observation sites, species and generations. RC is the quotient of the number of individuals caught during the sampling interval (1 night), and the mean values of the number of individuals of one generation counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

The data of meteorological events were collected into groups according to their occurrence on one day alone or together with other ones. They were collected into separated groups according to arriving after a day without any meteorological events or if there were any of them on the previous day. We made a comparison between the relative catch - calculated from the collecting results - and the meteorological events, and also the previous and following 2 - 2 days. Then it the relative catch values were summarized and averaged daily. The differences of daily average values of significance levels were controlled by t-test in all the groups.

RESULTS

The light trapping success of turnip moth (Scotia segetum Schiff.) connected with meteorological events is shown in *Table 1*. The significance level was more than 95% in relative catch values in 36 groups.

If the significant difference of value of relative catch is more than 95% level on two following days it is shown with italic numbers. If the value of relative catch differs more than 95% significance level from the relative catch average of summarized all the other data it is shown with bold numbers. The number of observing data are given in parentheses. No meteorological events are in the table, when there are less than 20 observing data, and probably this is the reason they do not show significant differences neither with the previous day's catching nor the average of summarized all the other data.

CONCLUSIONS

The instability line decreases alone the number of caught specimen only at that case, when it repeats during some days. If cold weather front comes after it still the same day, the unfavourable influence can be shown yet the same day. If it comes with other meteorological events the influence is unfavourable or ineffective for catching result. On the following day the quantity of collecting increases only, if subtropical air mass also arrives. The convergence zone is ineffective alone, but if it comes together with cyclogenesis the number of collected moths decreases on the previous day. There is an unfavourable influence if it comes with moderate maritime air mass from the previous day till following day. The collecting results are low on previous day if cyclogenesis can be found alone. On the day of arriving it is also low when it comes with any other meteorological events. If it comes with country - wide rain the catching is low even on the following day. It is remarkable that the country - wide rain alone is favourable before and after the event for success of catching, but if it comes with any other meteorological events the catching is unfavourable for it. The cold weather front arrived alone is favourable on previous days for collecting, but it is unfavourable on the day of arrival and following one. It is also unfavourable if it arrived together with moderate air mass, and collecting is increased by the coming with arctic air mass, but it is decreased on next day. The warm weather front arrived with subtropical air mass is favourable for catching already on previous day and day of arriving, but it is unfavourable if warm front comes with moderate maritime air mass. The number of caught moths is low on day of arriving and following one at coming of moderate maritime air mass and it is independent of combination with any other meteorological events. The catching is not very high - except if it comes with other meteorological event - on previous day of arriving the moderate continental air mass, but it is high on following days. If the instability line on previous day is followed by moderate continental air mass with cold front on day of arriving, the catching of previous night is high, but it is low on following one. If the instability line on previous day is followed by moderate maritime air mass with cold front on day of arriving, the low collecting can be observed on that day will change for high on following one. The subtropical maritime air masses - arrived alone, with instability line and cold front - are unfavourable, but they are favourable on previous and following days. If these kinds of air masses come with convergence zone and cyclogenesis the collecting is small on previous night. The subtropical maritime air masses - arrived with warm weather front - are favourable for success of collecting on previous day and also on day of arriving. The number of caught moths shows decrease on arriving day of subtropical continental air mass and it is the same on next day. The number of collected moths is lower on arriving and following days of subtropical continental air masses. The catching is high on previous and arriving days belonging to the arctic air mass coming with cold weather front, but there is a decrease on following day.

Our results prove clearly, it is not enough to examine alone the modifying influence of each meteorological events for light-trap collecting. The success of light trapping is modified by several combinations of each meteorological events and they are not very often the same as the catching result of event to have an influence alone. At the time of practical utilization of our results everyone has to pay attention to our hypothesis - expressed in one of our former publications (*Nowinszky* ed., 1994) - as the low values of relative catch mean those weather situations in all cases, when the flight activity of insects decreased, but the meaning of high values are not so equivalent. The significant environmental changes cause physiological changes in the organism of insects. The life of imago is short, unfavourable weather endangers not only the continuance of individual but also the continuance of the total species. According to our supposition the individuals can use two kinds of strategies to prevent the hindering influences of normal function in phenomenon of life. The first is the increased activity. It means the growing intensity in flying, copulation and oviposition. The second strategy is to hide and ride out in passivity the unfavourable situation. Seeing the above-mentioned facts, according to our present knowledge high light trapping results can belong to both favourable and unfavourable situations.

The results of these agrometeorological examinations can give chance to make better plant protection prognosis.

Table 1 Relative catches of turnip moth (Scotia segetum Schiff.) connected with meteorological events used the data of light-trap network in Hungary operated between 1967 and 1990. The explanation of abbreviations is in the text

Name of event						Values of relative catches at the days around events					
Number	Previous days	On the day event				-2	-1	0	→0	1	2
1.	∅	Inst.				1.17 (232)	1.01 (254)	*1.17* (317)	***0.55*** (39)	*0.95* (143)	1.01 (110)
2.	∅	Conv.				1.04 (236)	0.98 (297)	1.05 (391)	1.06 (457)	1.16 (284)	1.02 (189)
3.	∅	C				*1.00* (142)	***0.86*** (166)	*0.99* (395)	***0.86*** (222)	0.93 (367)	0.93 (264)
4.	∅	CF				***1.29*** (81)	***1.36*** (81)	0.89 (279)	***0.56*** (53)	*1.07* (243)	1.09 (180)
5.	∅	CR				**1.76** (52)	***1.78*** (72)	***1.22*** (76)	1.04 (28)	*1.13* (58)	***1.47*** (56)
6.	∅	Mc				*1.05* (91)	***0.66*** (90)	***1.34*** (90)		**1.32** (47)	**1.51** (44)
7.	∅	Mm				0.61 (20)	0.50 (16)	**0.64** (96)		***1.31*** (82)	***0.76*** (71)
8.	∅	Sc				***0.64*** (79)	*1.03* (87)	*0.95* (108)		***0.50*** (39)	***0.56*** (31)
9.	∅	Sm				**1.54** (55)	***1.36*** (68)	*0.97* (99)	***0.80*** (59)	***1.24*** (47)	**1.32** (47)
10.	∅	Inst.				1.11 (148)	1.02 (155)	0.97 (155)		0.96 (43)	0.87 (34)
11.	∅	Inst.	Mm			*1.05* (74)	***1.22*** (79)	***0.94*** (96)	1.10 (28)	1.17 (17)	1.42 (16)
12.	∅	Inst.	CF	Sm		1.11 (148)	***1.53*** (25)	***0.86*** (27)		***1.57*** (30)	***1.35*** (27)
13.	∅	Inst.	CF	Mm		1.02 (209)	1.03 (368)	**0.96** (304)		***0.92*** (306)	***1.14*** (252)

Table 1 continued

Name of event						Values of relative catches at the days around events					
Number	Previous days	On the day event				-2	-1	0	→0	1	2
14.	∅	Inst.	CF	Sm	Am	1.12 (29)	0.77 (29)	0.97 (28)		1.78 (29)	1.24 (27)
15.	∅	Inst.	CF	Mm	Sm	1.23 (22)	1.51 (51)	1.03 (50)		0.74 (36)	1.19 (34)
16.	∅	Inst.	CF	Mm	CR	1.06 (30)	0.78 (32)	0.73 (35)		0.59 (34)	1.07 (35)
17.	∅	Conv.	C	Sm		1.43 (25)	0.85 (28)	1.04 (21)			
18.	∅	Conv.	C	Sm	CR	1.20 (22)	0.81 (22)	0.94 (21)			
19.	∅	Conv.	Mm			1.46 (35)	0.82 (38)	0.72 (52)		0.44 (29)	0.93 (27)
20.	∅	C	CR			1.05 (94)	0.93 (134)	0.64 (202)	0.98 (75)	1.01 (180)	1.35 (94)
21.	∅	C	Mm			1.07 (62)	1.04 (69)	0.79 (95)	1.03 (14)	1.03 (103)	1.06 (90)
22.	∅	C	Mm	CR		1.25 (49)	0.66 (71)	0.62 (104)		0.80 (60)	0.96 (57)
23.	∅	C	Am	CR			1.06 (25)	0.90 (42)		0.87 (38)	1.49 (41)
24.	∅	CF	Mc			0.75 (218)	1.05 (245)	1.09 (318)		0.97 (266)	0.76 (199)
25.	∅	CF	Mm			1.02 (993)	1.03 (1201)	0.92 (1630)	0.88 (156)	0.94 (1463)	0.94 (1392)
26.	∅	CF	Mm	CR		1.02 (34)	1.07 (56)	0.75 (72)	0.71 (21)	0.83 (73)	0.66 (58)

Table 1 continued

Name of event						Values of relative catches at the days around events					
Number	Previous days	On the day event				-2	-1	0	→0	1	2
27.	∅	CF	Ac			*0.98* (45)	***1.21*** (59)	***1.16*** (73)		***0.46*** (63)	*0.99* (36)
28.	∅	CF	Am			0.94 (156)	*1.01* (208)	***1.22*** (228)		***0.92*** (203)	0.98 (173)
29.	∅	CF	Am	CR			*0.97* (46)	***0.70*** (48)		***0.90*** (23)	
30.	∅	WF	Sm			**1.38** (50)	**1.54** (60)	**1.66** (73)		1.18 (16)	
31.	∅	WF	Mm			0.96 (33)	***0.81*** (50)	***0.48*** (68)		*0.96* (39)	***1.35*** (30)
32.	∅	WF	Mc			0.91 (22)	***0.42*** (45)	***1.27*** (45)			
33.	Inst.	CF	Mc			1.11 (58)	**1.15** (60)	***1.12*** (62)		***0.95*** (60)	0.97 (33)
34.	Inst.	CF	Mm			0.99 (54)	*1.00* (69)	***0.42*** (68)		*1.00* (51)	**1.30** (46)
35.	Inst.	CF	Mm	CR		*1.11* (44)	***0.83*** (39)	***0.53*** (36)		*1.19* (25)	
36.	Conv.	CF	Mm			0.92 (45)	*1.02* (49)	***1.48*** (54)		*1.08* (33)	1.05 (20)

Acknowledgements

We hereby express our gratitude to Dr. Pál Szontagh, Doctor of Agricultural Science for collecting data coming from light-traps of forestry, Dr. András Vojnits, senior research-fellow at Museum of National Sciences and Györgyné Mohai research-fellow at Budapest Phytopathological and Soil Protecting Station for collecting data coming from light-traps of plant protection stations and agricultural ones.

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INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

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EFFICIENCY OF LIGHT-TRAPS INFLUENCED BY ENVIRONMENTAL FACTORS

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ABSTRACT
We mean the percentage of species on the efficiency of light traps, captured a number of species present in the environment. Daily changes in the efficiency were studied in connection with the weather elements and moon phases in nine years of collecting material of light-traps operating in Kámon Botanic Garden (Szombathely, Hungary). The first catching day of a particular species is called the appearance, and after the day of the last specimen caught is called disappearance. The difference of the number of species appearing and the disappearing ones means the present species. The number of caught species in the percentage of present ones is the efficiency of light- trap. The light trapping efficiency was investigated with combined data for 9 years. It was examined separately according to each aspects assigned to daily temperature, wind speed, precipitation, relative humidity, cloud height, cloud amount data and the polarized moonlight. The relationships were examined by fitting different models. We found that the efficiency of light traps increases in all aspects with higher temperature and a high proportion of polarized moonlight, but the same can be seen only in the spring and summer aspects at a little cloud, in the autumn and winter aspects a lot of cloud and in the autumn and winter aspects a higher relative humidity causes similar effect. There is a lower efficiency in all aspects because of rain, strong winds, low clouds and high humidity in the spring and summer aspects. Strong influences of abiotic factors cause irregular fluctuations in the efficiency values for each day.

KEY WORDS: efficacy, light-trap, abiotic influences etc.

INTRODUCTION

The first catching day of a particular species is called the appearance, and after the day of the last specimen caught is called disappearance. The difference of the number of species appearing and the disappearing ones means the present species. The number of caught species in the percentage of present ones is the efficiency of light-trap. Our interpretation is without antecedent in the special literature. We stated its theoretical base in our former study (Nowinszky and Puskás, 2011) and we investigate its practical adaptability in present paper. Researchers have examined the influence of the various weather elements on collecting by light-trap all over the world. We confine ourselves to referring to some of the works that illustrate the nature of the research carried out in the world over the past decades (Williams, 1940 Persson, 1972, Járfás, 1979, Honek and Kraus, 1981, Logiswaran and Mohanasundaram, 1987, Matalin 1998). Here are a few points of interest in the results of many years of research. Light-trap effectiveness was enhanced while bait trap effectiveness was not by growing cloudiness. 14 of the 20 noctuid (Noctuidae) and geometrid (Geometridae) species were in positive correlation with temperature and 11 in negative correlation with rain (Holyoak et al., 1997). 15-20 days after the onset of monsoon rain, Sharma et al. (2002) in India observed a positive correlation between rain and relative vapour content on the one hand and the catch by light-trap of *Mythimna separata* Walker on the other. At the same time, evaporation, solar radiation, and the number of sunny hours and wind speed were in negative correlation with the number of insects trapped. A significant negative correlation was established in India between the number of specimens captivated by light-trap of *Scirpophaga incertulas* Walker and relative vapour content (Pandey et al., 2001). The efficiency of light-trap was not earlier investigated in relationship with environmental factors.

MATERIAL AND METHODS

The chosen light-trap, on purpose of examinations, operated in Kámon Botanic Garden at Szombathely (Hungary) between 1962 and 1970. We used the whole Macrolepidoptera data for investigation of connection between the environmental factors and efficiency. There were caught altogether the specimen of 549 different Macrolepidoptera species by light-trap during 9 years. The yearly catching period of light-trap, the number of caught species and swarming are shown in Table 1.

TABLE 1 Light-trap catching periods in Kámon Botanic Garden (Szombathely) as well as the number of caught species and swarming

Years	Catching periods	Number of species	Number of swarming
1962	03. 05. - 11. 21.	343	435
1963	03. 08. - 12. 03.	349	472
1964	03. 23. - 12. 19.	354	463
1965	03. 14. - 12. 21.	205	242
1966	02. 02. - 12. 02.	153	191
1967	02. 03. - 11. 19.	261	312
1968	02. 20. - 11. 26.	296	418
1969	03. 13. - 11. 27.	316	427
1970	02. 03. - 11.30.	323	437

The weather data was collected from year-book of Hungarian Meteorological Service. The data of polarized moonlight was got from our former study (Nowinszky, 2008). The method of calculation of daily efficiency values was the same as it was written in our former study (Nowinszky and Puskás, 2011). Trap effectiveness was calculated on every day of the 9-year period from the Macrolepidoptera material of the light-trap Szombathely. The number of individuals of the respective species was not considered on a daily basis, it was only examined whether certain species was present on a particular day. Data on more-generation species were processed separately according to generations. On the other hand if between the swarming times of two generations vagile or migrating individuals between the swarming periods of two generations could be easily observed, these were considered as independent generation. And if the two generations were not to be separated unambiguously from each other, the procedure used with one-generation species was followed. The trapping data of the first sample of a given generation is called appearance, and the day following trapping data of the last individual is called disappearance. The frequency of appearance and disappearance of all generations of species were summarised day by day, then it was cumulated and illustrated. The difference between the cumulated appearance (A) and the disappearance (D) was calculated. This way we obtained the number of species present (P) in the surrounding of the trap (P=A-D) as a function of time. The number of species trapped daily (T) was determined from the light-trap record and displayed with the species present (P). The individual species of course appear and disappear continuously, thus the aspects following each other cannot be sharply distinguished. We have determined the division lines of aspects through the following procedure: from appearing (A) and disappearing (D) curves of species one can look at most steep slope, *i.e.* the most dynamic variations in time. These were compared with (P) curves and the approximate time data of aspect changes could be read. Finally ratio of entrapped individuals compared with those present in the vicinity was calculated in percentages. This result is what we considered to be the effectiveness of the trap (E). Regression models were fitted and statistically evaluated with PASW18 software. The explained variances (R^2) were calculated. The models were tested with ANOVA and the parameters were tested with t-test. The normality of the residuals was verified by Kolmogorov-Smirnov test with Lillieford correction at p>0.1 level.

1. The efficiency depending on the amount of precipitation was fitted with a decreasing exponential model:

$$Y = p_1 + p_2\left(1 - \exp(-p_3 * X)\right) + \varepsilon \qquad (1)$$

where Y is for efficiency, X is for precipitation amount, p_1 is the model parameter for the case $X = 0$, p_2 is the descending value of the model, p_3 is a speed factor of the model and ε is a normally distributed error term with zero expectation.

2. The efficiency depending on the cloudiness of the sky (okta) was expressed by a third degree polynomial model:

$$Y = p_0 + p_2 X^2 + p_3 X^3 + \varepsilon \qquad (2)$$

where Y is for efficiency, X is for cloudiness (okta), p_0, p_2 and p_3 are model parameters. We omitted the first-degree term because it was insignificant (p>0.1). We distinguished the spring-summer time from the fall-autumn one and calculated different parameters of the model.

3. The altitude effect on the efficiency was modeled with a growing exponential model of the form (1), X is for altitude.
4. The efficiency has a strong linear correlation with moon phases which can be described with a linear model of the form $Y = p_0 + p_1 X + \varepsilon$, X is for moon phases.
5. The temperature affects on efficiency through a logarithmic model: $Y = p_0 + p_1 \ln X + \varepsilon$, X is for temperature. We calculated the optimal parameters separately for each season. The model parameters were very similar for winter and spring, so we merge these data and calculated the parameters again.
6. The efficiency can also be modeled with an exponential model $Y = p_0 * \exp(p_1 X) + \varepsilon$ where X is for wind speed.
7. The efficiency depending on relative humidity was fitted by a third degree polynomial model of form

$$Y = p_0 + p_1 X + p_2 X^2 + p_3 X^3 + \varepsilon,$$

X is for relative humidity. We distinguished the spring-summer time from the fall-autumn one and calculated different parameters of the model.

The estimated model parameters, their significance level, the F values of the ANOVA tests for the models with their significance level and the explained variance (R^2) are presented in Table 1.

TABLE 2: The estimated model parameters, their significance level, the F values of the ANOVA tests for the models with their significance level and the explained variance (R^2)

Explaining factor	Model	estimated parameter		Sig.	F	Sig.	R^2
1. precipitation	$Y = p_1 + p_2(1-\exp(-p_3 * X)) + \varepsilon$	p_1	0.307	<0.001	3921.21	<0.001	0.945
		p_2	-0.079	<0.001			
		p_3	0.179	<0.01			
2.1 cloud-cover spring-summer	$Y = p_0 + p_2X^2 + p_3X^3 + \varepsilon$	p_0	0.330	<0.001	65.34	<0.001	0.956
		p_2	-0.005	<0.001			
		p_3	0.001	<0.01			
2.2 cloud-cover fall-autumn	$Y = p_0 + p_2X^2 + p_3X^3 + \varepsilon$	p_0	0.302	<0.001	43.27	<0.001	0.935
		p_2	0.000	<0.001			
		p_3	-0.002	<0.01			
3. cloud altitude	$Y = p_1 + p_2(1-\exp(-p_3 * X)) + \varepsilon$	p_1	0.222	<0.001	1516.60	<0.001	0.893
		p_2	0.085	<0.001			
		p_3	0.002	<0.05			
4. moon phases	$Y = p_0 + p_1X + \varepsilon$	p_0	0.264	<0.001	33.68	<0.001	0.584
		p_1	0.007	<0.001			
5. 1 temperature spring	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.259	<0.001	42.73	<0.001	0.767
		p_1	0.038	<0.001			
5.2 temperature summer	$Y = p_1 \ln X + \varepsilon$	p_1	0.104	<0.001	2851.57	<0.001	0.750
5.3 temperature fall	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.204	<0.001	11.56	<0.01	0.536
		p_1	0.037	<0.01			
5.4 temperature winter	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.240	<0.001	29.57	<0.001	0.767
		p_1	0.049	<0.001			
5.5 temperature winter-spring	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.254	<0.001	75.32	<0.001	0.758
		p_1	0.041	<0.001			
6. wind speed	$Y = p_0 * \exp(p_1X) + \varepsilon$	p_0	0.001	<0.001	166.16	<0.001	0.943
		p_1	-0.049	<0.001			
7.1 relative humidity spring-summer	$Y = p_0 + p_1X + p_2X^2 + p_3 * X^3 + \varepsilon$	p_0	2,472	<0,001	8566.46	<0.001	0.977
		p_1	-0,096	<0,001			
		p_2	0,001	<0,001			
		p_3	-6.494E-6	<0,001			
7.2 relative humidity fall-winter	$Y = p_0 + p_1X + p_2X^2 + p_3 * X^3 + \varepsilon$	p_0	8.892E-6	ns	1443.16	<0.001	0.637
		p_1	0.172	ns			
		p_2	-4.313	ns			
		p_3	-0.002	ns			

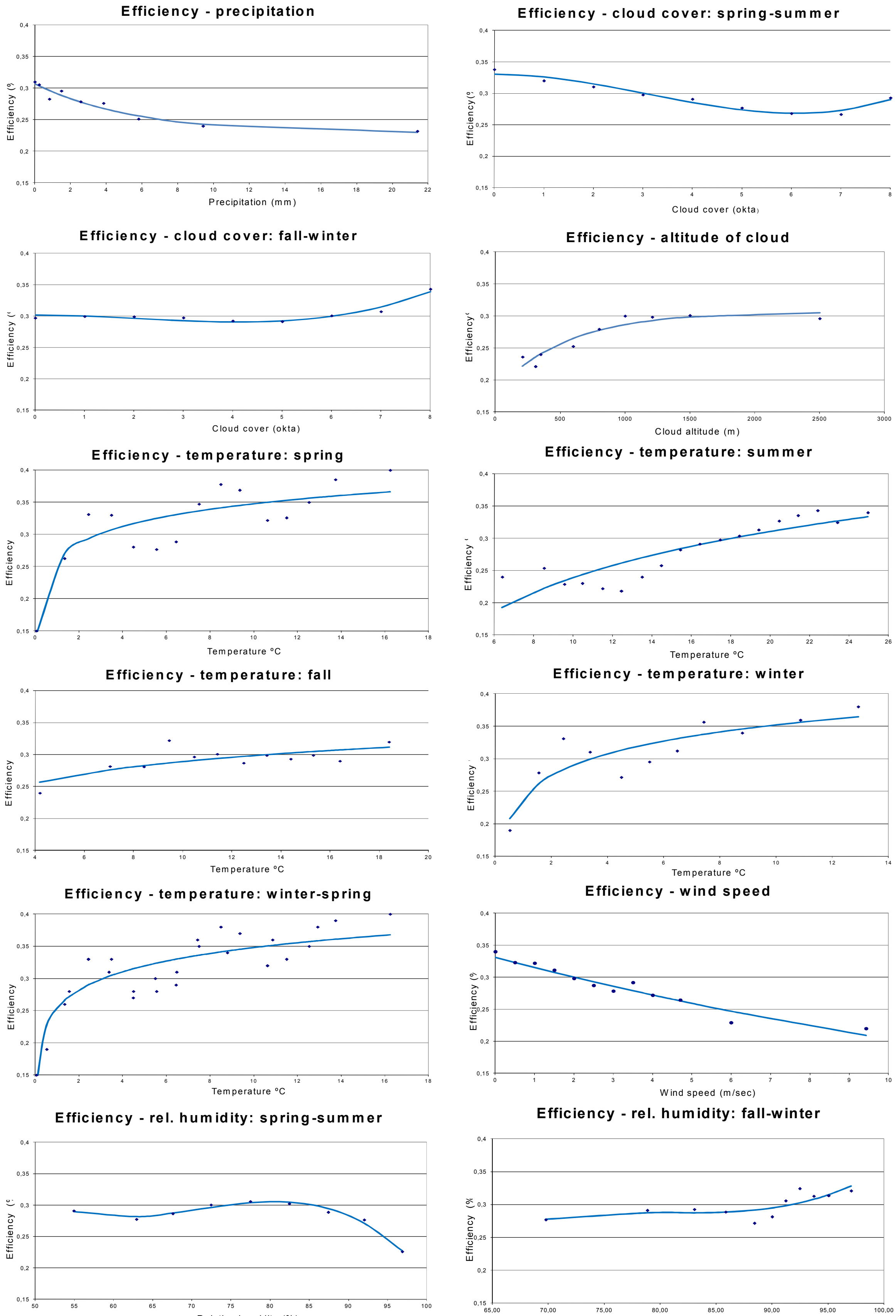

FIGURE 1: Observed data (dots) and models (lines) fitted to the efficiency (%) with predictive factors precipitation (mm), cloud cover (okta), altitude of cloud (m), temperature (°C), wind speed (m/sec) and relative humidity (%)

DISCUSSION

Higher temperature belongs to higher efficiency in all the four aspects. The wind speed is clearly reduces the efficiency of light traps in all aspects. The precipitation also caused efficiency loss, especially over the amount of 5 mm. The relative humidity of air drastically reduces the efficiency of light traps when it is above 80% in the spring and summer aspects. However, the highest efficiency is in the autumn and winter aspects if the humidity is above 90%. Probably the cause of this apparently unexpected result is the significantly higher moisture content of the air in the autumn and winter, because it was only 88.2 % and 77.1 % during spring and summer. The Macrolepidoptera species, flying in these periods, could adapt to these circumstances, thus the higher humidity is more favorable for them.

The threshold can be observed in all aspects at 1000 meters altitude clouds. The light trapping efficiency is lower below and higher above this altitude. The efficiency is high in spring and summer aspects at unclouded sky or if there is less cloud, but the efficiency decreases when sky is overcast. It is interesting that the efficiency is also high at full overcast sky (okta = 8). Probably this is because of the largest collection distance which is well used by the good flying species. The efficiency rises sharply in the autumn and winter aspects if the overcast value is above 6. The reason may be also because of the increased collection distance, and partly the higher relative humidity at cloudy sky.

The growing percentage values of polarized moonlight clearly increase the efficiency of light-traps in all aspects. This result confirms our previous statements we got about the number of moth specimens caught by light traps, also in the context of polarized moonlight (Nowinszky, 2008).

Our results show that the efficiency of light traps, similarly to the number of individuals captured, significantly changes because of the influence of environmental factors.

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P O L I S H J O U R N A L O F E N T O M O L O G Y
P O L S K I E P I S M O E N T O M O L O G I C Z N E

VOL. **83**: 269–280 Lublin 31 December 2014
DOI: 10.2478/pjen-2014-0021

Effect of weather conditions on light-trap catches of Trichoptera in Hungary (Central Europe)

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ABSTRACT. The study deals with the effect of weather conditions on the light trap catch of 2 caddisflies (Trichoptera) species: *Hydropsyche bulgaromanorum* and *Setodes punctatus*. We found that the light trap catch of both species increased when the daily maximum temperature, minimum and average values of temperature was higher. The results can be written down with second- or third-degree polynomials. The fluctuation in temperature had no clear influence on the catch. The hydrothermal quotient has a strong influence on the catch of both species. Precipitation has no significant influence on the catch of the tested species.

KEY WORDS: caddisflies, light-trap, weather conditions.

INTRODUCTION

Temperature may have an important influence from the point of view of insects' flying activity. The given temperature requirements of insects can be explained by the fact that their body mass is very small compared to both its surface and the environment. That is why the temperature of their body, instead of being permanent and self-sufficient, follows the changing temperature of the environment. This is because the ratio of the body mass and surface of insects determines the difference between the inner heat content and the incoming or outgoing heat. The heat content of the body is proportional to its mass, while, on the other hand, the heat energy intake or loss is proportional to the size of the surface of the body. Therefore an external effect makes its influence felt as against the inner, small heat content of a relatively small mass. The speed as well as the size of the impact brings on the ratio between the mass and surface of the body of the insect (BACSÓ 1964). And so the temperature value always exerts a substantial influence on the life processes of insects. The chemical processes described as metabolism that determine the life functions of insects always follow the temperature changes in the direct surroundings. Naturally, the activity of the organs of locomotion also depends on the temperature of the environment which explains why we can expect a massive light-trap turnout at what is an optimal temperature for the given species (MANNINGER 1948). SOUTHWOOD (1978), on the other hand, is of the view that the flight of insects has a bottom and top temperature threshold typical of each species. The insect flies if the temperature is above the bottom and below the top threshold and becomes inactive when the value is below the bottom or above the top threshold. In his view, other reasons explain the fluctuations in the number of specimens experienced in the interval between the low and high threshold values. However, research in Hungary has proved that in the context of a single species, a significant regression can be established between the temperature values and the number of specimens collected by a light-trap (JÁRFÁS 1979, NOWINSZKY et al. 2003). Polish research has also confirmed that the number of noctuids light-trapped increases with the rise of temperature (BUSZKO & NOWACKI 1990).

Researchers in many countries of the world have gathered Trichoptera species using light-traps. Examples are the following: SODE & WIBERG-LARSEN (1993) in Denmark, COLLIER et al. (1977) in New Zealand, CRICHTON (1978) in Great Britain, MALICKY (1987) in Austria, ÚJVÁROSI (1999) in Romania, KISS (2004) in Hungary, CZACHOROWSKI & SERAFIN (2004) in Poland and Belarus, DICKEN & BOYACI (2008) in Turkey, HIGLER et al. (2008) in Netherland, STANIĆ-KOŠTROMAN et al. (2012) in Bosnia and Herzegovina, RYCHŁA & BUCZYŃSKA (2013) in Poland, BUCZYŃSKA et al. (2014) in Russia.

Many studies also deal with the effect of weather conditions on light-trap catches of different Trichoptera species.

According to USSEGLIO-POLATERA (1987) the wind has a powerful influence on the flight direction of Trichoptera adults which generally fly against the wind. SODE & WIBERG-LARSEN (1993) contradict this, their results show a lot of *Silo pallipes* fly downwind. CIUBUC (1989) in Romania studied the effectiveness of light traps for two Trichoptera species as a function of temperature, wind speed, humidity and precipitation.

WARINGER (1991) tested the influence of precipitation, wind speed and night air temperature on light-trap catch of Trichoptera, but only the effect of air temperature was correlated with flight activity.

WARINGER (1991) collected imagos Trichoptera for 1 year (between February 1989 and March 1990) on the coast of Danube, in Lower Austria (Bad Deutsch Altenburg), with a Jermy-type light-trap. The influence of precipitation, wind speed and night air temperature (maximum, mean and minimum) on catch success was tested. Only the air temperature was significantly related to flight activity, however, this had a very significant effect ($p<0.001$). There was not any catch if the maximum temperature was under 6.8 °C, and the catch was highest on the warmest nights.

KIMURA et al. (2008) found a significant correlation between the daily caddisflies catches and average daily temperature. There were no imagos collected on those days when the average daily air temperature was lower than 10.7 °C.

The study of HIROBAYASHI et al. (2011) indicates that the average temperature in summer, and floods, influenced the seasonal mass of *Psychomyia acutipennis* ULMER, 1908 imagos.

In an earlier paper (KISS et al. 2011) we examined the relationship between the success of light trapping *Ecnomus tenellus* Rambur with air temperature measured at 10 pm. The results prove, there is an increase in the catch with an increase in air temperature between 11 and 23 °C. This increase can be described with an exponential function between the range of lower and higher temperature threshold. The collection was especially successful above 19 °C. In the same temperature range the number of nights with unsuccessful catch decreased linearly with increasing temperature.

PROMMI et al. (2012) in Thailand found that the air temperature and relative humidity are particularly important, and the higher temperature and low humidity shorten the life of aquatic beetles groups. A microclimate can affect flight activity of aquatic species.

We examined in our present study the influence of weather conditions that affect the light-trap catch in Hungary, near the Tisza River in Szolnok Region. The data of the two Trichoptera species which were caught in largest numbers, were processed.

MATERIAL AND METHODS

We used Jermy-type light-traps near Szolnok (geographical coordinates: 47°10' N, 20°11' E) on coast of the River Tisza (KISS & ZSUGA, 2012). Light-traps were in operation on all nights between 1st June and 30th September in 2000. In this study, the following species were selected: (1) *Hydropsyche bulgaromanorum* MALICKY, 1977 (Trichoptera: Hydropsychidae), at 94 nights 22500 individuals; (2) *Setodes punctatus* FABRICIUS, 1759 (Trichoptera: Leptoceridae), at 86 nights 1848 individuals.

The Jermy-type light-trap has the following characteristics:

The lamp is 200 cm above the ground; the light source is a 100W normal electric bulb; the metal roof protects the light source and also the captured insects from rain. Chloroform was used as the killing agent. The trap was in operation from sunset till sunrise. Determination of trapped insects and data logging took place in the morning.

The weather data, necessary to our investigations, were abstracted from daily weather reports issued by the National Weather Service. We examined the effect of the following weather features: daily maximum and minimum temperatures; daily mean temperature; daily temperature oscillation; hydrothermal quotient (maximum/minimum); maximum wind speed; daily rainfall (mm); occurrence of rain showers and thunderstorms.

We calculated relative catch values from the number of specimens trapped. The relative catch was defined as the quotient of the number of individuals of the species caught during a sampling time unit (1 night) per the average catch (number of individuals of all species) from that trap, relating to the same time unit. For example when the actual catch was equal to the average individual number captured, the relative catch value was 1 (NOWINSZKY 2003).

Data on the weather elements was organized into groups according to the method of STURGES (ODOR & IGLÓI 1987). The relative catch values of both species were grouped according to the weather elements and then the values were summarized and averaged. Finally we plotted our results.

RESULTS AND DISCUSSION

Our results are shown in Figures 1-11.

The characteristic curves and associated parameters are indicated in the figures and significance levels are also given.

Our results are usually characterized by a second or third degree polynomial.

We found that the light trap catch of both species increased when the daily maximum temperature, minimum and average values of temperature is higher. The fluctuation in temperature did not affect captures of *Hydropsyche bulgaromanorum*, but the catch of *Setodes punctatus* decreased when the temperature change was high.

As an important new result, we found that the hydrothermal quotient had a strong influence on the outcome of collections of both species. The numbers of both species was the highest when the daily maximum and minimum value of the ratio was between 1.2 and 1.8. This means that the catch was largest on those days when the maximum and minimum deviation is moderate.

The effect of maximum wind speed on catching *Hydropsyche bulgaromanorum* was not conclusive; however *Setodes punctatus* could be caught in lively winds.

Precipitation had no significant influence on the catch of the tested species. These results are therefore not shown.

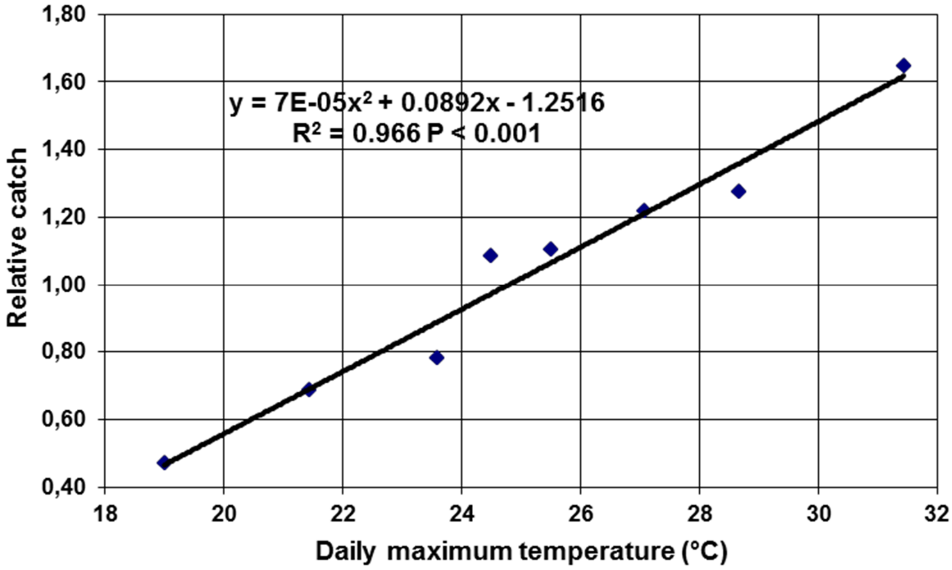

Fig. 1. Light-trap catch of *Hydropsyche bulgaromanorum* depending on the daily maximum temperature (Szolnok, 2000).

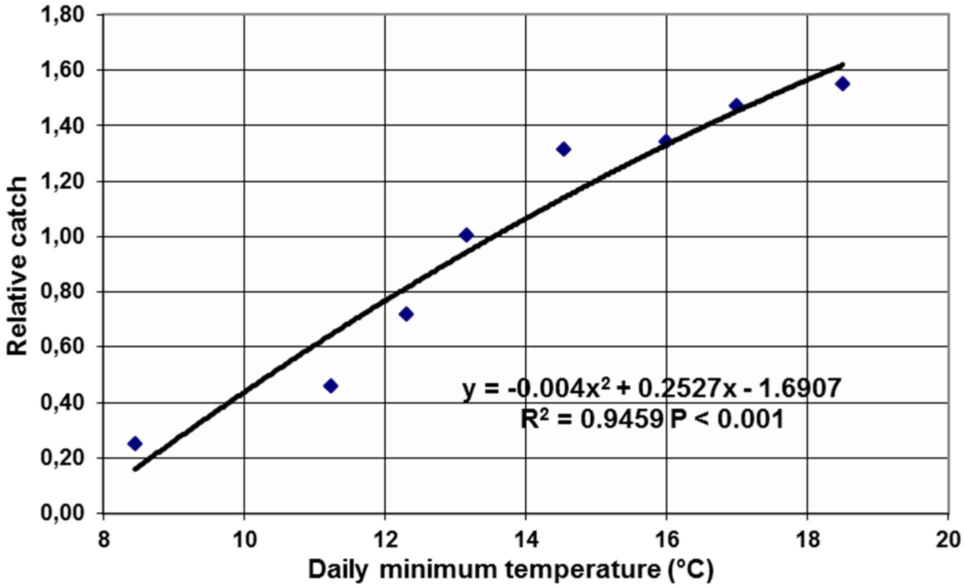

Fig. 2. Light-trap catch of *Hydropsyche bulgaromanorum* depending on the daily minimum temperature (Szolnok, 2000).

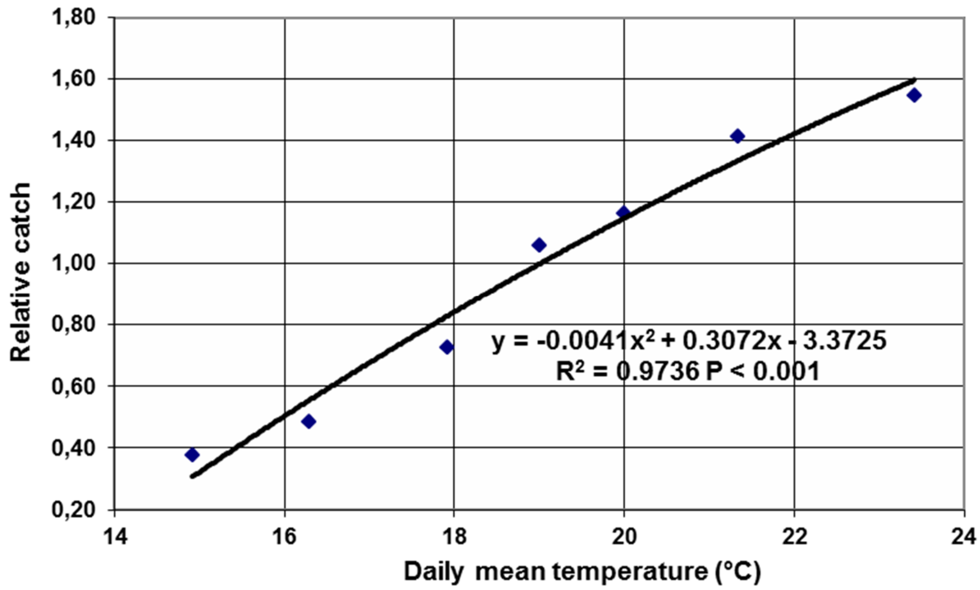

Fig. 3. Light-trap catch of *Hydropsyche bulgaromanorum* depending on the daily mean temperature (Szolnok, 2000).

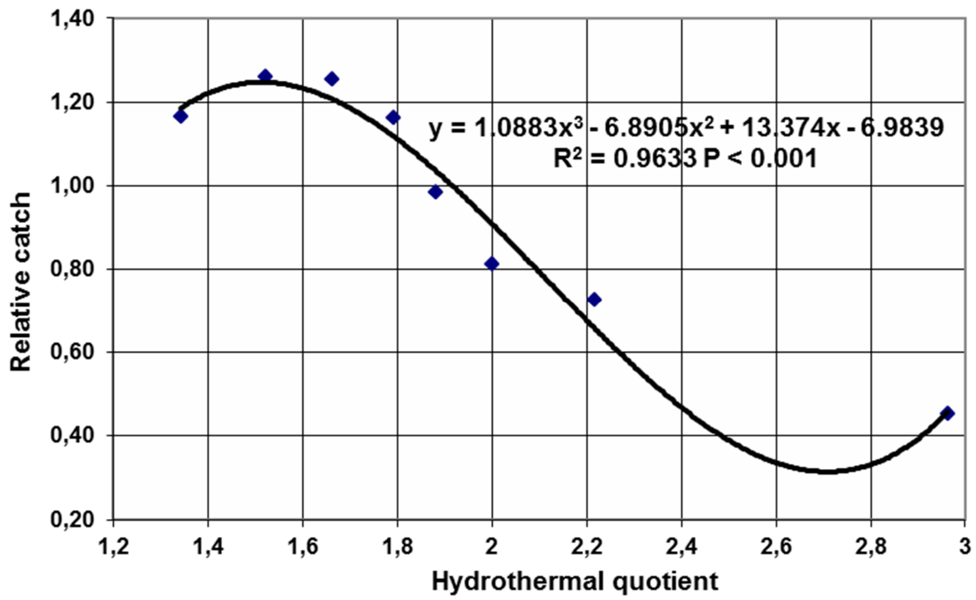

Fig. 4. Light-trap catch of *Hydropsyche bulgaromanorum* depending on the hydrothermal quotient (Szolnok, 2000).

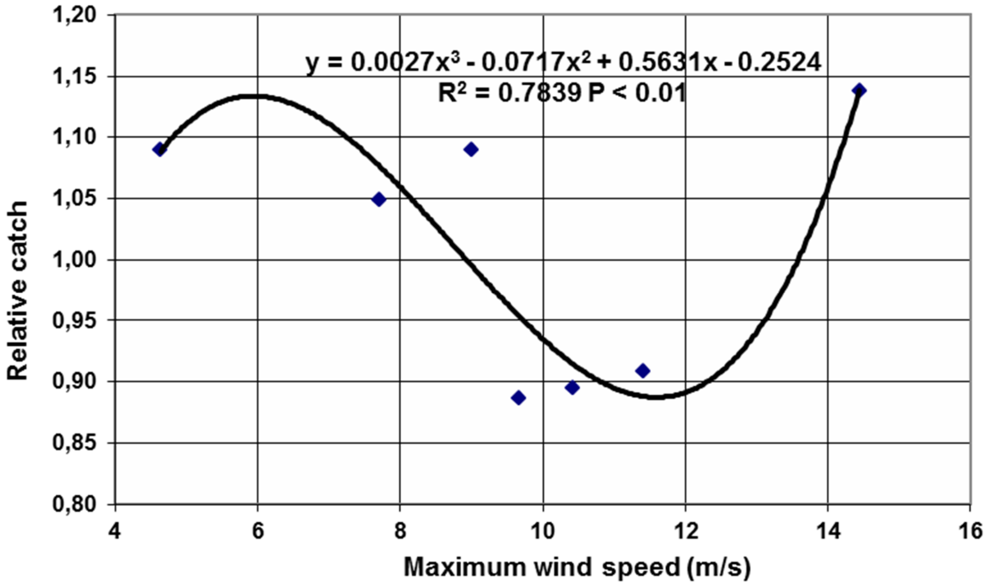

Fig. 5. Light-trap catch of *Hydropsyche bulgaromanorum* depending on the maximum wind speed (Szolnok, 2000).

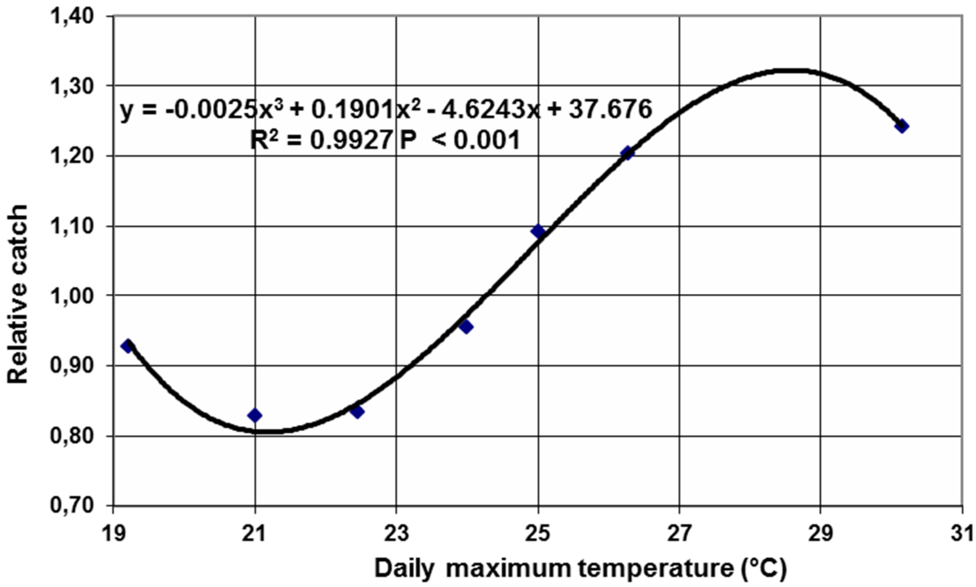

Fig. 6. Light-trap catch of *Setodes punctatus* depending on the daily maximum temperature (Szolnok, 2000).

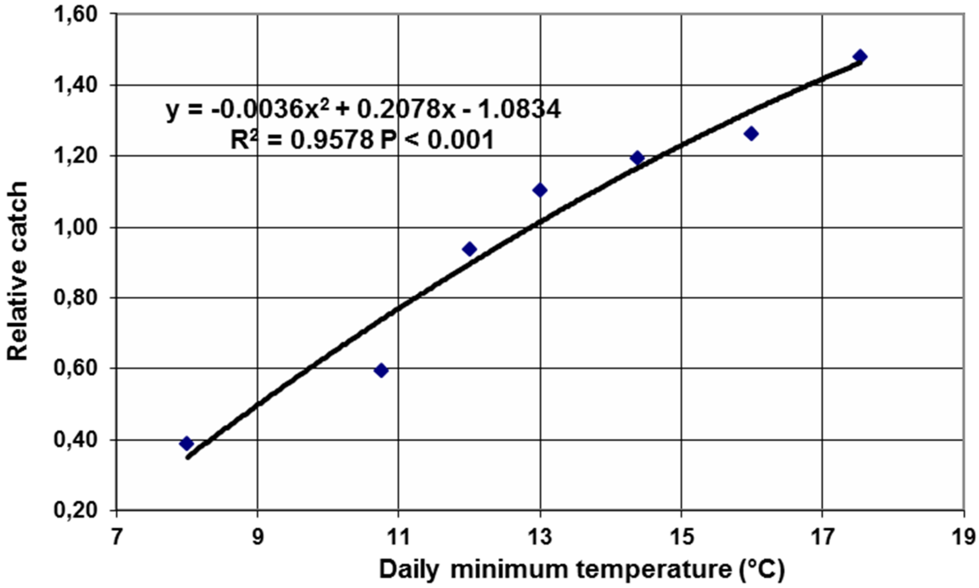

Fig. 7. Light-trap catch of *Setodes punctatus* depending on the daily minimum temperature (Szolnok, 2000).

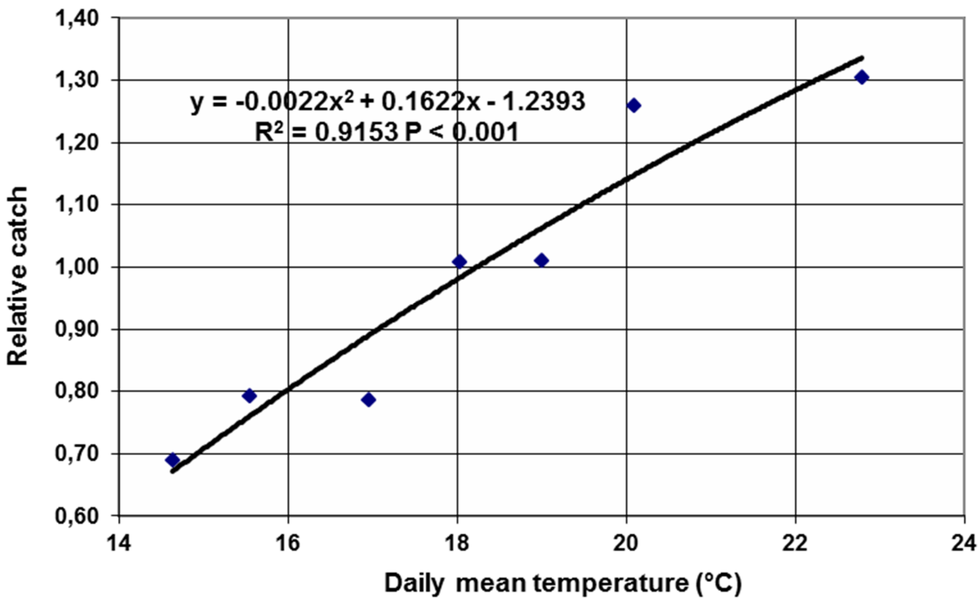

Fig. 8. Light-trap catch of *Setodes punctatus* depending on the daily mean temperature (Szolnok, 2000).

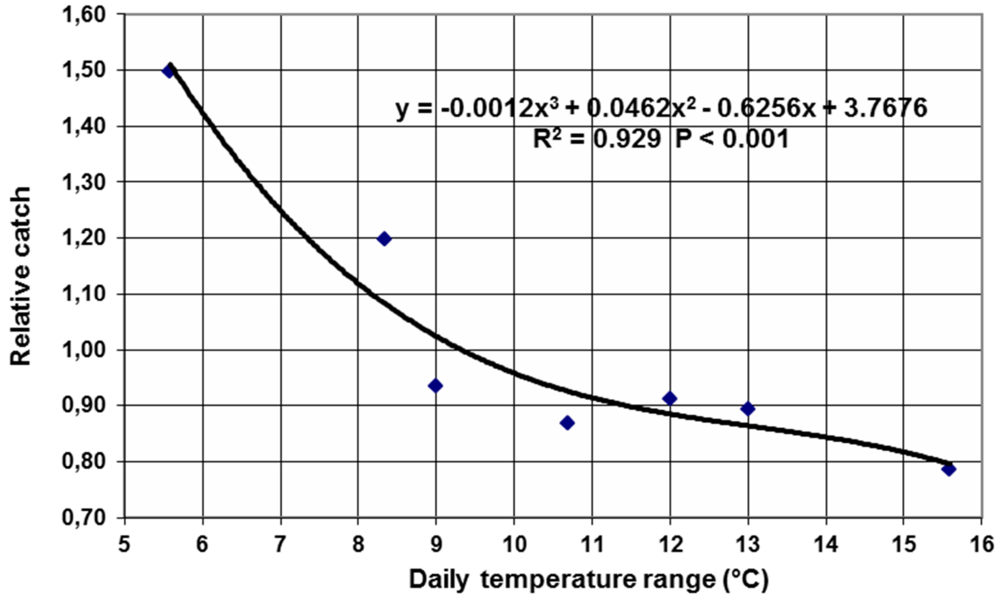

Fig. 9. Light-trap catch of *Setodes punctatus* depending on the daily temperature range (Szolnok, 2000).

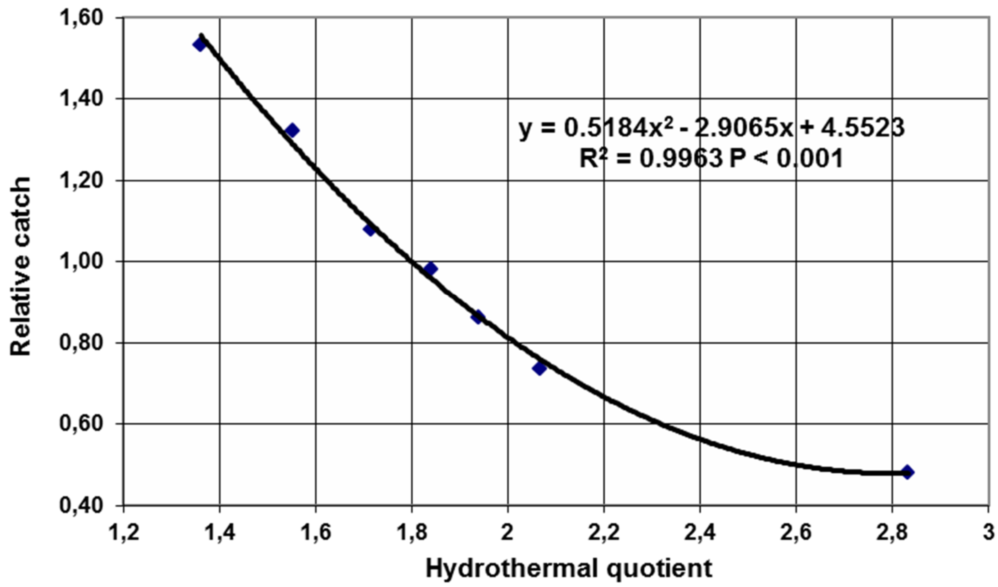

Fig. 10. Light-trap catch of *Setodes punctatus* depending on the on the hydrothermal quotient (Szolnok, 2000).

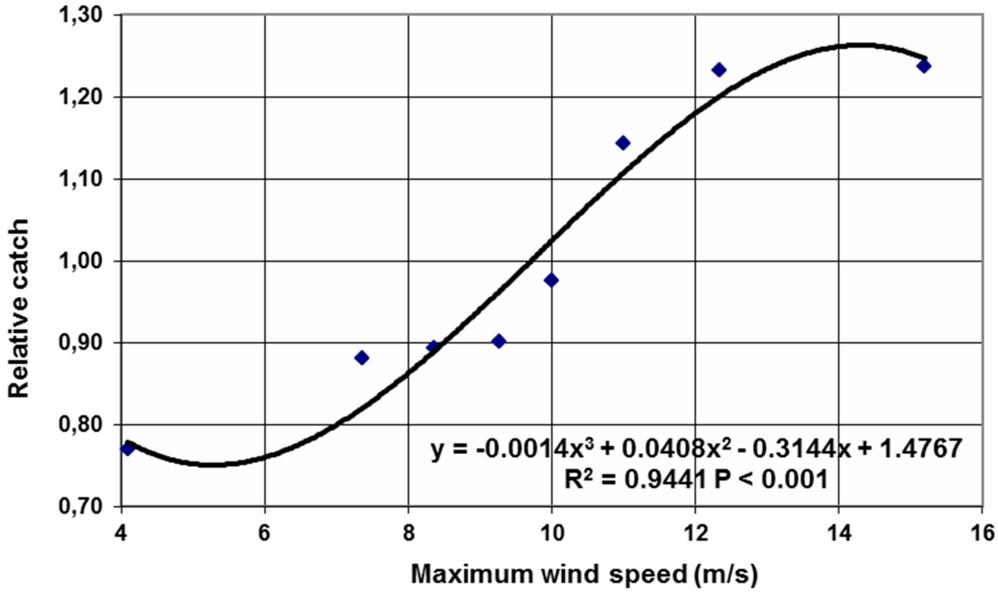

Fig. 11. Light-trap catch of *Setodes punctatus* depending on the on the maximum wind speed (Szolnok, 2000).

In the future, we plan to publish the results of similar investigation into other species caught at Szolnok with a summary paper to consider all the results.

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Received: 7 May 2014
Accepted: 23 September 2014

Annals of Natural Sciences
Vol. 2(2), June 2016: 16-23
Journal's URL: http://www.crsdindia.com/ans.html
Email: crsdindia@gmail.com

e-ISSN: 2455-667X

Annals of Natural Sciences

ORIGINAL ARTICLE

Light-Trap Catch of the Fluvial Trichoptera Species in Connection With the Air- and Water Temperature

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ABSTRACT

This study deals with the effectiveness of light trapping of caddisflies (Trichoptera) species in connection with the air- and water temperature. Our Jermy-type light-trap operated in riverside of River Tisza at Szolnok between 1st April and 31st October 2000 every night. We processed catching data of ten species were caught in large quantities. We arranged the data on both the averaged daily air temperature and water temperature in classes. The data are plotted for each species and regression equations were calculated for relative catch of examined species and temperature data pairs. Our results show that both the water and the air temperature modify significantly the flying onto light of the studied caddisfly species. The increase of temperature initially increases the number of caught species; there is only one number of the individuals where we found a decrease.

Key words: *light-trap, caddisflies, water- and air temperature*

Received: 12th Jan. 2016, Revised: 1st March 2016, Accepted: 25th March 2016

How to cite this article:
Puskás J., Nowinszky L. and Kiss O. (2016): Light-Trap Catch of the Fluvial Trichoptera Species in Connection With the Air- and Water Temperature. Annals of Natural Sciences, Vol. 2[2]: June, 2016: 16-23.

INTRODUCTION AND LITERATURE BACKGROUND

Temperature may have an important role from the point of view of flying activity. The given temperature requirements of insects can be explained by the fact that their body mass is very small com-pared to both its surface and the environment. That is why their body temperature, instead of being permanent and self-sufficient, follows the changing temperature of the environment. This is because the ratios of the body mass and surface of insects determine the difference between the inner heat content and the incoming or outgoing heat. The heat content of the body is proportionate to its mass, while, on the other hand, the heat energy in take or loss is proportionate to the size of the surface of the body. Therefore an external effect makes its influence felt as against the inner, small heat content of a relatively small mass. The speed and size of the effect depends on the mass and surface if the body of insects (Bacsó, 1964).

This statement is of course valid for the air temperature, water temperature, and the ground temperature.

And so the temperature value always exerts a substantial influence on the life processes of insects. The chemical processes described as metabolism that determine the life functions of insects always follow the temperature changes in the direct surroundings. Naturally, the activity of the organs of locomotion also depends on the temperature of the environment which explains why we can expect a massive light-trap turnout by what is an optimal temperature for the given species (Manninger 1948).

Air Temperature-

Kimura et al. (2008) found a significant correlation between the daily individual number of caddisflies and the average daily temperature. There was not caught any caddisflies when the daily average temperature was less, than 10.7 °C.

Higler et al. (2008) found that the flight activity of *Ceraclea dissimilis* Stephens already started at higher temperature of 16 °C, and it seems that there was a positive correlation, because of the very large number of flying, when the maximum temperature was over 20 °C. But it was not high catch during all warm evenings. The minimum temperature of catches generally was between 15 and 20 °C at those nights, and the catches follow the trends with the maximum temperatures.

According to Brakel et al. (2015) caddisfly flight periodicity is likely controlled by a combination of innate behaviour and environmental factors, primarily temperature. That is, species will be active for a predetermined period of time if temperature is appropriate.

Water Temperature-

The brook sections' water temperature follows the changes of the air temperature (Kiss, 2012). The water temperature is just as important in terms of light-trap catch of caddisflies. Indeed, the puppet climbs out onto the stones getting out from the water, moults and after 10-15 minutes testing his wings, flying out leaves the stream.

Kiss (2004) found the bottom of the brook is covered with large stones. The depth of water is between 3 cm and 5 cm. The brook flows in several branches of a width of 40-50 cm each. Water temperature is 17.9°C in August and 9.1°C in September.

Water temperatures were recorded by Malicky and Chantaramongkol (1993) only when collecting specimens. Correct measuring of water temperatures would need permanent records to determine the limits. This is important in temperate and cold regions where short-term variation of water temperature may be high.

Water temperature controls both oxygen supply and oxygen demand because oxygen concentrations are inversely related to temperature and metabolic rates of insects are positively related to temperature (Kovalak, 1976).

MATERIAL AND METHODS

The selected caddisflies specimens used in our investigations are originated from previous light-trap collections. There was the most important point of view at the selection of species and swarming the total number of male and female specimens exceeds 700. The collection site, they geographical coordinates and the year of collection are as follow:

Tisza River at Szolnok (47°10′76"N; 20°11′25"E) in year 2000.

The families, species, number of specimen and catching nights of examined caddishflies are shown in Table 1.

Jermy-type light-trap was used in catch of caddisflies.

The light-trap consists of a 125 W mercury lamp and a saving lid with a diameter of 1 metre. There was a collecting funnel under the lamp. Its diameter was 40 cm and this collector drove into a container. We used clear chloroform as killing material. Our light-traps operated in all years and on all settlements between 1st April and 31st October on all nights.

We mean a generation's flying period by swarming. Than the number of individuals of a given species in different observation years is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago (Nowinszky 2003).

The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals. If the number of specimens taken from the average of the same, the relative value of catch: 1 (Nowinszky 2003).
The data of air and water temperature were taken from year-book of Hungarian Meteorological Service. From the collection data pertaining to examined species we calculated relative catch values (RC) by swarming of examined species.
We calculated groups with consideration to the method of Sturges (Odor and Iglói, 1987) from the number of daily temperature ranges and the number of the individuals and species. The number of individuals and species were arranged into the proper classes.
Following we arranged the data on both the averaged daily air temperature and water temperature in classes. Relative catch values were placed according to the features of the given day, and then RC were summed up and averaged. The data are plotted for each species and regression equations were calculated for relative catch of examined species and temperature data pairs. We determined the regression equations, the significance levels which were shown in the Figures.

Table 1: The catching data
(Families, species, number of specimen and catching nights)

Families – Species	River Tisza (Szolnok, 2000)	
	Number of	
	Specimen	Nights
Hydroptilidae		
Agraylea sexmaculata Curtis, 1834	1,725	127
Ecnomidae		
Ecnomus tenellus Rambur, 1842	2,193	103
Polycentropodidae		
Neureclipsis bimaculata Linnaeus, 1758	1,593	95
Hydropsychidae		
Hydropsyche contubernalis Mc Lachlan, 1865	12,302	179
Hydropsyche bulgaromanorum Malicky, 1977	22,224	81
Limnephilidae		
Limnephilus affinis Curtis, 1834	723	104
Leptoceridae		
Athripsodes albifrons Linnaeus, 1758	814	115
Ceraclea dissimilis Stephens, 1836	928	100
Setodes punctatus Fabricius, 1759	1,848	87
Oecetis ochracea Curtis, 1825	385	103

Notes: The taxonomic classification of the species was carried out according to Kiss (2003).

RESULTS AND DISCUSSION

Our results are shown in Fig. 1-10 and Table 2.
Our results show that both the water and the air temperature modify significantly the flying onto light of the studied caddisfly species. The increase of temperature initially increases the number of caught species; there is only one (*Hydropsyche bulgaromanorum* Malicky) number of the individuals where we found a decrease. According to our opinion the increasing catch, in parallel with higher temperature, can be explained that the value of temperature optimum of the species is equal or higher as the maximum values measured at the time of swarming. In the beginning, in parallel with the increase of temperature rising, then at a given taller temperature, when there is decreasing catch, we think more reason for it.

- The more rising temperature is already unfavourable in terms of flight activity

- Prolonged swarming when the temperature continues to rise, but the number of clamped caddisflies has decreased (*Athripsodes atterimus* Linnaeus)
- Due to the different developmental stages the pupation is delayed, this time may be less flying insects (*Limnephilus affinis* Curtis)
- Because of the protracted laying eggs hectic light flying can be detected (*Hydropsyche bulgaromanorum* Malicky)
- The stray beetles can cause more swarming peaks (Kiss et al. 2006)

Table 2: Temperature threshold and optimum of water, temperature and air ones of examined Trichoptera species

Families – Species	Water temperature (°C)			Air temperature (°C)		
	threshold	optimum	I or D	threshold	optimum	I or D
Hydroptilidae						
Agraylea sexmaculata Curtis, 1834	10.2	20.4	I–D	5.5	23.2	I
Ecnomidae						
Ecnomus tenellus Rambur, 1842	16.0	25.2	I	12.5	23.3	I
Polycentropodidae						
Neureclipsis bimaculata Linnaeus, 1758	16.0	25.5	I	12.5	20.5	I–D
Hydropsychidae						
Hydropsyche contubernalis Mc Lachlan, 1865	9.5	25.1	I	5.5	22.6	I
Hydropsyche bulgaromanorum Malicky, 1977	18.4	20.3	I	14.0	24.4	D
Limnephilidae						
Limnephilus affinis Curtis, 1834	18.4	21.6	I–D	8.5	23.6	I–D
Leptoceridae						
Athripsodes albifrons Linnaeus, 1758	16.0	22.9	I–D	13.5	23.6	I
Ceraclea dissimilis Stephens, 1836	16.0	22.9	I–D	13.5	23.6	I
Setodes punctatus Fabricius, 1759	16.0	23.9	I	12.5	20.7	I
Oecetis ochracea Curtis, 1825	18.2	24.5	I	13.5	20.7	I–D

Notes: I = increasing, D = decreasing, I–D = at first increasing after it decreasing

Figure 1 Light-trap catch of *Agraylea sexmaculata* Curtis depending on the water- and air temperature (River Tisza Szolnok, 2000)

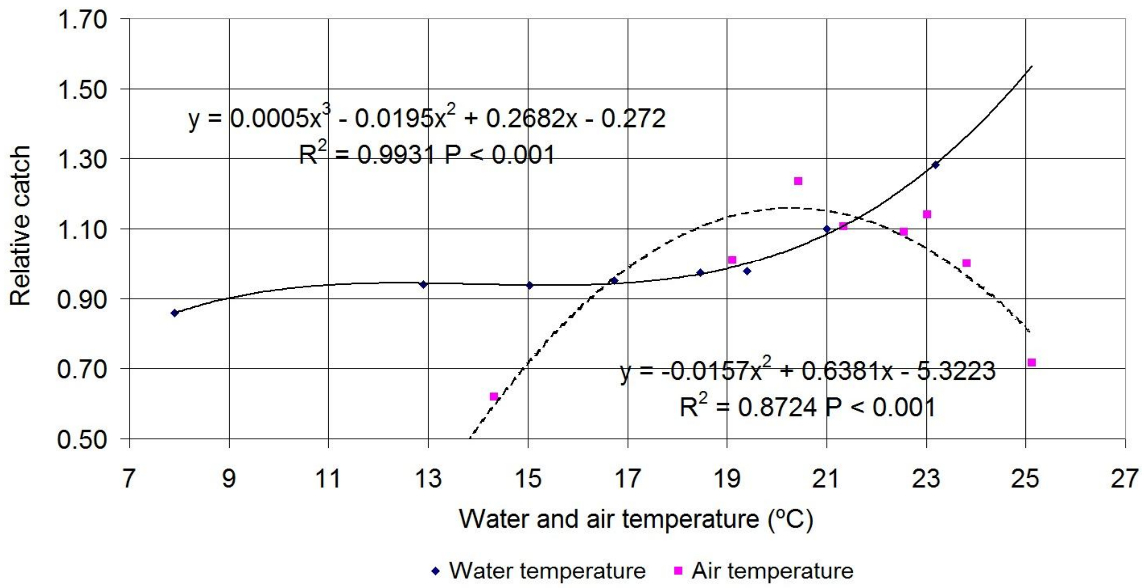


Figure 2 Light-trap cach of *Ecnomus temellus* Rambur depending on the water and air temperature (River Tisza Szolnok, 2000)

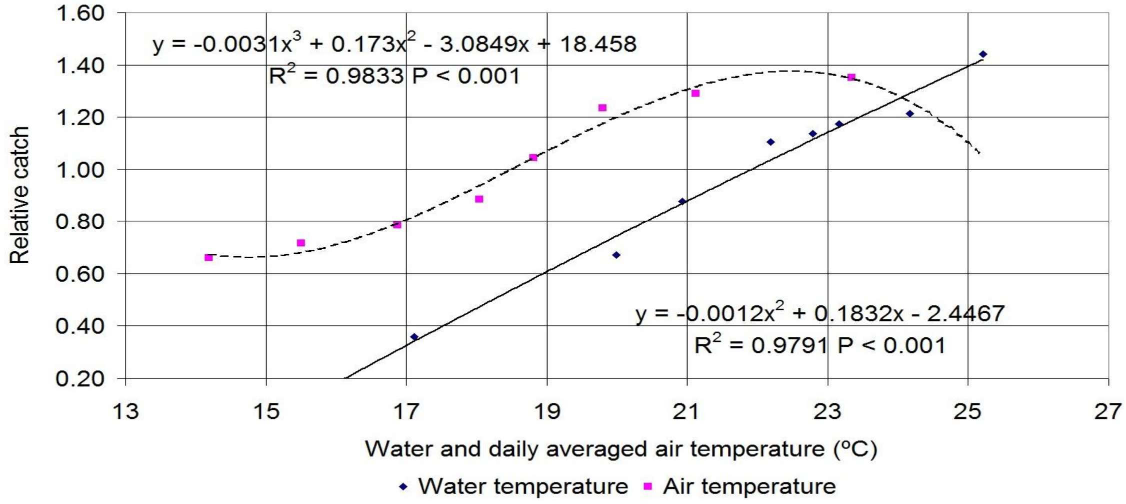


Figure 3 Light-trap catch of *Neureclipsis bimaculata* Linnaeus depending on the water and air temperature (River Tisza, Szolnok, 2000)

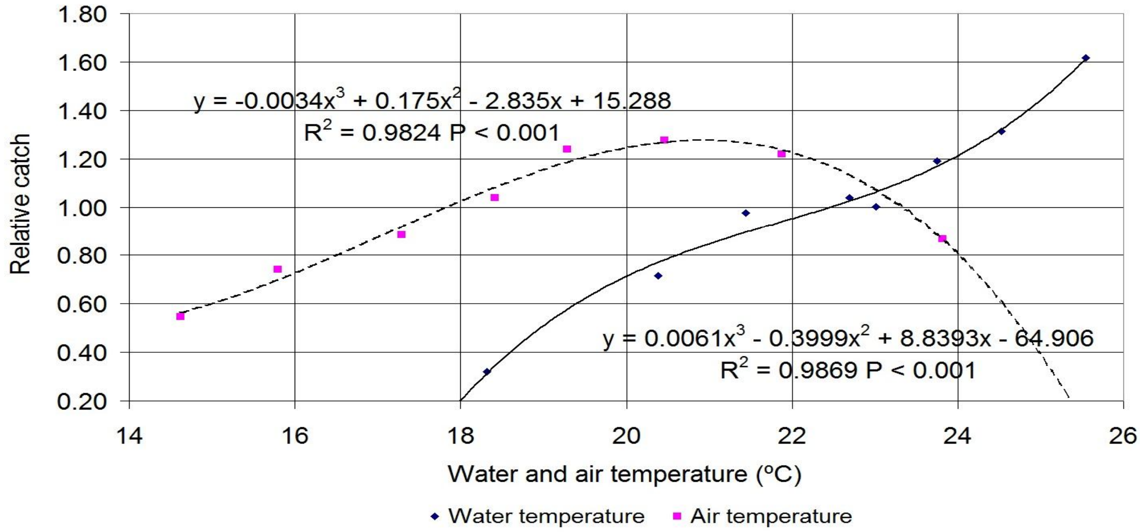


Figure 4 Light-trap catch of *Hydropsyche contubernalis* Mc Lachlan depending on the water and air temperature (River Tisza Szolnok, 2000)

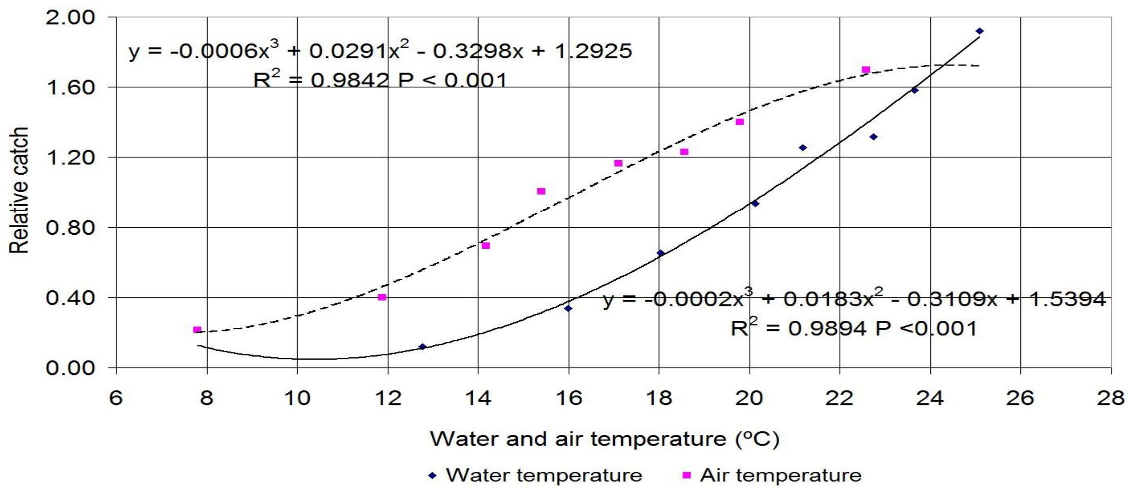


Figure 5 Light-trap catch of *Hydropsyche bulgaromanorum* Malicky depending on the water and air temperature (River Tisza Szolnok, 2000)

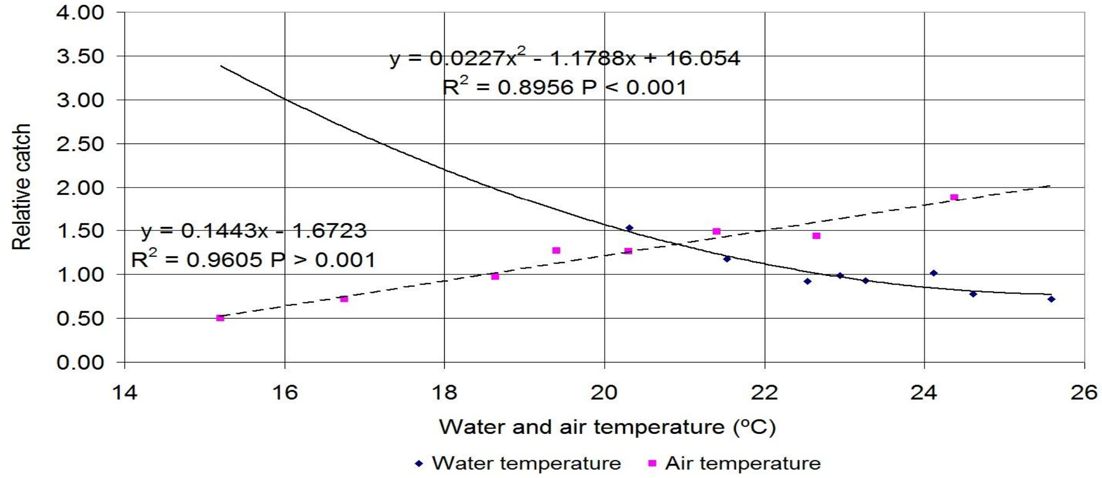


Figure 6 Light-trap catch of *Limnephilus affinis* Curtis depending on the water and air temperature (River Tisza, Szolnok, 2000)

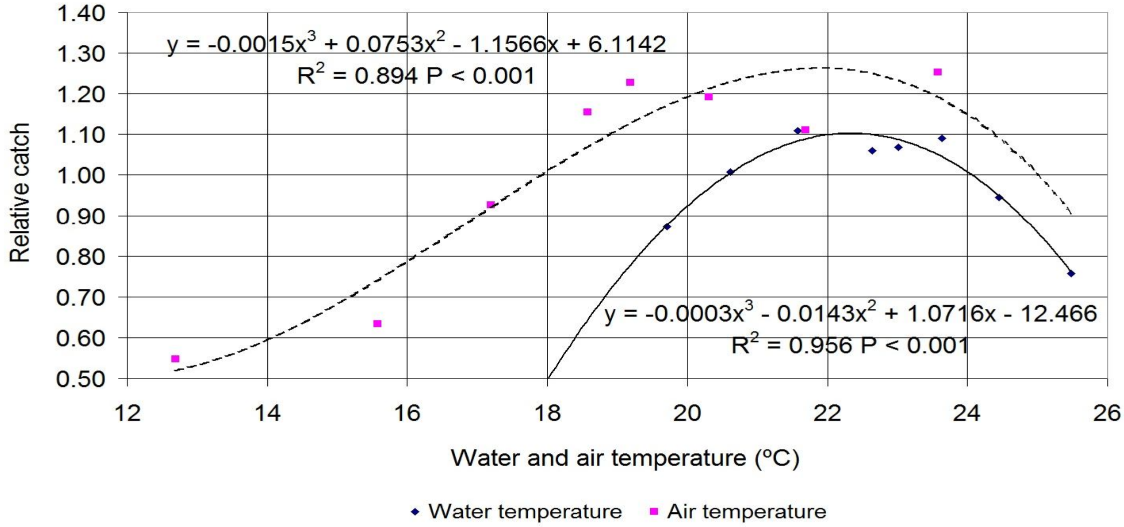


Figure 7 Light-trap catch of *Athripsodes albifrons* Linnaeus depending on the water and air temperature (River Tisza, Szolnok, 2000)

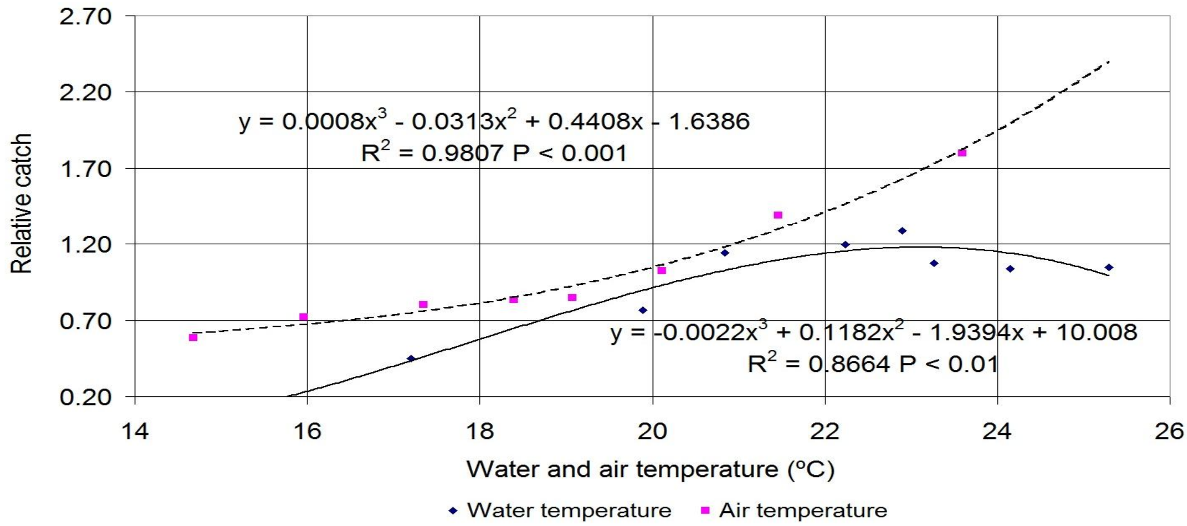


Figure 8 Light-trap catch of *Ceraclea dissimilis* Stephens depending on the water- and air temperature (River Tisza, Szolnok, 2000)

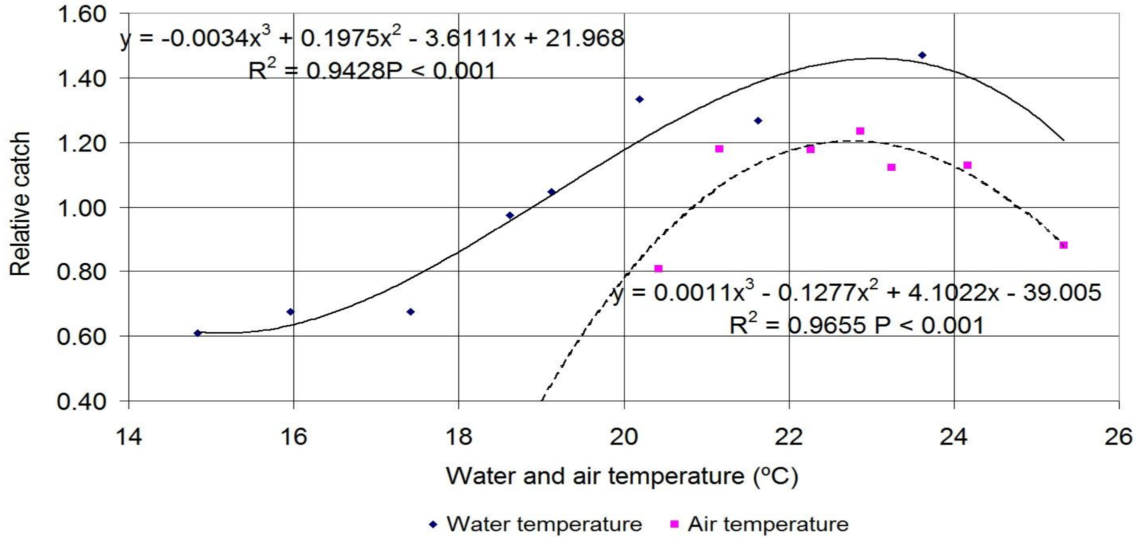


Figure 9 Light-trap catch of *Setodes punctinalis* Fabricius depending on the water and air temperature (River Tisza, Szolnok, 2000)

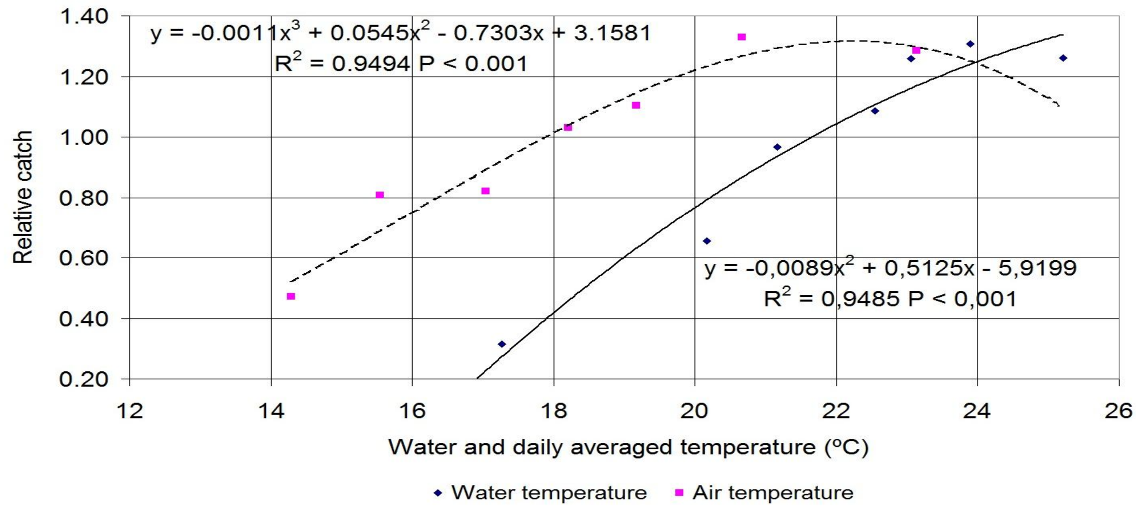
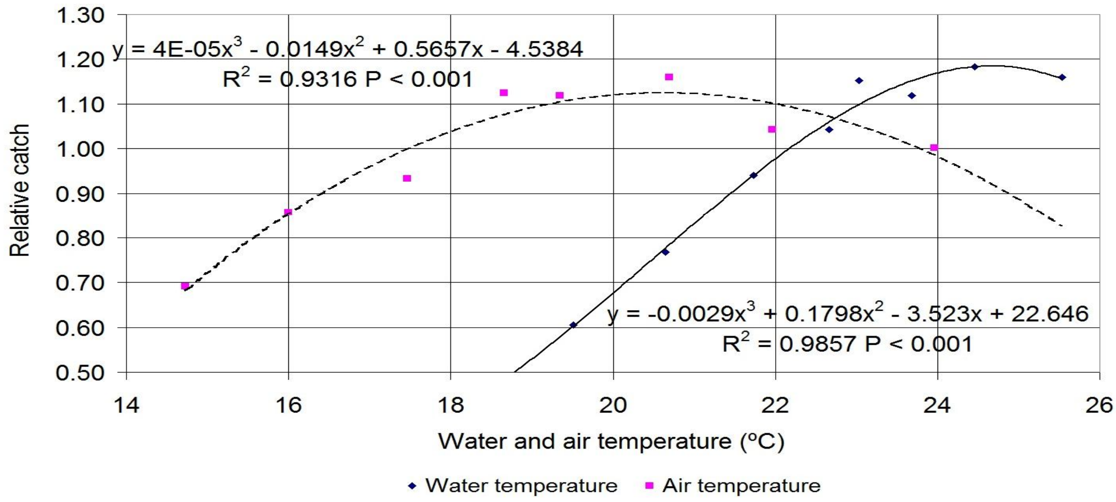


Figure 10 Light-trap catch of *Oecetis ochracea* Curtis depending on the water and air temperature (River Tisza, Szolnok, 2000)



The increase or decrease of the catch is explainable by our previous hypotheses (Nowinszky, 2003). This opposite form of behaviour may be the many reasons. The claim and tolerance to environmental factors of the species are different. Environmental factors interact with each other to exert their effects. Thus the same factor can be different effect. The species have different survival strategy. Adverse effects of two possible answers: passivity, or hiding or even increased activity, because you want to ensure the survival of the species. Therefore, the insect do "to carry out their duties in a hurry". The fact that on the higher and increasing values of geomagnetic horizontal component the catches are not suddenly, but gradually decline, we deduce that the tolerance and response of insect specimens adverse effects to individually change.

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Nature & Environment
Vol. 19 (1), 2014: 54-58
Website: www.natureandenvironment.com

ISSN (Print) : 2321-810X
ISSN (Online) : 2321-8738

RESEARCH ARTICLE

The Number of Macrolepidoptera Species and Individuals in Kámon Botanic Garden (Hungary) Depending on the Daily Hydrothermal Situations

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Received: 5th Dec. 2013, Revised: 29th Dec 2013, Accepted: 4th Jan. 2014

ABSTRACT

The Forest Research Institute operated a Jermy-type light-trap in Kámon Botanic Garden (Szombathely, Hungary) between 1962 and 1970. The temperature and precipitation can influence the flight activity of insect. We developed a method that is characterized day by day both the temperature and the character of precipitation. We worked up the collecting data of summer aspects because in spring and autumn is far fewer species and individuals were caught by light trap. The days during the period may be wet or dry, cool or hot, relative of a decade average. Based on the possible combinations of these characteristics every day can be ranged into one of the four types (cool-dry, cool-wet, warm-dry and warm-wet). We examined the number of caught species and individuals and effectiveness of trap. Our results demonstrated that these were significantly different from different hydrothermal situations.

Key Words: *Light-trap, Macrolepidoptera species, individuals, hydrothermal situations*

INTRODUCTION

Temperature may have an important part from the point of view of insects' flying activity. The given temperature requirements of insects can be explained by the fact that their body mass is very small compared to both its surface and the environment. That is why the temperature of their body, instead of being permanent and self-sufficient, follows the changing temperature of the environment. This is because the ratios of the body mass and surface of insects determine the difference between the inner heat content and the incoming or outgoing heat. The heat content of the body is proportionate to its mass, while, on the other hand, the heat energy intake or loss is proportionate to the size of the surface of the body. Therefore an external effect makes its influence felt as against the inner, small heat content of a relatively small mass. The speed as well as the size of the impact follows from the ratio between the mass and surface of the body of the insect (Bacsó 1964). And so the temperature value always exerts a substantial influence on the life processes of insects. The chemical processes described as metabolism that determine the life functions of insects always follow the temperature changes in the direct surroundings. Naturally, the activity of the organs of locomotion also depends on the temperature of the environment which explains why we can expect a massive light-trap turnout by what is an optimal temperature for the given species (Manninger 1948). Southwood (1978), on the other hand, is of the view that the flight of insects has a bottom and top temperature threshold typical of each species. The insect flies if the temperature is above the bottom and below the top threshold and becomes inactive when the value is below the bottom or above the top threshold. In his view, other reasons explain the fluctuations in the number of specimens experienced in the interval between the low and high threshold values. However, research in Hungary has proved that in the context of a single species, too, a significant regression can be established between the temperature values and the number of specimens collected by light-trap (Járfás 1979, Nowinszky et al. 2003). Polish research has also confirmed that the number of noctuids light-trapped increases with the rise of temperature (Buszko and Nowacki 1990). Kádár and Erdélyi (1991) established positive correlation's between the temperature measured at 19h and 01h on the one hand and the number of ground beetles flying to light, on the other. Researchers published different results after the investigation of the optimum temperature range for the flight of some species: Zlokovity et al. (1958) found it at 20°C, Szabó and Járfás (1974) at 17°C, and Loewer (1976) published it between 18-21°C. According to B. Balázs (1965) the optimum temperature zone of Turnip Moth (*Agrotis segetum* Den. et Schiff.) is between 21-25 °C by contrast according to Szabó (1969) it is between 15-23°C. According to Holyoak et al. (1997) 14 of the 20 noctuid (Noctuidae) and geometrid (Geometridae) species were in positive correlation with temperature. (IJSN_2012_NPL). However, the minimum flight temperature varies according to latitude (Mazochin-Porsnjakov 1956). The flight in the North Caucasus has been very low at 15 °C, but still around Kursk (N51°43' E51°43') there was found mass flight.

According to most of authors the precipitation clearly inhibits the collection. Homonnay (1961) found that much rain clog up the swarming of Cockchafer (*Melolontha melolontha* L.) It is written by Járfás et al. (1979) that the Silver Y (*Autographa gamma* L.) barely flies during thunderstorms. However, the quiet evening rain did not prevent the catch.

Most researchers hold that rain hinders the collecting of insects by light-trap. There are different interpretations of the modifying role of precipitation of different states and intensity. Examining migratory noctuids, Poitout et al. (1974) observed flying activity even in snowfall. Papp and Vojnits (1976) found that a typical night of monsoon rain, despite several hours of downpour, produced the richest light trapping yield of a whole collecting tour of Korea. Several researchers observed an increase in the number of specimens trapped on stormy days (Williams 1940, Hosny 1955). In Hungary, Wéber (1957) found that the collecting peak preceded a storm front by more than 24 hours. However, the combined effects of temperature and precipitation expressive method have been developed only during certain periods, such as Seljaninov (1966).

MATERIAL

The chosen light-trap, on purpose of examinations, operated in Kámon Botanic Garden (N47°28'29" E17°57'71") at Szombathely, Hungary between 1962 and 1970. There were caught altogether the specimen of 549 different Macrolepidoptera species by light-trap during 9 years. The yearly catching period of light-trap, the number of caught species, individuals and swarming are shown in Table 1.

We carried out only the collecting data of early and late summer aspects because in both the spring and autumn aspects few species and specimens were caught by light-trap. The average daily temperature and precipitation values were got from the Year-Books of Hungarian National Weather Service.

Table 1 Light-trap collecting data of early and late summer aspects in Kámon Botanic Garden of Szombathely, Hungary as well as the number of caught species and swarming

Years	Summer aspects	No. of species	No. of individuals
1962	05. 01. - 08. 31.	291	3359
1963	05. 01. - 08. 31.	300	5646
1964	05. 01. - 08. 31.	303	2562
1965	05. 01. - 08. 31.	146	919
1966	05. 01. - 08. 31.	113	599
1967	05. 01. - 08. 31.	229	4096
1968	05. 01. - 08. 31.	226	2364
1969	05. 01. - 08. 31.	268	3670
1970	05. 01. - 08. 31.	268	4268

METHODS

The results of an earlier study (Nowinszky 1977) using each night temperatures average value was divided by the average of the given decade. If the ratio is less than 1, then it was put to cool group, if greater, it was classified to the warm one. It was a rainy day when amount of rainfall exceeded 0.5 mm (Kéri 1941). We used these four characteristics and we got four hydrothermal situations. The concept of light trapping efficiency was determined in our earlier studies (Nowinszky and Kiss 1990, Nowinszky and Puskás 2011, Nowinszky et al. 2012) as follows:

We ignored the specimen numbers of the various species, examining only the question of whether the daily catch confirms the presence of the species. The different generations of multi generation species were studied separately. However, all clearly recognizable vagile or migrant individuals turning up in between the swarming periods of two generations were regarded as separate generations. And in cases when it was not possible to draw a clear line of distinction between the two generations, we followed the procedure applied with one generation species. The catch data of the first trapped individual of the given generation was marked as 'appearance' and the day following the catch data of the last specimen of the same generation was labelled as 'disappearance'. The difference of the number of species appearing and the disappearing ones means the present species.

We added up by calendar days the frequency of the appearance and disappearance of every generation of all the species and after cumulating plotted them in a graph. We calculated the difference between cumulated appearance and disappearance, receiving in this way the number of species "present" in the environment surrounding the trap in the function of time. We established the number trapped species by nights and represented these together with the species "present".

Naturally the various species appear and disappear continuously; therefore it is not possible to draw a sharp line of distinction between the different aspects. The approximate data of changes of spring, summer and autumn aspects can be read from the curves of “presents”.

All days were classified into one of the hydrothermal situations. The trapped species and individual number and the efficiency values were assigned to the hydrothermal situations. Then t-test was used for the differences of significance level calculation.

RESULTS AND DISCUSSION

Our results (Table 2 and 3) demonstrate that both the highest caught individuals and the number of species and the trap efficiency is in the warm-dry (WD) hydrothermal situation. This is followed by cold dry (CD), then the warm-wet (WW) position. The worst is cold and wet (CW) position. The results show that individuals of each species fly into the light-trap high number on the warm a dry nights. This fact indicates that the flying activity of individuals of all species in warm a dry nights is higher. It is also demonstrated that the hydrothermal situations are suitable for agricultural meteorology investigations.

Table 2 The hydrothermal situations, averaged numbers of individuals, species, efficiency and number of data

Characters	Averages of			Number of data
	Individuals	Species	Efficiency	
CD	27.148	13.271	0.269	443
CW	16.659	9.852	0.225	220
WD	35.705	16.705	0.324	397
WW	23.658	12.570	0.285	158

Table 3 Significance levels calculated for the different hydrothermal situations

Characters of Hydrothermal Situations		Individuals P <	Species P <	Efficiency P <
CD	CW	0.001	0.001	0.001
CD	WD	0.001	0.001	0.001
CD	WW	NS	NS	NS
CW	WD	0.001	0.001	0.001
CW	WW	0.010	0.010	0.001
WD	WW	0.001	0.001	0.050

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ADVANCES IN BIORESEARCH
Volume 3, Issue 1, March 2012: 11 - 13
ISSN 0976-4585

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Research Article

Light-trap Catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) in connection with the Atmospheric Electricity

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ABSTRACT
The study examines the success of light-trap catch of the turnip moth (Agrotis segetum Den. et Schiff.) and the various values of atmospheric electricity. The number of specimens trapped is the largest near by the region close to 0 V/m. The rising positive values have a slight effect on the catch, while the negative values of atmospheric electricity are extraordinarily unfavourable for trapping. Accordingly, it is expedient to consider the modifying effect of atmospheric electricity when light-trap catch data are being evaluated.
Key words: *light-trap, atmospheric electricity, turnip moth*

INTRODUCTION

A number of papers in entomological literature discuss the modifying effect of electric fields on the life phenomena of insects. Jahn [1] holds that an electric field influences the pupation of the black-arches moth (*Lymantria monacha* L.). Elimination of the field, by use of the Faraday cage, had an unfavourable effect on young caterpillars and a favourable effect on old ones. In subsequent studies, [2 and 3] sums up the results of his research into the connection between biophysical fields and the life phenomena, behaviour and gradations of insects. Haine [4] examined the moulting of *Myzus persicae* Schulz in permanent temperature in laboratory conditions. This process which in natural circumstances requires about 3 hours took place in 15-20 minutes in an electric field. Moulting is facilitated especially be negative ions. Maw [5] reports that the ion concentration of air exerts an influence on the biological activity of insects. He proved by laboratory experiments that any reduction of the ion concentration of the air is accompanied by diminishing activity on the part of the species belonging to the orders of Hymenoptera, Diptera and Lepidoptera. If the ion concentration rises, the above insects display stepped up activity. Maw [6] also reports that females of the *Itoplectis conquisitor* Say wasp are much more active on an electrically charged plastic surface than they are in their usual surroundings. Tshernyshev et al. [7] observed a significant rise in the abundance of two Collembola species and a fallback in that of another one when they filtered out the natural electric field of the atmosphere with a Faraday cage. Afonina et al. [8] also studied the effect of static and varying electric fields in laboratory conditions. Bergh [9] examined under constant conditions the effect of meteorological factors on the take-off activity of the desert locust *Schistocerca gregaria* Forsk and found that it was not affected by electromagnetic radiation of a very low frequency. Schneider [10] proved that the regular orientation by magnetic field of the cockchafer (*Melolontha vulgaris* F.) changes in a static electromagnetic field. Taft et al. [11] found that the dry ripening cotton plant becomes electrically charged under the impact of the wind and thus exerts stronger attraction on the pest *Anthonomus grandis* Boheman. A smaller number of insects appeared on the plants once the accumulated electricity was discharged. Perumpral et al. [12] wrote: "House flies, *Musca domestica* L., were given a choice of either an electrostatic field gradient ranging from 200-1500 v/cm or no field. They preferred no electrical field to one of 1000 v/cm or higher. At 750 v/cm slightly, but significantly, more flies preferred the electrostatic field. At less than 500 v/cm no preference was observed. A significant effect on wing-beat frequency among male cabbage loopers, *Trichoplusia ni* (Hübner), was observed for electrostatic field gradients ranging from 200-1500 v/cm."

Callahan and Mankin [13] discuss an interesting topic. They assume that the UFO phenomena observed in many cases over the territory of the USA and Canada in 1965-1968 can be attributed to the migration of the species *Choristoneura fumiferana* Clemens in the higher layers of the atmosphere. This is because during storms, in a highly charged electrostatic field, these insects may produce light phenomena resembling Saint Elmo's fire. The publication was widely debated in literature [14, 15, 16]. The papers referred to support the idea of the probability of electric fields having an influence on the vital functions of insects, while we have come across with hardly any publication on the interrelationship of atmospheric electricity and light trapping. Helson and Penman [17] analyzed their light trapping results in connection with approaching cold fronts in New Zealand. They found that there was a sudden and short lived ion activity peak preceding by about 55 hours the arrival of these fronts. After that another ion activity peak could be experienced about 30 hours before the rain. This phenomenon, accompanied by an abundant light-trap catch, can be observed in early spring and in the summer months. We have no information of any similar study in special literature.

MATERIAL AND METHODS

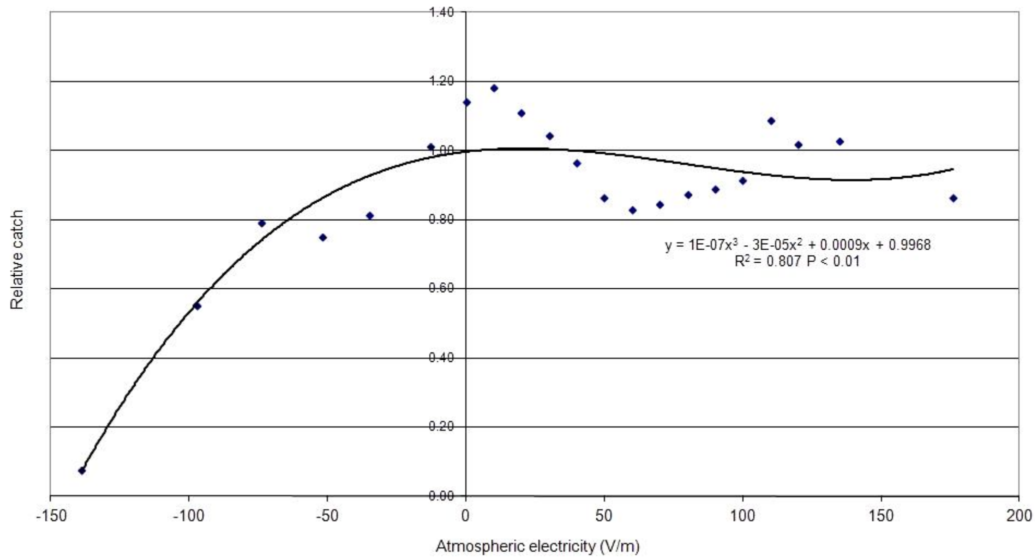
The values of atmospheric electricity given in V/m are measured at the Sopron-Nagycenk Observatory of the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences and are published in the Yearbooks of the Institute. We used the volumes to obtain the data we needed. Measuring is carried out with the help of a radioactive collector fitted with a Ra preparatum rated at 20 C activities and placed on an insulating bar one meter above the ground in free space above a grounded, electrically heated measuring enclosure with a double wall. An electronic device measures the current in the collector. The system has linear characteristics in the -300 to +300 V/m regions. The device is in operation day and night without interruption. Registered hourly, the measuring results are published in the yearbooks.

For the purposes of our study we selected the catch data for turnip moth (*Agrotis segetum* Den. et Schiff.) from the material in 1962-1976 of the Sopron light-trap of the Forestry Scientific Institute. The trap caught 610 specimens in 563 nights. From the catch data we calculated relative catch values for generations and nights. We arranged the data of atmospheric electricity and the related relative catch values in classes, and then drew averages within each class. Of these we formed 3 point weighted moving averages. We made correlation calculations of the related pairs of values.

RESULTS AND DISCUSSION

Our result can be seen in Fig. 1.

Fig. 1. Light-trap catch of the turnip moth (*Agrotis segetum* Den. et Schiff.) depending on the atmospheric electricity



Within a certain range of values, atmospheric electricity has a modifying effect on the number of specimens light-trapped. The trap is the most effective near by the range around 0 V/m. Rising positive values do not considerably influence the results of light trapping. However, all the negative values of atmospheric electricity are unfavourable.

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Acta Geod. Geoph. Hung., Vol. 33(2–4), pp. 377–389 (1998)

LIGHT TRAPPING OF INSECTS DURING EARTHQUAKES

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[Manuscript received March 5, 1998]

The success of light trapping is examined in connection with the earthquakes occurred in Hungary between 1956 and 1986. There were 29 earthquakes in this period where a light-trap operated within a distance of 20–50 km from their epicentres. Data of those species from the total Macrolepidoptera collection of these stations were processed which had their swarming period during the earthquake. 564 swarmings of 191 species were examined. Swarming means a flying period of one generation of one species (counted in days).

The relative catch values were calculated from the trapping data for each species, observing stations and generations. These relative catch values of all species were summarized on the day of the earthquakes, on the each previous and following three days and then the averages were calculated. The significance level of relative catch value differences on consecutive days was calculated by t-test. As the available data of swarmings were relatively few for each species, besides the joint data procession of all the catched species only the two most frequent species, the heat lattice (Chiasmia clathrata L.) and the large blood-vein (Calothysanis amataria L.) were examined separately.

According to our results the number of caught moths increases remarkably one day before the earthquake in most cases. This high catch result remains for further two days and decreases only on the second day after the earthquake. In some cases the trapping results increased only after the earthquake occurred. Although the destroying earthquakes are not frequent in Hungary, their forecast is very important mainly beacause of the large earthquake-sensitive constructions. It is even more critical in the zones of serious earthquakes to work out a method which can contribute to the improvement of forecasts. That is why we consider it important to make further examinations regarding the recognized phenomenon.

Keywords: biological effect of earthquakes; earthquake forecast; earthquake forecast; light-trap; moth; swarming

1. Introduction

The connection between light trapping data and earthquakes occurred in Hungary between 1956 and 1986 was examined. The Dialog Dialindex database — the world's greatest database centre — was entered to find the 'light-trap', 'insect' and 'earthquake' keywords together. 400 file indices were looked through from the total 411 files but no one record contained these 3 keywords together.

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2. Material

Hungarian earthquake data were taken from the works of Zsíros et al. (1988) and Zsíros (1989). We examined those 29 earthquakes between 1956 and 1986, where a light-trap observing station operated within a distance of 50 km from their epicentres. In some cases it is not easy to determine the exact place of the epicentre, that is why the catalogues also contain the possible differences. According to the above the distance of the light-traps and the epicentres could not have been determined with the desired exactness. The data of some farther observing stations were also involved in the examinations, if data proved that the earthquake was sensible there.

Characteristic data of the examined earthquakes are shown in Tables II–IV based on the aforementioned studies. The light-trap observing stations and catching results are also given. Besides the aforementioned studies further particulars on this theme can be found by Szeidovitz and Mónus (1993).

Data of those species from the total Macrolepidoptera collection of the 17 light-traps operating close to the epicentres were processed which had their swarming period during the earthquake. Totally 564 swarmings of 191 species were examined (see the Appendix). Those data coming from the swarmings when the previous or following days of earthquakes did not coincide with the swarming time were also processed. That is why the number of observed days is sometimes less than the number of swarmings. Swarming means the days of a flying period of one generation of one species. As the available data of swarmings were relatively few for each species, besides the joint data processing of all the catched species only the two most frequent species (Chiasmia clathrata L. and Calothysanis amataria L.) were examined separately.

3. Methods

Relative catch values were calculated from the trapping data for each species, observing stations and generations. These relative catch values of all species were summarized and averaged on the day of the earthquake and on each the previous and following three days. The significance level of relative catch value differences on consecutive days was controlled by t-test.

All the earthquakes in Hungary between 1956 and 1986 which coincided with the swarming time of insects were examined first to find a possible effect of the earthquake on the flight activity of insects. As the relative catch values showed significant differences in the ±3 days period of the earthquakes, separate examinations were also performed in those cases where higher catch was observed on the day before the earthquake and those on the day of the earthquake. Those cases were also identified where the number of catched insects did not increase significantly in the environment of the earthquakes.

Table I.

Relative catch of all examined species in the environment of all earthquakes

All earthquake between May and October in 1956-1986	Days before and after the earthquake						
	−3	−2	−1	0	1	2	3
All examined species							
Average of relative catches	1.107∗	∗0.727∗	∗1.404	1.323	1.408∗	∗0.665	0.592
Number of data	408	402	411	446	419	375	405

Note: ∗ = the difference of neighbouring relative catch average is significant on 99.9% level

Relative catch of all examined species in the environment of earthquakes

All examined species	Days before and after the earthquake						
	−3	−2	−1	0	1	2	3
The maximum value of RC is on previous day of earthquake							
Average of relative catches	1.306∗	∗0.663∗	∗1.785∗	∗1.144	1.494∗	∗0.595	0.592
Number of data	279	266	299	288	300	282	288
The maximum value of RC is on day of earthquake							
Average of relative catches	0.597	0.473	0.489∗	∗1.920∗	∗1.231	0.974	0.640
Number of data	102	106	107	125	104	93	91

Note: ∗ = the difference of neighbouring relative catch average is significant on 99.9% level

4. Results

Table I contains all those earthquakes separately where higher catch results were observed at the night of the earthquake, at the previous night and those without any connection in catch results and the earthquake.

5. Discussion

According to our results (15 earthquakes and 22 observing stations) the number of caught moths increases remarkably already one day before the earthquake in most cases. This high catch result remains for further two days and decreases only on the second day after the earthquake. In other cases (11 earthquakes and 13 observing stations) the trapping results showed increase only after the earthquake occurred. In several cases (7 earthquakes and 7 observing stations) connection was not found between trapping data and the earthquake.

Based on our present knowledge we still cannot explain what insects perceive a

Table I. (cntd.)

Relative catch of the large blood-vein (Calothisanis amataria L.) and the heath lattice (Chiasmia clathrata L.) in the environment of earthquakes

The examined species	Days before and after the earthquake						
	–3	–2	–1	0	1	2	3
The maximum value of RC is on previous day of earthquake							
Large blood-vein (Calothisanis amataria L.)							
Average of relative catches	1.247	0.743 ∗	∗ 3.149	1.230	1.356 ∗	∗ 0.470	0.861
Number of data	9	9	9	10	11	11	11
Heath lattice (Chiasmia clathrata L.)							
Average of relative catches	1.931	0.848 ∗	∗ 4.166	2.158	1.574	0.301	0.196
Number of data	14	14	14	14	15	15	15
The maximum value of RC is on day of earthquake							
Large blood-vein (Calothisanis amataria L.)							
Average of relative catches	0.200	0.638	0.798	1.582	1.048	0.200	0
Number of data	5	5	5	5	5	5	5
Heath lattice (Chiasmia clathrata L.)							
Average of relative catches	0.953	0.505	0.277 ∗	∗ 1.376	1.675	1.172	0.508
Number of data	7	8	8	8	6	6	6

Note: ∗ = the difference of neighbouring relative catch average of Calothisanis amataria L. is significant on 90% level, and the difference of neighbouring relative catch average of Chiasmia clathrata L. is significant on 95% level.

short time before or after the earthquake which results in the more intensive flight activity and consequently the higher catch results in light-traps. We also do not know why the catch is higher at the previous night of the earthquake in certain cases and why it increases sometimes after the earthquake occurred. The distance differences offer a good explanation only in some cases. There was an earthquake in Dunaharaszti on July 5th, 1966. The catch was higher at the previous night of the earthquake in the light-traps of Budakeszi, Budatétény, Budapest-Rókushegy and Nagytétény, which are close to Dunaharaszti. However, in the light-trap of Velence, which is a farther observing station, the catch became higher only at the next night, on July 5th. Another earthquake was examined in Berhida on August 15th, 1985. The catch was higher at the previous night in Csopak, which is not far from Berhida. Remote observing stations, where the earthquake was also perceptible, like

Table II. Catalogue of earthquakes in Hungary after Zsíros et al. (1988). The maximum value of relative catch is on previous day of earthquake

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
No.	Year	Month	Day	Hour	Minute	Latitude	Longitude	Q	F.	M.	I.	Name	Remarks	Light-trap stations
3822	1956	07	29	23	30	47.35N	19.09E	B		2.3	2.5	Dunaharaszti	M, 25	Budapest, Herman O. u.
3825	1956	08	04	04	05	47.35N	19.09E	B		2.6	3.0	Dunaharaszti	M, 25	Budapest, Herman O. u.
3826	1956	08	24	22	00	47.35N	19.09E	B		2.0	2.0	Dunaharaszti	L, 25	Budapest, Herman O. u.
3897	1960	07	05	12	17	47.90N	20.38E	B		2.0	2.0	Eger	L, 29	Gyöngyös
3905	1961	06	07	12	25	47.01N	16.97E	B		2.6	3.0	Bérbaltavár	L, 29	Tanakajd
3960	1965	07	23	20	50	47.35N	19.07E	A		2.6	3.0	Dunaharaszti	L, 30	Budakeszi, Budapest-Rókushegy, Tass, Velence
3973	1966	07	05	11	14	47.35N	19.07E	B		2.6	3.0	Dunaharaszti	L, 31	Budakeszi, Budatétény, Bp-Rókushegy, Nagytétény, Tass
3997	1968	10	21	02	02	46.89N	17.45E	B		3.2	4.0	Tapolca	M, 32	Badacsony
4153	1975	05	09	03	42	47.11N	21.69E	B				Biharkeresztes	M, 62	Mikepércs
4180	1976	08	28	11	11	46.77N	17.25E	B		2.9+	3.0	Keszthely	L, 68	Pacsa
4272	1978	07	10	19	20	46.75N	21.13E	B				Békés	M, 60	Tarhos
4285	1978	09	26	17	47	47.26N	19.05E	C	14	4.5+	5.0	Délegyháza	M, 34	Tass
4468	1982	07	29	11	57	47.30N	22.20E	D				Érmellék	M, 62	Mikepércs
4226	1984	06	27	18	48	47.34N	17.28E	A	4+	3.2+		Marcal basin	M, 62	Pápa
4724	1985	08	15	05	28	47.06N	18.01E	A	10+	4.7+	6.5	Berhida	M, 62	Csopak

Notes: 1. series number according to the catalogue, 2. year, 3. month, 4. day, 5. hour, 6. minute, 7. and 8. geographical location of the epicenter, 9. quality factor of epicenter determination (A = ±5 km, B = ±10 km, C = ±20 km, D = ±50 km), 10. focal depth in km, 11. magnitude, 12. intensity (MSK scale), 13. place of earthquake, 14. accuracy of intensity value (M = ±0.5 MSK, L = ±1.0 MSK, K = more than 1.0 MSK. The number refers to the main reference in the catalogue of Zsíros et al. 1988), 15. light-trap station

Table III. Catalogue of earthquakes in Hungary after Zsíros et al. (1988). The maximum value of relative catch is on day of earthquake

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
No.	Year	Month	Day	Hour	Minute	Latitude	Longitude	Q	F.	M.	I.	Name	Remarks	Light-trap stations
3829	1956	09	13	22	00	47.35N	19.09E	B		2.3	2.5	Dunaharaszti	M, 26	Budapest, Herman O. u.
3857	1957	08	31	12	57	47.35N	19.09E	B		2.0	2.0	Dunaharaszti	L, 26	Budapest, Herman O. u.
3858	1957	09	19	07	01	47.35N	19.09E	B		2.0	2.0	Dunaharaszti	L, 26	Budapest, Herman O. u.
3874	1958	07	28	21	09	47.35N	19.09E	B		2.6+	4.0	Dunaharaszti	M, 68	Budapest, Herman O.u.
3875	1958	09	07	23	45	47.35N	19.09E	B		2.9	3.5	Dunaharaszti	M, 27	Budapest, Herman O.u.
3898	1960	08	06	09	45	46.45N	16.79E	C		2.0	2.0	Becsehely	L, 29	Pacsa
3973	1966	07	05	11	14	47.35N	19.07E	B		2.6	3.0	Dunaharaszti	L, 31	Velence
4268	1978	06	30	08	34	46.75N	21.13E	B		3.5+		Békés	M, 79	Tarhos
4425	1981	09	21	06	10	47.20N	18.14E	B		2.9+	4.5	Várpalota	M, 34	Csopak
4724	1985	08	15	05	28	47.06N	18.01E	A	10+	4.7+	6.5	Berhida	M, 62	Hódmezővásárhely, Pápa, Kaposvár
4886	1985	09	10	01	38	47.03N	18.12E	A	10+	3.9+	5.5	Berhida	L, 62	Csopak

Notes: 1. series number according to the catalogue, 2. year, 3. month, 4. day, 5. hour, 6. minute, 7. and 8. geographical location of the epicenter, 9. quality factor of epicenter determination (A = ±5 km, B = ±10 km, C = ±20 km,), 10. focal depth in km, 11. magnitude, 12. intensity (MSK scale), 13. place of earthquake, 14. accuracy of intensity value (M = ±0.5 MSK, L = ±1.0 MSK. The number refers to the main reference in the catalogue of Zsíros et al. 1988), 15. light-trap station

Table IV. Catalogue of earthquakes in Hungary after Zsíros et al. (1988). There is no connection between earthquake and catch

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
No.	Year	Month	Day	Hour	Minute	Latitude	Longitude	Q	F.	M.	I.	Name	Remarks	Light-trap stations
3876	1958	09	12	22	31	47.53N	19.01E	C		3.4+	2.0	Budapest	L, 68	Budapest, Herman O. u.
3960	1965	07	23	20	50	47.35N	19.07E	A		2.6	3.0	Dunaharaszti	L, 30	Nagytétény
4254	1978	06	22	03	33	46.75N	21.13E	B	8	4.6+	6.0	Békés	M, 34	Tarhos
4285	1978	09	26	17	47	47.26N	19.05E	C	14	4.5+	5.0	Délegyháza	M, 34	Velence
4644	1984	08	15	09	58	47.20N	22.10E					Érmellék area	M, 62	Mikepércs
4649	1984	09	08	22	08	47.18N	17.28E	A	4+	3.1+		Jánosháza	M, 62	Pápa
4970	1986	05	10	22	38	47.11N	18.13E	A		2.9+	4.5	Vilonya-Litér	K, 51	Csopak

Notes: 1. series number according to the catalogue, 2. year, 3. month, 4. day, 5. hour, 6. minute, 7. and 8. geographical location of the epicenter, 9. quality factor of epicenter determination (A = ±5 km, B = ±10 km, C = ±20 km,), 10. focal depth in km, 11. magnitude, 12. intensity (MSK scale), 13. place of earthquake, 14. accuracy of intensity value (M = ±0.5 MSK, L = ±1.0 MSK, K = more than 1.0 MSK. The number refers to the main reference in the catalogue of Zsíros et al. 1988), 15. light-trap station

Hódmezővásárhely, Pápa and Kaposvár recorded a higher catch result only at the following night. It seems to be sure that this is not the consequence of the different behaviour of the insect species. The same differences can be found in the catch results of heath lattice (Chiasmia clathrata L.) and large blood-vein (Calothysanis amataria L.). We cannot explain further, that trapping data of 7 stations close to the epicenter of the earthquake did not show an increase, neither before, nor immediately after the earthquake.

Although the destroying earthquakes are not frequent in Hungary, we consider their forecast very important, mainly because of the large earthquake-sensitive constructions. It is even more critical in the zones of destroying earthquakes (megaseisms) to work out methods contributing to the improvement of forecasts. That is why we consider it important to make further examinations regarding the recognized phenomenon. It would be expedient to control these results with experiments in those countries, where the destroying earthquakes are frequent. To establish and operate a light-trap network in the endangered regions would not take high costs.The collected data can also be used for entomological and plant protection purposes. The continuously operating light-trap network gives more information about the behaviour of insects than any other collecting instrument. That is why it seems to be more suitable in earthquake-prognoses, than other ethological observations of other animal species, which are often sporadic and occasional.

Appendix

1. Hungarian Earthquake Catalog (1956–1986) for investigation of light trapping in connection with earthquakes

Dunaharaszti earthquake source

Active region, it is possible that the earthquake of 1561 occurred in this region. The greatest earthquake observed in this region occurred in the vicinity of the village Dunaharaszti on January 12, 1956 causing severe damages in several villages and a casualty and more injuries were also recorded.

The parameters of the earthquake are as follows: magnitude $M_L = 5.6$, focal depth $h = 6.5$ km, epicentral intensity $I_o = 7.5°$ on MSK-scale (Szeidovitz 1986).

The geological structure that generated this earthquake was probably the crossing of the margin of subsiding Alsónémedi-basin and the Ördögárok fault.

This earthquake was followed by numerous aftershocks but their intensity had not surpassed $I_o = 5°$.

Budapest earthquake source

Active region, the first known earthquake occurred in 1561. This earthquake caused severe damages and casualties.

In the time span investigated, according to Hungarian Earthquake Catalog (Zsíros et al. 1988), only one earthquake with Budapest epicenter was observed. From a different source (Kiss 1961) it turned out that this earthquake was observed by two persons only: one lived in Székesfehérvár, the other in Budapest.

The earthquake was recorded by seismological stations in Budapest and Kecskemét as well (Szilber and Csomor 1961). The earthquake was localized (47.5°N, 18.5°E) about 40 km far from Budapest in the vicinity of village Szár. The magnitude of the earthquake was $M_L = 3.2$. Considering the fact that there was no report from the epicentral region, the intensity of this earthquake cannot be determined.

Eger

The first vague observation of the activity of this earthquake source dated from 1676. The largest earthquake occurred in the vicinity of Eger on January 31, 1925 at 08:05 (local time) causing severe damages in several villages (mainly in Ostoros) but neither casualties nor injuries were recorded.

The parameters of the earthquake are as follows: magnitude $M_L = 5.3$, focal depth $h = 5$ km, epicentral intensity $I_o = 7.5°$ on MSK-scale (Szeidovitz and Mónus 1993).

The geological structure that generated the earthquake is the edge of Egerszalók-Ostoros-Noszvaj depression.

In the investigated time span, according to Hungarian Earthquake Catalog (Zsíros et al. 1988), only one earthquake with Eger epicenter was listed (1960.07.05). This earthquake was observed by one persons only ($I_o = 2°$) and was not recorded by any seismological station (Csomor 1967).

Becsehely

The earthquake (1960.08.06) was not recorded by Hungarian seismological stations (Csomor 1967). This earthquake was felt at Becsehely only (Simon 1964). The intensity of this earthquake was about $I_o = 2°$ on MSK-scale.

Bérbaltavár

Active region, the first earthquake was observed in Szombathely (456).

An earthquake occurred at Bérbaltavár on June 7, 1961. The parameters of the earthquake are as follows: magnitude (calculated from intensity) $M = 2.3$, focal depth $h = ?$, epicentral intensity $I_o = 2.5°$ on MSK-scale (Zsíros et al. 1988).

Biharkeresztes

Nobody felt this earthquake so it is epicentral intensity cannot be determined. This earthquake was recorded by foreign seismological stations only (Bulletin of International Seismological Center). It is known from experience that determination of earthquake foci from data recorded by far stations is rather unreliable.

Keszthely

The earthquake of August 28, 1976 was recorded by seismological stations at Budapest and Piszkéstető (Kiss 1976). The earthquake was localized (46.8°N, 17.3°E) at town Keszthely. Magnitude of the earthquake was $M_L = 3$, its intensity was $I_o = 3°$.

Békés

An earthquake occurred at Békés on June 30, 1978. The parameters of the earthquake are as follows: magnitude $M_L = 4.6$, focal depth $h = 8$ km, epicentral intensity $I_o = 6°$ on MSK-scale (Zsíros et al. 1988).

The geological structure that generated the earthquake was the edge of Békés basin.

The earthquake was followed by a few aftershocks. Because of lack of detailed information the epicentral intensities of a few aftershocks are indefinable.

Délegyháza

An earthquake occurred at Délegyháza on September 26, 1978. The parameters of the earthquake are as follows: magnitude $M_L = 4.5$, focal depth $h = 14$ km, epicentral intensity $I_o = 5°$ on MSK-scale (Zsíros 1983, Zsíros et al. 1988). The earthquake occurred at the edge of Bugyi block. The earthquake was not followed by aftershocks.

Várpalota

Várpalota is a well known active source (Simon 1943). An earthquake occurred in Várpalota on September 21, 1981. The parameters of the earthquake are as follows: magnitude $M_L = 2.9$, focal depth $h =?$, epicentral intensity $I_o = 4.5°$ on MSK-scale (Zsíros et al. 1988).

The earthquake was not followed by any aftershock. However, the source remained active and a few years later on September 12, 1995 an earthquake occurred at Várpalota ($M_L = 3.5$, focal depth $h = 7.5$ km, epicentral intensity $I_o = 5 - 6°$ on MSK-scale).

Érmellék

In the Érmellék area two great earthquakes occurred in the last century (1829, 1834). The geological structure that generated these earthquakes was the Gálospetri-graben.

The activity of this region decreased recently but smaller earthquakes (1982, 1984) remind us of the process of stress accumulation. This area belongs to Romania and we have no detailed information on the main parameters of these small earthquakes.

Marcal basin

The earthquake of June 27, 1984 was recorded by seismological stations at Budapest, Jósvafő, Piszkéstető and Sopron. The earthquake was localized (47.33°N, 17.29°E) at village Vinár. Magnitude of the earthquake was $M_L = 3.2$. Considering the fact that there was no information from the epicentral region, the intensity of this earthquake cannot be determined.

Jánosháza

On September 9, 1984 an earthquake was localized by ISC (Bulletin of International Seismological Center). The parameters of the earthquake are as follows: magnitude MS = 3.1, focal depth $h = 4$ km. Nobody felt this earthquake, so the epicentral intensity of it cannot be determined. This earthquake was recorded by Hungarian seismological stations. According to our calculation the focus of this earthquake was a few km east of Jánosháza. It is known, that determination of earthquake foci from data recorded by far stations is unreliable.

Berhida

An earthquake occurred at Berhida on August 15, 1985. The parameters of the earthquake are as follows: magnitude $M_L = 4.7$, focal depth $h = 10$ km, epicentral intensity on MSK-scale $I_o = 6 - 7°$ (Zsíros et al. 1988). The geological structure generated this earthquake was the boundary of subsiding Berhida basin and Küngösi-block.

The earthquake was followed by a lot of aftershocks, some of them was felt at Vilonya-Litér and at Polgárdi villages.

In the investigated time span, according to the Hungarian Earthquake Catalog (Zsíros et al. 1988), a lot of aftershocks occurred and about 30% of them coincided with the swarm of moths.

2. The examined species and number of swarmings for each families

Sphingidae: Sphinx ligustri L. (1), Marumba quercus Schiff. (1), Smerinthus ocel-lata L. (1), Laothoe populi L. (1), Pergesa elphenor L. (1), Pergesa porcellus L. (1);

Notodontidae: Pterostoma palpinum L. (3), Phalera bucephala L. (1), Pygaera curtula L. (1), Pygaera pigra L. (1);

Drepanidae: Cilix glaucata Scop. (3)

Lasiocampidae: Dendrolimus pini L. (1);

Lymantriidae: Stilpnotia salicis L. (2), Lymantria dispar L. (5);

Arctiidae: Miltochrista miniata Forst. (1), Lithosia quadra L. (3), Eilema pygmae-ola ssp. pallifrons Z. (2), Eilema complana L. (2), Eilema lurideola Zinck. (2), Chelia maculosa Gern. (1), Phragmatobia fuliginosa L. (14), Spilosoma lubrici-peda L. (4), Spilosoma urticae Esp. (3), Spilosoma menthastri Esp. (4), Hyphant-ria cunea Drury (4), Rhyparia purpurata L. (1), Arctia caja L. (1);

Synthomidae: Dysauxes ancilla L. (4);

Nolidae: Roeselia albula Schiff. (4), Celama centonalis Hbn. (2);

Noctuidae: Euxoa obelisca Schiff. (1), Euxoa aquilina Schiff. (1), Scotia segetum Schiff. (5), Scotia ipsilon Hfn. (2), Scotia exclamationis L. (11), Ochropleura plecta L. (7), Noctua fimbriata Schreb. (1), Amathes c-nigrum L. (14), Amathes triangulum L. (2), Amathes xanthographa Schiff. (2), Discestra trifolii Hfn. (16), Discestra dianthi Tausch. (2), Sideritis evidens (1), Sideritis albicolon Hbn. (1), Heliophobus calcatrippae View. (2), Heliophobus reticulata Goeze. (3), Mamest-ra brassicae Hufn. (8), Mamestra suasa Schiff. (8), Mamestra persicariae L. (1), Mamestra oleracea L. (8), Mamestra nana Hufn. (1), Mamestra pisi L. (1), Ma-mestra dysodea Schiff. (1), Harmodia cucubali Schiff. (1), Harmodia lepida Esp. (1), Harmodia luteago Schiff. (7), Tholera decimalis Poda (3), Panolis flammea Schiff. (1), Mythimna turca L. (3), Mythimna albipuncta Schiff. (2), Mythimna pallens L. (3), Mythimna l-album L. (7), Mythimna conigera L. (1), Apamea scolopacina Esp. (1), Apamea secalis L. (3), Oligia strigilis L. (1), Oligia latrun-cula Schiff. (1), Mesoligia furuncula Schiff. (2), Luperina testacea Schiff. (5), Callogonia virgo Tr. (2), Achmis comma Schiff. (1), Caradrina clavipalpis Scop. (1), Athetis gluteosa Tr. (2), Hoplodrina alsines Brahm. (4), Hoplodrina blanda Schiff. (1), Hoplodrina ambigua Schiff. (2), Cosmia pyralina Schiff. (1), Arenos-tola fluxa Hbn. (1), Calamia tridens Hfn. (1), Aegle koekeritziana Hbn. (3), Chlo-ridea maritima Grasl. (1), Chloridea viriplaca Hufn. (2), Pyrrhia purpurina Schiff. (1), Axylia putris L. (5), Jaspidia pygarga Hfn. (1), Eustrotia uncula Cl. (1), Eustrotia candidula Schiff. (7), Erastria trabealis Scop. (14), Tarache luctuosa Esp. (14), Nycteola asiatica Krul. (1), Earias chlorana L. (1), Earias vernana Hbn. (1), Colocasia coryli L. (1), Chrysaspidia festucae L. (3) Macdunnoughia confusa Steph. (13), Autographa gamma L. (12), Plusia chrysitis L. (4), Abrostola tri-plasia L. (1), Apatele rumicis L. (2), Symira albovenosa Goeze. (1), Oxycesta geographica F. (1), Rusina tenebrosa Hbn. (2), Apamea lythoxylaca Schiff. (1), Apamea anceps Schiff. (1), Cucullia fraudatricula Hbn. (1), Cucullia artemisiae Hfn. (1), Calophasia lunula Hfn. (2), Scoliopteryx libatrix L. (1), Lygephila craceae Schiff. (1), Aedia funesta Esp. (2), Colobochyla salicalis Schiff. (1), Prothymia viridaria Cl. (2), Rivula sericealis Scop. (7), Zanclognatha lunalis Scop. (1), Zanclognatha tarsipennalis Tr. (2), Herminia tentacularia L. (2), Para-colax glaucinalis Schiff. (3), Hypena proboscidalis L. (1);

Geometridae: Scopula fuscovenosa Gze. (2), Scopula humiliata Hfn. (3), Scopula dimidiata Hfn. (3), Scopula aversata L. (1), Scopula deversaria H.-Sch. (2), Scopula immorata L. (1), Scopula nigropunctata Gze. (2), Scopula rufaria Hbn. (5), Scopula muricata Hfn. (1), Scopula rusticata Schiff. (2), Scopula moniliata Schiff. (1), Scopula dilutaria (1), Scopula rubiginata (Hfn. (4), Scopula marginepunctata Gze. (2), Scopula immutata L. (1), Scopula flaccidaria Z. (2), Chlorissa viridata L. (2), Euchloris smaragdaria F. (2), Thalera fimbrialis Sc. (4), Hemistola chrysoprasaria Esp. (5), Rhodostrophia vibicaria Cl. (2), Cyclophora annulata Schlze. (1), Cyc-lophora punctaria L. (3), Cyclophora trilinearia Hbn. (1), Calothysanis amataria L. (16), Lythria purpuraria L. (1), Cidaria fulvata Forst. (1), Philereme transver-sata Hfn. (1), Lygris pyraliata Schiff. (1), Xanthorrhoe fluctuata L. (4), Xanthor-rhoe spadicearia Schiff. (1), Paraulype berberata Schiff. (1), Euphya rubidata Schiff. (1), Euphya bilineata L. (1), Epirrhoe alternata Müll. (5), Pelurga comitata L. (1), Hydrelia flammeolaria Hfn. (1), Cataclysme riguata Hbn.(1), Eupithecia linariata F. (3), Eupithecia oblongata Tnbg. (10), Eupithecia millefoliata Rössl. (2), Eupithecia subnotata Hbn. (1), Gymnoscelis pumilata Hbn. (1), Abraxas grossulariata L. (3), Lomaspis marginata L. (2), Horisme tersata Schiff. (1), Lig-dia adustata Schiff. (3), Lomographa dilectaria Hbn. (1), Campaea margaritata L. (1), Ennomos autumnaria Wernbg. (1), Ennomos fuscantaria Steph. (2), Selenia lunaria Schiff. (1), Selenia tetralunaria Esp. (2), Angerona prunaria L. (1), Maca-ria alternaria Hbn. (6), Chiasmia clathrata L. (24), Chiasmia glarearia Brahm. (6), Tephrina murinaria Schiff. (1), Tephrina arenacearia Schiff. (12), Narraga fascio-laria Hfn, (1), Narraga tessularia Metzn. (2), Biston betularius L. (2), Boarmia punctinalis Sc. (2), Ascotis selenaria Schiff. (15), Ectropis bistortata Gze. (3), Ectropis extersaria Hbn. (1), Ematurga atomaria L. (2), Bupalus piniarius L. (1), Gnophos obscuraria Hbn. (1);

Cossidae: Phragmatoecia castaneae Hbn. (3);

Hepialidae: Hepialus sylvinus L. (2);

Limacodidae: Cochlidion limacodes Hfn. (1);

Zygaenidae: Proctis globulariae Hbn. (2)

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J. Entomol. Res. Soc., 19(3): 27-34, 2017 *ISSN:1302-0250*

Light Trap Catch of Beetle Species (Coleoptera) in Connection with the Chemical Air Pollutants

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ABSTRACT

In this study light-trap catch of three beetle (Coleoptera: Scarabaeidae) species were examined in connection with the everyday function of the chemical air pollutants (SO_2, NO, NO_2, NO_x, CO, PM10, O_3). Between 2004 and 2012 light-traps were operating in Fejér County, Hungary, Europe). The data were processed following species: *Rhizotrogus aequinoctialis* Herbst, 1790; *Rhizotrogus aestivus* Olivier, 1789; *Melolontha melolontha* Linnaeus, 1758. The data from different years were combined. The number of the chemical air pollutants and the caught beetles were assigned into classes. The results obtained were plotted. We determined the regression equations, and the levels of significance. We found that the behaviour of the studied beetle species can be divided only into two types: if the air pollution increases, the catch increases or decreases.

Key words: Light trapping, beetles, air pollution.

INTRODUCTION

Since the last century, air pollution has become a major environmental problem, mostly over large cities and industrial areas (Cassiani *et al*., 2013). It is natural that the air pollutant chemicals influence the life phenomena of insects, such as flight activity. According to Heliövaara and Väisänen (1990) some Lepidoptera groups are used as environmental pollution indicators by heavy metals and carbon dioxide (CO_2) concentrations in locations close to industrial areas and even within urban areas. Presence and consequences of copper, iron, nickel, cadmium, sulphuric acid ions and other substances used in fertilizers were studied with pupae of different Geometridae and Noctuidae species. Study of da Rocha *et al*. (2011) concluded that Insecta has many potential representatives that can be used as environmental bioindicators, among which are some species from the Coleoptera, Diptera, Lepidoptera, Hymenoptera, Hemiptera, Isoptera and others. Lepidoptera species are more sensitive environmental changes heavy metals and CO_2 pollution. Alstad *et al*. (1982) suggested that air pollution has been associated with boot primary (direct) and secondary (indirect) effects on insect populations. In the former case, airborne pollutants are directly implicated in the toxicology and decline of insect numbers. Conspicuous examples are those in which an economically valuable insect is poisoned; the best developed.

According to Buttler and Trumble (2008) the pollutants are harmful onto the plants of the terrestrial ecosystems and the insects, including air pollutants, such as ozone, sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon oxides (CO_x), fluoride and acid rain (fog and rain) and polluting metals and heavy metals. The population density reduction can be most frequently explained by the toxicity of pollutants (Kozlov *et al*., 1996). However, there are some species which prefer pollutants; they can strong growth and consequently cause serious damage to the polluted forests (Baltensweiler, 1985). There is a response of insect populations from negative to positive environmental pollution. Führer (1985) emphasized the urgent need of experimental evidence to demonstrate the modes of action of air contaminants upon forest insects. There are some hypotheses which refer to the polluting effect on plant consuming insects. These are the following:

(1) it causes a change in the quality of the habitat on plant consuming ones,

(2) it may modify the quality of the plant,

(3) it is harmful for the natural enemy, so decreases because of this (Zvereva and Kozlov, 2000).

Kozlov and Haukioja (1993) published the densities of males of the Large Fruit-tree Tortrix *A. podana* Scopoli which were determined by pheromone traps in the Lipetsk district, central Russia, in 1991. The sulphur dioxide was significant at Lipetsk among industrial emissions. The individual density of *Archips podana* Scopoli reached a peak at about 3-7 km from the nearest source of emission.

Some examples are given below:

Terrestrial insects: distinct types of response to SO_2 pollution have been identified which distinguish some groups of land-living insect, for example: very sensitive: e.g. many butterflies and moths; moderately sensitive - the Pine Engraver (*Ips dentatus* Sturm) and the Pine Flat-bug *Aradus cinnamoneus* Panz.; very tolerant and sometimes benefitted by SO_2 pollution - aphids. The Migratory Grasshopper (*Melanoplus sanguinipes* F.) density tended to decrease with increasing SO_2 concentration. Sulphur dioxide did not alter the relative proportions of this species in the total population (Mcnary *et al*.,1981). The abundance and dynamics of the European Spruce Bark Beetle (*Ips typographus* L.) populations was evaluated by Grodzki *et al.* (2014) in 60-80 year old spruce stands in Norway. The mean daily capture of beetles in pheromone traps was significantly higher at sites where the O_3 level was higher. The particulate matter adsorb toxic materials (e.g. metals, mutagenic substances) as well as bacteria, viruses, fungi and promote their getting into the body. PM10 can be cause irritation in the lung and mucous membrane (Dockery, 2009). 211 lives could have been saved in Hungary yearly by the reduction of PM10 to yearly mean of 20 μg/m^3 (Bobvos *et al*., 2014). Research groups studied in Europe in several cities of PM10 pollution (Makra *et al*., 2011; 2013; Papanastasiou and Melas, 2004; 2008; 2009; Papanastasiou *et al*., 2010). According to Vaskövi *et al.* (2014) and Chłopek (2013) the yearly mean concentration of PM10 is generally higher near the main traffic roads than in areas with less traffic. However, we did not find any studies in the literature examining the activity and daily pheromone trapping the insects in connection with air pollution.

MATERIAL

Between 2004 and 2012 light-traps were operating in Fejér County, Hungary Europe). The light traps were operated at the following villages and years: Csákvár (47º23′73”N; 18º28′17”E), 2004. Pálhalma-Dunaújváros (46º58′03”N; 18º56′13), 2004, 2005, 2006. Kőszárhegy (47º05′71”N; 18º20′62”E), 2004, 2005, 2006. Sukoró (47º17′40”N; 18º19′69”E), 2004, 2005, 2006, 2007, 2009, 2011, 2012. The data were processed of following species: *Rhizotrogus aequinoctialis* Herbst, 1790, *Rhizotrogus aestivus* Olivier, 1789 and *Melolontha melolontha* Linnaeus, 1758. The values of the chemical air pollutants: SO_2, NO, NO_2, NO_x, CO, PM10, O_3 (in milligram per cubic meter) was measured in nearest automatic measurement station Székesfehérvár (47°17’45”N, 18°19’59”E). Distance between the Kőszárhegy and Sukoró from Székesfehérvár are 22 km, Csákvár is 34 km and Pálhalma-Dunaújváros is 58 km as the crow flies.

METHODS

From the catch data of the examined beetle species, relative catch (RC) data were calculated for each observation post and day. The RC is the quotient of the number of individuals caught during a sampling time unit (1 day) per the average number of individuals of the same generation falling to the same time unit. In case of the expected averaged individual number the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps (Nowinszky, 2003). The data from different years were combined. The number of the chemical air pollutants and the beetles caught were calculated in classes with consideration to the method of Sturges (Odor and Iglói, 1987). The RC values of all species were arranged into the proper classes. The results obtained are plotted. We determined the regression equations, the levels of significance, which were shown in the Table 1.

Table 1. The regression equations, levels of significance of air pollutants and beetle species.

Air pollutants	Equations	R^2	P <
Nitrogen dioxide (NO_2)			
Rhizotrogus aequinoctialis Herbst	$y = 0.001x^2 - 0.0625x + 1.7477$	0.7775	0.001
Rhizotrogus aestinus Olivier	$y = 0.002x^2 - 0.0645x + 1.3443$	0.8595	0.01
Melolontha melolontha Linnaeus	$y = 0.0009x^2 - 0.0019x + 0.3263$	0.9802	0.001
Nitrogen oxides (NO_x)			
Rhizotrogus aequinoctialis Herbst	$y= -4E-05x^3+0.0042x^2\ 0.1538x +2.6475$	0.857	0.01
Rhizotrogus aestinus Olivier	$y = 0.0004x^2 - 0.0073x + 0.8371$	0.812	0.01
Melolontha melolontha Linnaeus	$y = 9E-05x^2 + 0.0103x + 0.4733$	0.9525	0.001
Nitrogen oxide (NO)			
Rhizotrogus aequinoctialis Herbst	$y = 1.3843^{e}-0.1x$	0.8812	0.001
Rhizotrogus aestinus Olivier	$y = -0.003x^2 + 0.1245x + 0.4584$	0.8688	0.001
Melolontha melolontha Linnaeus	$y = -0.0015x^2 + 0.074x + 0.5522$	0.937	0.001

Table 1. Continued.

Air pollutants	Equations	R^2	P <
Carbon monoxide (CO)			
Rhizotrogus aequinoctialis Herbst	y = 3E-06x^2 - 0.0053x + 2.79	0.9856	0.001
Rhizotrogus aestinus Olivier	y = 3E-07x^2 + 0.0002x + 0.5624	0.8925	0.001
Melolontha melolontha Linnaeus	y = 1.8708Ln(x) - 11.012	0.8275	0.01
Ozone (O_3)			
Rhizotrogus aequinoctialis Herbst	y = 3E-06x^2 - 0.0053x + 2.7909	0.9856	0.001
Rhizotrogus aestinus Olivier	y = 3E-07x^2 + 0.0002x + 0.5624	0.8925	0.001
Melolontha melolontha Linnaeus	1.8708Ln(x) - 11.012	0.8275	0.01
Particulate matter (PM10)			
Rhizotrogus aequinoctialis Herbst	y = 0.0011x^2 - 0.1924x + 8.8142	0.9392	0.001
Rhizotrogus aestinus Olivier	-2E-05x^3 + 0.0033x^2 - 0.248x + 7.3574	0.9217	0.001
Melolontha melolontha Linnaeus	y = 3E-05x^2 - 0.0144x + 1.7495	0.9278	0.001

RESULTS AND DISCUSSION

All of our results are shown in Figs. 1-6. and Table 1 and Table 2. We found that the behaviour of the studied beetle species can be divided into two types: if the air pollution increases, the catch increases or decreases. Our results are without antecedents in the literature. We can only mention one of our own studies, dealing with examination between the pheromone trap catches and PM10 (Nowinszky *et al.,* 2015; 2016a; 2016b). We distinguished three types of trends in these studies of ours: increasing, decreasing and increasing then decreasing. We didn't find any studies in the special literature dealing with the contact of the light trap catch results and the air pollution. It is remarkable that the "increasing then decreasing" type is missing at the investigated beetle species. The emission of solid materials (dust, PM10) in Hungary from the early 90s fell by almost half, initially strongly, later with declining pace. The main are the industry, energy production and population. Today, more and more attention is paid to this pollutant. Research results have proved that the health effects of dust is far greater than previously thought. The small amount of material in the air, which is highly toxic, bind on the surface of the small size particles (PM2.5) and together with these particles they directly pass into the blood through the respiratory system. We know little about their effect has on the insects however

The response of different insect groups (Microlepidoptera, Macrolepidoptera, Trichoptera) to environmental factors is strikingly different. We do not know the impact of other pollutants on insect flight activity in the air. This opposite form of behaviour may be the many reasons. The claim and tolerance to environmental factors of the species are different. Environmental factors interact with each other to exert their effects. Thus the same factor can different effects. The species have different survival

(Nowinszky, 2003). Adverse effects of two possible answers: passivity, or hiding or even increased activity, because you want to ensure the survival of the species. Therefore, the insect “to carry out their duties in a hurry.”

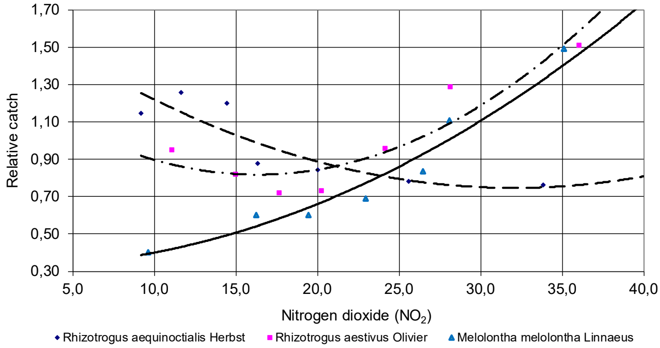

Fig. 1. Light-trap catch of beetle (Coleoptera) species in connection with the nitrogen dioxide (NO_2) content of the air (Fejér County).

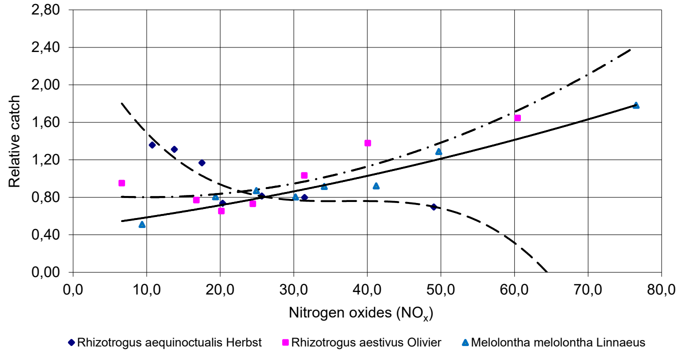

Fig. 2. Light-trap catch of beetle (Coleoptera) species in connection with the nitrogen oxides (NOx) pollution of air.

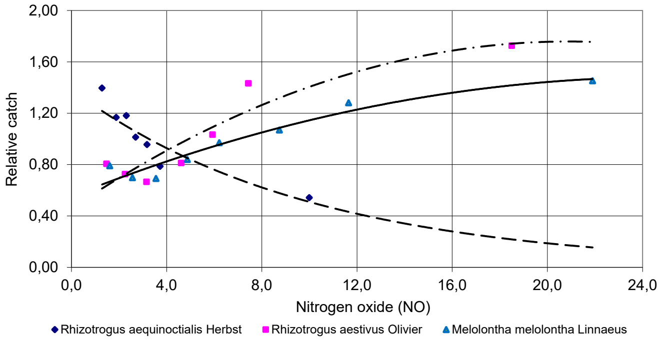

Fig. 3. Light-trap catch of beetle (Coleoptera) species in connection with the nitrogen oxide (NO) content of the air (Fejér County).

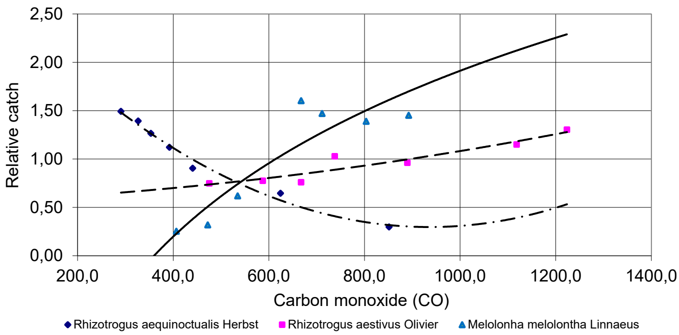

Fig. 4. Light-trap catch of beetle (Coleoptera) species in connection with the carbon monoxide (CO) content of the air (Fejér County).

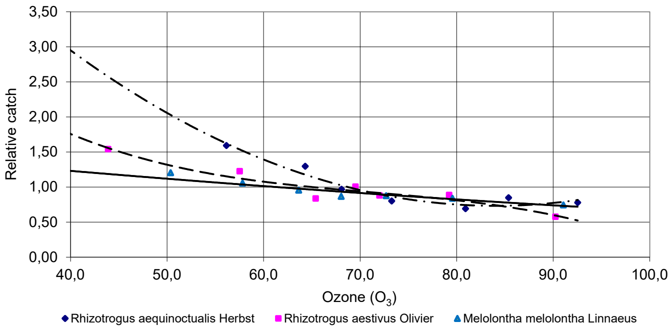

Fig. 5. Light-trap catch of the beetle (Coleoptera) species in connection with the ozone (O3) content of air.

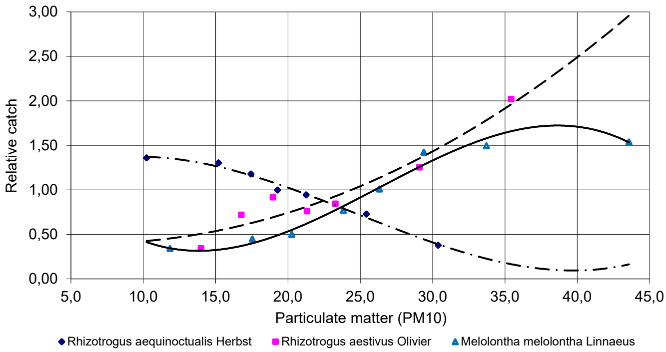

Fig. 6. Light-trap catch of the beetle (Coleoptera) species in connection with the particulate matter (PM10) content of air.

There may be more reasons for this contradictory behavioural forms. The different species need different circumstances and have difference tolerance levels to environmental factors. Environmental factors interact with each other to exert their effects. Thus the same factor can cause different influence. It is possible that there are two answers to the unfavourable environmental factors: passivity (e.g. hiding) or even increased activity, because the insect wants to ensure the survival of the species. Therefore, he does his tasks quickly. The fact that on the higher and increasing values of air pollutants the catches are not suddenly, but gradually, we deduce that the tolerance and response of insect specimens to adverse effects. Further studies are planned. We will continue our research in other insect species and trap types for analyses.

Table 2. The behaviour types of the examined beetle (Coleoptera) species.

Species	NO_2	NOx	NO	CO	O_3	PM10
Rhizotrogus aequinoctialis Herbst	D	D	D	D	D	D
Rhizotrogus astivus Olivier	I	I	I	I	D	I
Melolontha melolontha Linnaeus	I	I	I	I	D	I

Notes: I=increasing, D=decreasing.

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Received: April 05, 2016 *Accepted: October 16, 2017* e • Acta Naturalia Pannonica

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Light-trap catch of Macrolepidoptera species compared the 100 W normal and 125 W BL lamps

Macrolepidoptera fajok fénycsapdás gyűjtése 100 W normál és 125 W BL fényforrással

PUSKÁS JÁNOS & NOWINSZKY LÁSZLÓ

Abstract – Puskás, J. & Nowinszky, L. 2011: Light-trap catch of Macrolepidoptera species compared the 100 W normal and 125 W BL lamps. – e-Acta Naturalia Pannonica **2** (**2**): 000-000. – The study carried out by comparing catch data of the Hungarian light-trap network normal and BL trap types operating simultaneously in 19 observation sites. The behaviour of 630 species was considered in total and for 384 species was established, which trap type is more suitable for their collection? More species of *Sphingidae, Notodontidae, Arctiidae* and *Noctuidae* families can be collected by BL traps whereas the majority of *Geometridae* flies to normal ones. No family contains, however, species that would fly solely to one or other type.

Key words – Macrolepidoptera, normal, BL lamps

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Összefoglalás – A tanulmány a normál és az UV fényforrással gyűjtő fénycsapdák Macrolepidoptera fajok fogási eredményeinek összehasonlításával foglalkozik. Összesen 630 faj befogott példányainak számát feldolgozva, 384 fajról sikerült megállapítani, hogy melyik fényforrással gyűjthetők eredményesebben. A Sphingidae, Notodontidae, Arctiidae és Noctuidae családok fajainak többsége az UV csapdában, míg a *Geometridae* család fajainak többsége a normál csapdában fordult elő nagyobb számban. Egyetlen családban sem találhatók azonban olyan fajok, amelyek kizárólag egyik vagy másik típusú fényforrással lennének gyűjthetők.

Introduction

There have been a lot of entomologists in the world examining the spectral sensitivity of insects' eyes for a long time. They also made a comparison between the collecting results of light-traps operating with different light sources. We have not enough place to write on these studies in detail but according to the researches of Agee 1972, 1973; Gui et al. 1942; Williams 1951; Cleve 1954; Frost 1955; Zlokovity et al. 1958; Belton & Kempster 1963; Jászainé 1977; Sifter 1971; Mikkola 1972; Blomberg et al. 1976; Bürgés et al. 1976; Járfás 1978 most of species fly to light-traps operating with short wave-length light (HGL and BL). There is an opposite conclusion in some studies, some species fly better to the normal light (Theoward 1963; Jászainé 1969; Járfás 1977).

There were two light-traps run by the Plant Protection Research Institution, one operating with normal and the other with BL light, operating parallel in Keszthely from 1962 to get information about the practicability of normal and BL light-traps in Hungary. The distance was about 100 meters between these traps. There was a building between them (Sáringer 1995), so the catching results of traps were not modified by the light of traps. A new light-trap network was organized operating with BL light at all the county plant protection stations, working parallel with normal light-traps, by Plant Protection Service in 1962 and 1963. The normal and BL light-trap network provided useful information for the examination of trapping data of the two light-trap types. The harmful species of Macrolepidoptera data, caught by normal and BL light-traps, was determined by Mészáros (1966) and he made a comparison among the most important species. He stated that the BL light-traps collected more individuals but because of their complicated operation he did not find this data suitable for phenological examinations. It is easier to determine the insects caught by the normal light-trap than by BL one

(Mészáros 1966). In the second case the problem is the breaking to pieces of insects. The normal light-traps have been used in the light-trap network in Hungary from the early times of operating. The collected data given by the normal and BL light-trap network, operated parallel in Hungary, can give an unprecedented possibility to make some important examinations. We would like to get answers to these questions in our present work:

– Is there a significant difference between the caught of two trap types examining species and families?

– Is the normal or BL light-trap more favourable for caught of different species?

– Which species are**,** with their different, catching results can be explained by the local circumstances (the microclimate of light-traps, the different distance of each species' living territory) and not by the different light-source?

– Are there any species that can be caught by only normal light-trap or BL one?

– Are there any species that can be caught better by one of the trap types?

With the inclusion of 630 Macrolepidoptera species by use of material yielded by the national light-trap network in order to answer the above questions have determined which type is more suitable to collect 384 selected species.

Material and Methods

The operating periods for each observing stations of normal and BL light-traps are shown in Table 1.

We has used the old nomenclature and taxonomy (Karsholt & Razowski 1996) this study. We will use the adopted in Europe, new nomenclature and taxonomy in the future studies.

We could not use the data of Mohora and Tass from the county plant protection stations because their phenological data were not correct. We also could not use the data of Keszthely in 1962 because there were not normal light-trap data between the middle of May and the late autumn. Probably there was a mistake during this period. We could use all the data of Macrolepidoptera species provided by observing stations.

Generally the light-traps worked in the yard of plant protection stations Mészáros (1966). We had information about the distance between the two light-traps and their isolation only from Tanakajd and Nagytétény. There were 300 meters between the two light-traps and they worked totally isolated at Tanakajd but there were only 10 meters between them at Nagytétény.

The individual Macrolepidoptera species' number of caught individuals was summarized for each observing station and type of light-trap but the samples coming from different generations were not separated. The Mann-Whitney test was used in calculating the significance level of difference between the individual's number caught by normal and BL light-traps for each species. The theoretical base and use of test was explained in detail by Hajtman (1971), Odor & Iglói (1987). There was made a mixed model using the data of normal and BL light-traps at all the observing stations. The element number of model was the same as the double of observing stations (two light-traps were in work at every observing station), where one of the species was caught by a light-trap. The number of samples was summarized separately in the mixed model. The significance level of difference was determined by making a comparison to the value of the table.

Making a comparison between the data of normal and BL light-trap at Nagytétény was very important, because the two light-traps were nearby each other so the microclimate, the vegetation and the living territory of each species was the same that is why the moths could select between the light-traps operating with different light-source. There was an investigation to determine the number and percentile proportion of species can be caught successfully by normal and BL light-trap for each family. We also made an examination to find non-significant differences in some species' catching data of two type light-trap, although the number of light-traps would be enough to determine the significant difference. We could not make the examinations with those species, which were caught at less than four observing stations because the test used can not give a significant difference in this case.

We could not make a comparison between the specific combination and the sample number of each species belonging to the different observing stations because:

The catching period was not the same at all the observing stations, the environmental factors (weather situations, vegetation etc.) were not the same, the individual species might have been in

Table 1. The collecting period and examined period of normal and UV light-traps at the observing stations

N	*Light-trap stations*	*Years*	*Normal*	*BL*	*Examined periods*
1.	Baj	1963	12. 04. - 30. 10.	04. 04. - 11. 11.	12. 04.- 30. 10.
2.	Csopak	1963	25. 03. - 12. 11.	18. 04. - 20. 11.	18. 04. - 12. 11.
3.	Fácánkert with the exception of	1963	29. 03. - 19. 11.	28. 05. - 29. 11. 15. 06. - 30. 06.	28. 05. - 19. 11. 15. 06. - 30. 06.
4.	Gyöngyös	1963	27. 03. - 20. 11.	12. 04. - 07. 11.	12. 04. - 07. 11.
5.	Győr-Kismegyer	1963	09. 04. - 28. 11.	12. 04. - 12. 11.	12. 04. - 12. 11.
6.	Hódmezõvásárhely	1963	29. 03. - 17. 11.	08. 05. - 16. 11.	08. 05. - 16. 11.
7.	Kaposvár with the exception of	1963	14. 05. - 20. 11.	10. 05. - 28. 11. 27. 07. - 30. 09.	14. 05. - 20. 11. 27. 07. - 30. 09.
8.	Kállósemjén	1963	14. 04.- 31. 10.	15. 04. - 25. 10.	15. 04. - 25. 10.
9.	Kenderes	1963	30. 03. - 10. 11.	09. 05. - 17. 11.	09. 05. - 10. 11.
10.	Mikepércs with the exception of	1963	31. 03. - 27. 11.	12. 05. - 27. 11. 06. 06. - 27. 06.	12. 05. - 27. 11. 06. 06. - 27. 06.
11.	Miskolc	1963	28. 04. - 08. 11.	28. 04.- 08. 11.	28. 04. - 08. 11.
12.	Pacsa	1963	21. 03. - 23. 10.	03. 04. - 05. 11.	03. 04. - 23. 10.
13.	Szederkény	1963	20. 03. - 15. 10.	10. 07. - 10. 10.	10. 07. - 15. 11.
14.	Tanakajd	1963	29. 03. - 14. 11.	10. 04. - 25. 11.	10. 04. - 14. 11.
15.	Tarhos with the exception of	1963	29. 03. - 26. 11.	15. 04. - 26. 11. 01. 06. - 15. 05.	15. 04. - 26. 11. 01. 06. - 15. 05.
16.	Tass	1963	11. 04. - 14. 11.	13. 04. - 09. 11.	13. 04. - 09. 11.
17.	Velence	1963	28. 03. - 09. 11.	28. 08. - 16. 11.	28. 08. - 09. 11.
18.	Nagytétény	1962	10. 04. - 03. 11.	17. 05. - 28. 10.	17. 05. - 28. 10.
19.	Nagytétény	1963	03. 05. - 09. 11.	06. 04. - 25. 11.	03. 05. - 19. 11.
20.	Keszthely	1963	21. 03. - 20. 11.	07. 05. - 18. 11.	07. 05. - 18. 11.
21.	Keszthely	1964	29. 03. - 24. 11.	20. 03. - 15. 11.	29. 03. - 15. 11.
22.	Keszthely	1966	20. 04. - 27. 10.	11. 05. - 17. 09.	11. 05. - 17. 09.

different phase of their hypercycle.

Because of these problems we could make comparison between the catching data of normal and BL light-trap at of the ilk. The weather was the same at the territory of a village and the hypercycle of each species also was in the same section. We made the examinations only on those days, when both light-traps operated. Because of these factors the reasons for differences in the data of normal and BL light-traps can be the quality of used light-source, the difference of microclimate, the different dispersion and distance of living territory of species.

Results

From among the examined 630 species we managed to establish 384 ones which trap type is more suitable for their collection.

There are 394 species shown in Table 2 that were caught at least by four observing stations with normal and BL light-trap. Those light-traps and number of observing station is marked, near the name of species, which were caught significantly more numbers of moths. The numbers of observing stations are also marked if that species were caught with the light-traps. There are given for every species, which light-trap caught more individuals at Nagytétény in 1962 and 1963.

Discussion

It is characteristic of those families (*Notodontidae, Lasiocampidae* and *Geometridae*), which ones are rich in species, most of their species fly well to both normal and BL light-trap and there is no significant difference between the number of individuals caught by the different light-traps. The conclusion can be drawn that these species were caught by the normal or BL light-trap because of local influences (microclimate, vegetation, distance of living territory). It is very remarkable examining those species where there was not any significant difference in the result of all the observing stations, they were caught at Nagytétény by BL light-trap in 82%. This proportion was nearly the same in the largest families (*Noctuidae* - 83% and *Geometridae* - 79%). If the moths can choose between the two light-traps, operating not far off each other, they fly to BL light-trap.

This finding is true especially for species of family Geometridae. Where the traps have worked in isolation from each other, the species is only 29 percent chose the BL trap, however, both could see 9 percent of species fly to BL trap out and away.

Probably it is because of the shorter wavelength of light as it is known from literature (Mikkola 1972).

It is characteristic of *Sphingidae* family (nearly 70%) can be caught successfully by BL light-trap, and normal light-trap does not catch any species in numerous specimen. The species of *Notodontidae, Arctiidae* and *Noctuidae* families can be caught better by BL light-trap but the species of *Geometridae* family relatively prefer to fly to the normal light-trap. We could not find any species in the families which were caught alone by the normal or BL light-trap.

Today the establishment of Mészáros (1966) is also true because of the complicated operation and poor quality data the use of BL light-traps in numerous places is not useful for the purpose of phenological data collecting. The operating of BL light-traps is justified in the cases of "purpose light -trap" or faunistical trapping. In these cases the mentioned problems have to be solved. If the collected moths can be separated according to their dimension, the smaller bodied and breakable insects can be unhurt. To solve this problem, the literature can give correct method (Pataki 1973, Varga & Mészáros 1973).

The number of species data caught by normal and BL light-traps in each family was very different in each observing station.

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Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in

Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
SPHINGIDAE				
1. Herse convolvuli L.	BL	14	-	-
2. Sphinx ligustri L.	BL	19	BL	N
3. Hyloicus pinastri L.	BL	11	-	-
4. Marumba quercus D. & Sch.	=	5	-	-
5. Mimas tiliae L.	BL	12	BL	BL
6. Smerinthus ocellata L.	BL	21	BL	=
7. Laothoe populi L.	BL	17	N	=
8. Macroglossum stellatarum L.	=	5	-	-
9. Celerio euphorbiae L.	BL	21	BL	BL
10. Pergesa elphenor L.	BL	14	-	-
11. Pergesa porcellus L.	BL	14	-	BL
NOTODONTIDAE				
1. Cerura furcula Cl.	BL	12	BL	-
2. Cerura bifida Hbn.	BL	16	-	BL
3. Drymonia querna F.	=	7	-	-
4. Drymonia trimacula Esp.	=	6	-	-
5. Drymonia chaonia Hbn.	=	4	-	-
6. Dicranura vinula L.	BL	7	-	-
7. Pheosia tremula Cl.	BL	14	BL	-
8. Notodonta dromedarius L.	=	5	-	-
9. Notodonta ziczac L.	BL	17	-	BL
10. Notodonta phoebe Sieb.	BL	6	-	-
11. Spatalia argentina D. & Sch.	BL	11	-	-
12. Lophopteryx camelina L.	=	5	-	-
13. Pterostoma palpinum L.	N	20	N	N
14. Ptilophora plumigera Esp.	=	6	-	BL
15. Phalera bucephala L.	BL	17	BL	BL
16. Gluphisia crenata Esp.	=	13	-	-
17. Pygaera anastomosis L.	=	14	-	BL
18. Pygaera curtula L.	N	14	BL	BL
19. Pygaera pigra L.	=	9	-	N
THAUMETOPOIDAE				
1. Thaumetopoea processionea L.	=	8	BL	-
THYATIRIDAE				
1. Habrosyne pyrithoides Hufn.	=	5	-	-
2. Polyploca ruficollis F.	=	4	-	-
3. Tethea or F.	=	7	-	-
4. Tethea ocularis L.	BL	4	-	-
DREPANIDAE				
1. Drepana falcataria L.	=	6	-	-
2. Drepana binaria Hufn.	=	10	-	-
3. Drepana harpagula Esp.	=	5	-	-
4. Cilix glaucata Scop.	=	20	BL	N
SATURNIDAE				
1. Saturnia pyri D. & Sch.	=	7	BL	-
2. Eudia pavonia L.	BL	5	BL	-

Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in

Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
LASIOCAMPIDAE				
1. Poecilocampa populi L.	=	6	-	-
2. Trichiura crataegi L.	=	5	-	-
3. Malacosoma neustrium L.	=	12	-	-
4. Pachygastria trifolii Esp.	=	6	BL	-
5. Macrothylacia rubi L.	=	11	-	-
6. Odonestis pruni L.	BL	17	-	-
7. Epicnaptera tremulifolia L.	BL	11	-	-
8. Gastropacha quercifolia L.	BL	17	BL	N
LYMANTRIIDAE				
1. Dasychira pudibunda L.	=	7	-	-
2. Orgya antiqua L.	BL	7	BL	-
3. Stilpnotia salicis L.	=	7	-	-
4. Lymantria dispar L.	BL	18	BL	-
5. Ocneria rubea F.	=	6	=	-
6. Porthesia similis Fssl.	=	5	-	-
7. Euproctis chrysorrhoea L.	=	15	N	BL
ARCTIIDAE				
1. Comacla senex Hbn.	=	12	-	-
2. Miltochrista miniata Forst	=	4	-	-
3. Lithosia quadra L.	=	12	BL	-
4. Eilema pygmaeola ssp. pallifrons Z.	=	14	BL	=
5. Eilema unita Hbn.	BL	7	BL	-
6. Eilema complana L.	BL	15	BL	-
7. Eilema lurideola Zinck.	=	4	-	-
8. Eilema sororcula Hufn.	BL	5	-	-
9. Pelosia muscerda Hufn.	=	7	-	-
10. Pelosia obtusa H-Sch.	=	8	BL	-
11. Ocnogyna parasita Hbn.	=	5	-	-
12. Chelia maculosa Gern.	=	11	=	BL
13. Phragmatobia fuliginosa L.	BL	22	BL	BL
14. Spilosoma lubricipedum L.	=	18	BL	=
15. Spilosoma menthastri Esp.	=	20	=	=
16. Spilosoma urticae Esp.	=	18	=	-
17. Hyphantria cunea Drury	=	21	BL	BL
18. Arctinia caesarea Goeze.	=	7	BL	BL
19. Diaphora mendica Cl.	=	8	-	BL
20. Diacrisia sannio L.	=	14	-	-
21. Arctia caja L.	BL	21	BL	BL
22. Arctia villica L.	BL	14	N	=
23. Dysauxes ancilla L.	=	12	-	-
NOLIDAE				
1. Roeselia albula D. & Sch.	=	5	-	-
2. Celama centonalis Hbn.	=	7	-	-
NOCTUIDAE				
1. Euxoa temera Hbn.	BL	10	BL	-
2. Euxoa obelisca D. & Sch.	BL	11	BL	BL
3. Euxoa aquilina D. & Sch.	=	10	-	-
4. Scotia cinerea D. & Sch.	=	7	=	-

Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in

Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
5. Scotia vestigialis Hufn.	=	4	-	-
6. Scotia segetum D. & Sch.	BL	22	BL	BL
7. Scotia ipsilon Hufn.	BL	22	BL	BL
8. Scotia exclamationis L.	BL	22	BL	BL
9. Scotia crassa Tr.	BL	18	BL	BL
10. Ochropleura plecta L.	BL	21	BL	BL
11. Eugnorisma depuncta L.	BL	10	-	-
12. Rhyacia fugax Tr.	=	5	-	-
13. Rhyacia ravida D. & Sch.	=	8	BL	-
14. Rhyacia saucia Hbn.	BL	11	BL	BL
15. Noctua pronuba L.	BL	22	BL	BL
16. Noctua comes Tr.	=	4	-	-
17. Noctua fimbriata Schreb.	BL	14	BL	BL
18. Noctua janthina D. & Sch.	BL	6	BL	-
19. Diarsia rubi View.	=	6	BL	-
20. Amathes c-nigrum L.	BL	22	BL	BL
21. Amathes triangulum L.	BL	15	-	BL
22. Amathes xanthographa D. & Sch.	BL	11	BL	BL
23. Cerastis rubricosa D. & Sch.	=	9	-	=
24. Mesogona acetosellae D. & Sch.	BL	5	BL	-
25. Discestra trifolii Hufn.	BL	5	BL	-
26. Discestra dianthi Tausch.	=	8	-	BL
27. Sideritis albicolon Hbn.	BL	14	N	BL
28. Heliphobus calcatrippae View.	=	9	N	BL
29. Polia nebulosa Hufn.	=	4	-	-
30. Pachetra sagittigera Hufn.	=	7	-	BL
31. Mamestra brassicae Hufn.	BL	21	BL	BL
32. Mamestra persicariae L.	BL	4	-	-
33. Mamestra w-latinum Hufn.	BL	17	=	BL
34. Mamestra thalassina Hufn.	BL	11	BL	-
35. Mamestra suasa D. & Sch.	=	22	BL	BL
36. Mamestra oleracea L.	BL	22	BL	BL
37. Mamestra aliena Hbn.	=	5	-	-
38. Mamestra nana Hufn.	=	12	-	-
39. Mamestra pisi L.	=	10	BL	-
40. Mamestra dysodea D. & Sch.	BL	9	-	BL
41. Harmodia cucubali D. & Sch.	BL	11	BL	BL
42. Harmodia lepida Esp.	=	13	-	-
43. Harmodia luteago D. & Sch.	=	20	N	BL
44. Harmodia bicruris Hufn.	BL	18	BL	BL
45. Tholera cespitis F.	=	15	BL	-
46. Tholera decimalis Poda	=	21	BL	BL
47. Xylomania conspicillaris L.	BL	13	-	BL
48. Hyssia cavernosa Ev.	=	10	-	-
49. Orthosia cruda D. & Sch.	BL	10	-	-
50. Orthosia miniosa D. & Sch.	BL	8	-	-
51. Orthosia opima Hbn.	=	5	-	-
52. Orthosia populi Ström.	=	4	-	-
53. Orthosia gracilis D. & Sch.	=	10	-	BL

Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in

Families and species		*All light-traps*		*Nagytétény*	
		BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
54.	Orthosia stabilis D. & Sch.	BL	9	-	-
55.	Orthosia incerta Hufn.	BL	11	BL	-
56.	Orthosia munda D. & Sch.	BL	9	-	-
57.	Orthosia gothica L.	=	11	-	-
58.	Mythimna ferrago F.	BL	7	BL	-
59.	Mythimna turca L.	BL	8	-	-
60.	Mythimna albipuncta D. & Sch.	BL	20	BL	BL
61.	Mythimna pudorina D. & Sch.	=	4	-	-
62.	Mythimna vitellina Hbn.	BL	10	BL	-
63.	Mythimna pallens L.	BL	22	BL	BL
64.	Mythimna l-album L.	BL	21	BL	BL
65.	Mythimna obsoleta Hbn.	BL	12	BL	BL
66.	Cucullia lactuceae D. & Sch.	BL	5	-	-
67.	Cucullia chamomillae D. & Sch.	=	4	BL	-
68.	Cucullia umbratica L.	BL	22	BL	BL
69.	Cucullia fraudatrix Ev.	=	6	-	-
70.	Calophasia lunula Hufn.	=	18	BL	=
71.	Brachionycha sphinx Hufn.	=	11	-	-
72.	Derthisa glaucina Esp.	=	9	N	BL
73.	Derthisa trimacula D. & Sch.	BL	11	BL	-
74.	Aporophyla lutulenta D. & Sch.	=	7	-	-
75.	Allophyes oxyacanthe L.	=	7	BL	BL
76.	Lamprosticta culta D. & Sch.	BL	4	-	BL
77.	Ammoconia caecimacula D. & Sch.	BL	10	BL	BL
78.	Eupsilia transversa Hufn.	=	13	-	-
79.	Conistra erythrocephala D. & Sch.	=	7	-	-
80.	Conistra rubiginosa Scop.	=	6	-	-
81.	Conistra vaccinii L.	=	16	-	BL
82.	Agrochola helvola L.	=	4	-	-
83.	Agrochola humilis D. & Sch.	BL	6	-	-
84.	Agrochola lota Cl.	=	9	BL	-
85.	Agrochola circellaris Hufn.	=	5	-	-
86.	Agrochola litura L.	BL	15	BL	BL
87.	Agrochola lychnidis D. & Sch.	BL	19	BL	BL
88.	Atethmia xerampelina Esp.	=	4	BL	-
89.	Cirrhia gilvago Esp.	BL	4	-	-
90.	Cirrhia ocellaris Bkh.	=	8	BL	BL
91.	Craniophora ligustri D. & Sch.	BL	10	-	-
92.	Apatele rumicis L.	BL	21	BL	BL
93.	Apatele psi L.	=	7	-	BL
94.	Apatele tridens D. & Sch.	BL	16	BL	BL
95.	Apatele aceris L.	BL	4	-	BL
96.	Apatele megacephala D. & Sch.	BL	20	BL	BL
97.	Symira albovenosa Goeze.	=	10	-	N
98.	Symira nervosa D. & Sch.	=	7	-	-
99.	Oxycesta geographica F.	N	4	N	N
100.	Cryphia simulatricula Gn.	=	9	-	-
101.	Cryphia raptricula D. & Sch.	BL	10	-	-
102.	Cryphia algae F.	BL	4	-	-

Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in Hungary

Families and species	All light-traps		Nagytétény	
	BL or Normal	Number of traps	1962 BL or N	1963 BL or N
103. Amphipyra pyramidea L.	BL	5	-	BL
104. Amphipyra livida D. & Sch.	=	8	BL	BL
105. Amphipyra tragopoginis L.	BL	17	BL	-
106. Dypterygia scabriuscula L.	=	13	BL	-
107. Rusina tenebrosa Hbn.	=	9	-	-
108. Euplexia lucipara L.	=	7	-	-
109. Apamea monoglypha Hufn.	BL	13	BL	=
110. Apamea sublutris Esp.	=	5	N	-
111. Apamea anceps D. & Sch.	BL	15	-	-
112. Apamea sordens Hufn.	=	16	N	BL
113. Apamea secalis L.	BL	7	-	-
114. Oligia strigilis L.	BL	17	N	BL
115. Oligia latruncula D. & Sch.	=	19	N	BL
116. Mesoligia furuncula D. & Sch.	=	9	BL	-
117. Luperina testacea D. & Sch.	=	22	BL	BL
118. Gortyna flavago D. & Sch.	=	9	-	-
119. Trachea atriplicis L.	=	12	-	-
120. Phlogophora meticulosa L.	BL	12	BL	-
121. Hydraecia micacea Esp.	=	5	-	BL
122. Callogonia virgo Tr.	=	13	-	-
123. Actinotia polyodon Cl.	=	5	-	-
124. Laphygua exigua Hbn.	BL	12	BL	-
125. Laphygua morpheus Hufn.	=	17	BL	BL
126. Caradrina kadenii Fr.	BL	8	-	BL
127. Caradrina clavipalpis Scop.	BL	21	BL	BL
128. Acosmetia caliginosa Hbn.	N	10	N	BL
129. Athetis gluteosa Tr.	=	19	BL	BL
130. Athetis furvula Hbn.	=	11	-	-
131. Athetis lepigone Mschl.	=	20	BL	BL
132. Hoplodrina alsines Brahm.	BL	17	-	BL
133. Hoplodrina blanda D. & Sch.	BL	14	BL	BL
134. Hoplodrina ambigua D. & Sch.	BL	19	BL	BL
135. Hoplodrina respersa D. & Sch.	=	4	-	-
136. Meristis trigrammica Hufn.	=	16	-	BL
137. Cosmia pyralina D. & Sch.	=	4	-	-
138. Cosmia affinis L.	BL	7	-	-
139. Cosmia trapezina L.	=	13	BL	-
140. Rhizedra lutosa Hbn.	BL	18	BL	BL
141. Nonagria typhiae Thnbg.	=	6	BL	-
142. Arenostola pygmina Haw.	=	10	-	BL
143. Arenostola fluxa Hbn.	=	9	BL	-
144. Archanara sparganii Esp.	=	8	-	-
145. Archanara geminipuncta Haw.	=	5	BL	BL
146. Archanara dissoluta Tr.	=	4	-	-
147. Archanara cannae O.	=	7	-	-
148. Chilodes maritima Tausch.	=	7	BL	BL
149. Calamia tridens Hufn.	=	13	=	BL
150. Aegle koekeritziana Hbn.	=	9	N	N
151. Agrotis venustula Hbn.	=	7	-	-

Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in Hungary

Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
152. Chloridea maritima Grsl.	BL	22	BL	BL
153. Chloridea viriplaca Hufn.	BL	21	BL	BL
154. Chloridea scutosa D. & Sch.	=	5	-	-
155. Pyrrhia umbra Hufn.	=	15	-	BL
156. Pyrrhia purpurina D. & Sch.	BL	18	BL	BL
157. Chariclea delphinii L.	BL	19	BL	BL
158. Axylia putris L.	BL	21	BL	BL
159. Eublemma arcuinna Hbn.	=	4	BL	BL
160. Porphyrinia respersa Hbn.	BL	8	-	N
161. Lithacodia deceptoria Scop.	=	4	-	-
162. Jaspidia pygarga Hufn.	=	9	-	-
163. Eustrotia uncula Cl.	=	13	-	-
164. Eustrotia olivana D. & Sch.	=	11	-	-
165. Eustrotia candidula D. & Sch.	=	21	BL	BL
166. Erastria trabealis Scop.	=	22	BL	BL
167. Tarache lucida Hufn.	BL	22	BL	BL
168. Tarache luctuosa Esp.	=	22	BL	BL
169. Nycteola asiatica Krul.	BL	15	BL	-
170. Earias chlorana L.	=	14	BL	BL
171. Earias vernana Hbn.	=	11	BL	BL
172. Bena prasinana L.	BL	15	-	BL
173. Colocasia coryli L.	=	10	-	-
174. Episema coeruleocephala L.	=	15	-	-
175. Chrysaspidia festucae L.	BL	12	-	-
176. Macdunnoughia confusa Steph.	=	21	BL	BL
177. Autographa gamma L.	BL	21	BL	BL
178. Plusia chrysitis L.	BL	21	BL	N
179. Abrostola triplasia L.	=	10	-	-
180. Abrostola trigemina Werb.	=	10	-	BL
181. Catocala elocata Esp.	BL	10	BL	BL
182. Gonospileia glyphica L.	=	14	BL	N
183. Scoliopteryx libatrix L.	=	11	-	N
184. Lygephila craceae D. & Sch.	BL	7	-	BL
185. Aedia funesta Esp.	BL	20	N	BL
186. Colobochyla salicalis D. & Sch.	=	7	-	-
187. Prothymia viridaria Cl.	=	9	BL	-
188. Rivula sericealis Scop.	=	21	BL	N
189. Zanclognatha lunalis Scop.	N	7	-	-
190. Zanclognatha tarsipennalis Tr.	=	5	-	-
191. Zanclognatha tarsicrinalis Knoch.	=	8	N	-
192. Herminia tentacularia L.	=	4	-	-
193. Simplicia rectalis Ev.	=	6	BL	-
194. Paracolax glaucinalis D. & Sch.	=	11	-	-
195. Schrankia costaestrigilis Steph.	N	5	-	-
196. Hypena proboscidalis L.	=	4	-	-
197. Hypena rostralis L.	=	12	N	BL
GEOMETRIDAE				
1. Alsophila aescularia D. & Sch.	=	4	-	-
2. Chlorissa viridata L.	N	20	N	N

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Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
3. Chlorissa cloraria Hbn.	=	6	-	-
4. Chlorissa pulmentaria Gn.	N	9	-	=
5. Euchloris smaragdaria F.	=	15	-	-
6. Thalera fimbrialis Scop.	=	16	-	-
7. Hemistola chrysoprasaria Esp.	=	10	-	-
8. Scopula rufaria Hbn.	=	6	N	=
9. Scopula serpentata Hufn.	=	5	-	-
10. Scopula aureolaria D. & Sch.	BL	4	-	-
11. Scopula muricata Hufn.	=	8	-	-
12. Scopula rusticata D. & Sch.	=	17	BL	-
13. Scopula obsoletaria Hbn.	N	4	-	-
14. Scopula fuscovenosa Goeze.	=	12	-	BL
15. Scopula humiliata Hufn.	N	12	N	N
16. Scopula seriata Schrk.	=	5	BL	-
17. Scopula politata Hbn.	N	5	-	-
18. Scopula dimidiata Hufn.	N	17	-	N
19. Scopula nitidata H.-Sch.	=	4	-	BL
20. Scopula aversata L.	=	16	-	BL
21. Scopula degeneraria Hbn.	=	7	BL	-
22. Scopula inorata Haw.	=	10	BL	-
23. Scopula immorata L.	=	17	N	BL
24. Scopula corrivalaria Kretschm.	=	5	-	-
25. Scopula nigropunctata Gze.	=	4	-	-
26. Scopula virgulata D. & Sch.	N	20	BL	N
27. Scopula ornata Scop.	N	11	-	N
28. Scopula rubiginata Hufn.	=	19	BL	N
29. Scopula marginepunctata Gze.	=	18	BL	N
30. Scopula immutata L.	N	17	BL	N
31. Scopula flaccidaria Z.	=	14	-	N
32. Scopula incanata L.	=	7	-	-
33. Rhodostrophia vibicaria Cl.	=	16	BL	BL
34. Cyclophora annulata Schlze.	=	15	BL	BL
35. Cyclophora ruficiliaria H.-Sch.	=	4	-	-
36. Cyclophora punctaria L.	=	14	-	-
37. Cyclophora trilinearia Hbn.	BL	8	-	-
38. Calothysanis amataria L.	N	22	BL	N
39. Lythria purpuraria L.	=	15	BL	BL
40. Mezotype virgata Hufn.	=	7	BL	-
41. Lithostege farinata Hufn.	=	19	N	BL
42. Lithostege asinata F.	=	11	BL	-
43. Anaitis plagiata L.	=	12	BL	-
44. Operophthera brumata L.	N	11	-	-
45. Philereme vetulata D. & Sch.	=	9	-	BL
46. Lygris pyraliata D. & Sch.	=	4	-	-
47. Xanthorrhoe fluctuata L.	=	20	BL	BL
48. Xanthorrhoe spadicearia D. & Sch.	=	4	-	-
49. Xanthorrhoe ferrugata Cl.	N	16	-	N
50. Orthonama vittata Bkh.	=	7	-	-
51. Nycterosea obstipata F.	=	16	BL	=

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Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
52. Euphya cuculata Hufn.	=	4	-	-
53. Euphya rubidata D. & Sch.	N	6	N	-
54. Euphya polygrammata Bkh.	=	7	-	-
55. Epirrhoe alternata Müll.	=	15	BL	-
56. Epirrhoe galiata D. & Sch.	=	5	-	-
57. Pelurga comitata L.	=	13	BL	N
58. Perizoma alchemillata L.	BL	10	-	N
59. Eupithecia linariata F.	=	14	=	N
60. Eupithecia oblongata Tnbg.	=	22	BL	BL
61. Eupithecia vulgata Hw.	=	7	-	-
62. Eupithecia millefoliata Rössl.	N	8	-	-
63. Eupithecia subnotata Hbn.	=	12	BL	BL
64. Eupithecia innotata Hufn.	=	4	BL	-
65. Gymnoscelis pumilata Hbn.	=	5	-	BL
66. Chloroclystis rectangulata L.	=	5	-	-
67. Abraxas grossulariata L.	=	5	-	-
68. Lomaspilis marginata L.	=	11	-	-
69. Ligdia adustata D. & Sch.	=	15	-	BL
70. Bapta temerata D. & Sch.	=	4	-	-
71. Lomographa dilectaria Hbn.	=	9	-	=
72. Cabera pusaria L.	=	10	-	-
73. Cabera exanthemata Scop.	=	15	-	BL
74. Ennomos autumnaria Wernbg.	=	16	BL	=
75. Ennomos fuscantaria Haw.	BL	11	-	-
76. Ennomos tiliaria Hbn.	BL	12	-	-
77. Selenia lunaria D. & Sch.	=	16	BL	N
78. Artiora evonymaria D. & Sch.	N	4	-	N
79. Angerona prunaria L.	=	9	-	-
80. Epione repandaria Hufn.	=	7	-	-
81. Therapis flavicaria D. & Sch.	N	5	-	-
82. Crocallis elinguaria L.	=	5	BL	-
83. Elicrinia trinotata Metzn.	=	6	-	-
84. Colotois pennaria L.	=	8	-	-
85. Macaria alternaria Hbn.	=	17	-	=
86. Chiasmia clathrata L.	=	22	BL	BL
87. Chiasmia glarearia Brahm.	=	14	BL	BL
88. Diastictis artesiaria D. & Sch.	=	6	-	-
89. Tephrina murinaria D. & Sch.	=	11	BL	BL
90. Tephrina arenacearia D. & Sch.	=	22	BL	BL
91. Narraga tessularia Metzn.	=	6	-	-
92. Erannis bajaria D. & Sch.	=	7	-	-
93. Erannis aurantiaria Hbn.	=	20	N	BL
94. Erannis defoliaria Cl.	=	7	-	BL
95. Biston betularius L.	BL	11	BL	-
96. Peribatodes gemmaria Brahm.	=	13	BL	-
97. Cleora cinctaria D. & Sch.	=	6	-	-
98. Boarmia danieli Whrli.	=	7	-	-
99. Boarmia punctinalis Scop.	=	12	-	N
100. Lycia hirtaria Cl.	=	9	-	BL

Table 2. Macrolepidoptera species collected in numerous samples by normal and BL light-trap network in Hungary

Families and species	*All light-traps*		*Nagytétény*	
	BL or Normal	*Number of traps*	*1962 BL or N*	*1963 BL or N*
101. Synopsia sociaria Hbn.	=	5	-	-
102. Ascotis selenaria D. & Sch.	=	21	BL	BL
103. Ectropis bistortata Gze.	N	20	BL	=
104. Ematurga atomaria L.	=	17	-	BL
105. Aethalura punctulata D. & Sch.	=	5	-	-
106. Bupalus piniarius L.	BL	4	-	-

Fig. 1. *Synopsia sociaria* Hbn.

Fig. 2. *Ascotis selenaria* D. & Sch.

Fig. 3. *Aethalura punctulata* D. & Sch.

Fig. 4. *Bupalus piniarius* L.

THE DEPENDENCE OF NORMAL AND BLACK LIGHT TYPE TRAPPING RESULTS UPON THE WINGSPAN OF MOTH SPECIES

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(Received 4th September 2013; accepted 28th October 2013)

Abstract. In the last decade several researchers found relation between the wingspan size of moths and their light sensitivity. Generally, moths with larger wingspan have higher light sensitivity. We tested these findings using the catch data of 378 Macrolepidoptera species from 19 black light (BL, 125 W) and normal light trap (100 W) pairs of the Hungarian Light Trap Network. We have found that wingspan size of about 25 mm is the limit below which some species were trapped more effectively by normal light trap, compared to BL. However, BL trap catch ratio of moths with wingspan of over about 35 mm is nearly 100 %, compared to normal light trap. According to the catch results of a site where normal and BL traps were placed close enough for the moths to perceive both at the same time, 75 % of moths with even small wingspan were caught by BL traps. Regarding the fact that BL traps collected significantly more individuals of Macrolepidoptera species with their wingspan over 35 mm on all sites of observation, we can conclude that Wolfram light bulb of 100 W is hardly suitable to use for this purpose. Consequently, considering our results, the light trap type can more effectively be specialized to the purpose of the observation according to the wingspan of the targeted species from which fact plant protection applications and entomological research projects can successfully benefit.
Keywords: *Macrolepidoptera, wingspan, spectral sensitivity, light traps*

Introduction

For a long time, researchers have been investigating the catch results of light traps with different light sources and the spectral sensitivity of insects' eye.

A given type of light source determines, among others, the temperature, the colour temperature and the spectral distribution of the light energy it emits. Electroretinogram measurements are used to determine the spectral sensitivity of the insects' eye. In the literature, several studies are devoted to the results of laboratory measurements carried out on various species. No reports of such experiments are known in Hungary and data on the most important Hungarian pestilent species are also missing from the international literature of the subject.

Review of literature

Mikkola (1972) established that moths and butterflies (Lepidoptera) and caddisfly species (Trichoptera) have an eye sensitivity that remains practically unchanged in the spectrum of 350-600 nm. Its maximum is around 550 nm (as the value of human eye during daytime). The sensitivity is mightily reduced at about 620 nm.

McFarlane and Eaton (1973) have reported that the responses of Cabbage Looper (*Trichoplusia ni* Hbn.) to monochromatic light stimuli have been investigated by electroretinogram (ERG) and electromyogram (EMG) techniques. The spectral sensitivity curves for male and female Cabbage Loppers show a major peak at 540 to 550 nm and a minor peak at 360 nm.

Agee (1973) showed by elektroretinogram test that the sensitivity of eyes of the Bollworm Moth (*Heliothis zea* Boddie) and Tobbacco Bollworm (*Heliothis virescens* F.) to 365 nm and 480-575 nm wavelengths light is highest.

Pappas and Eaton (1977) found that the ocelli of the Tobacco Hornworm (*Manduca sexta* L.) are more sensitive to 520 nm light, than to 360 nm light stimuli.

Similar results are reported by Eguchi et al. (1982) about the Sphingid moths. These moths possess the highest peak sensitivity at 540 nm.

Gui et al. (1942) reported that the colours on which comparable data are available arrange themselves in order from least to most attractive to insects, as follows: red, yellow, white and blue.

From tests of Taylor and Deay (1950) it appears that the maximum attractiveness for the European corn borer (*Ostrinia nubilalis* Hbn.) is in the near ultraviolet region between 320 and 380 nm.

Frost (1954) had a comparative experiment. He found that for all taxa of insects the black light was more attractive than the white light. The only exceptions were the Miridae and Chrysopidae families, which preferred white light.

Cleve (1954) found a strikingly successful ultraviolet fluorescent lamp to collect the insects, if it illuminated a white sheet.

Belton and Kempster (1963) caught more noctuid moths (Noctuidae) and geometrid ones (Geometridae) with the black light (BL) fluorescent tube than with the cold light (CW).

Jászainé (1964) analyzed the catching results of Common Meadow Bug (*Exolygus pratensis* Wagner) (Heteroptera: Miridae) in normal and BL light traps. The standard light traps caught more individuals.

In the comparative studies of Mészáros (1966), each of the Microlepidoptera species were more effectively collected by the BL traps than by normal light ones.

In the test of Day and Reid (1969) the 15 W fluorescent BL lamps were more attractive for the *Conoderus falli* Lane (Coleoptera: Elateridae) than similar yellow ones.

According to the experiment of Komlódi (1970) the standard light trap caught only a few specimens of the Eurasian Hemp Moths (*Grapholita delineana* Walker), a lamp operating with HgLS light source, however, caught numerous of these moths. Wingspan of the Eurasian Hemp Moths is 10-14 mm.

Sifter (1971) examined the swarming of the Chestnut Weevil (*Curculio elephas* Gyllenhal, Coleoptera: Curculionidae) by normal and BL traps. The body length of this beetle is only 6-9 mm. The normal light trap has not caught a single specimen, but the BL one was suitable for investigation of swarming.

Mikkola (1972) verified the results of his laboratory measurements with the help of light trap monitoring. He caught the highest number of insects with lamps emitting both black light and visible light. The catch dwindled when he used BL alone and visible light produced even poorer result.

Striking contradiction was found between light sensitivity and the attracting effect of different types of light, regarding six insect groups (Coleoptera, Trichoptera, Lepidoptera, Brachycera, and Nematocera Ichneumonoidea). The eyes of these insects were more sensitive to yellow light than to BL, but the attracting effect was the opposite.

Blomberg et al. (1976) compared two types of light trap catch results. One of them was the so-called blended light trap that contained a 160 W Tungsram mercury fluorescent lamp and the other one was BL that was provided with a 125 W Philips HPW lamp. The mercury fluorescent lamp caught approximately twice as many moths of the Macrolepidoptera families (Geometridae and Noctuidae) and Microlepidoptera species than the BL trap.

According to laboratory tests of Teel et al. (1976) the maximum sensitivity of the eye of Hickory Shuckworm (*Laspeyresia caryana* Fitch) is at 365 nm and 515 nm. At these two values, there were six times as many individuals responding to the near-ultraviolet light than ones responding to the green one.

According to Gál et al. (1976), Bürgés and Gál (1981) and Bürgés (1997) for the light trapping of the Chestnut Weevil (*Curculio elephas* Gyllenhal) and the Acorn Moth (*Cydia splendana* Hbn.) the most effective tool is the mercury vapour lamp (HgW).

Some observers report that there are species showing a greater attraction to regular light: some fruit flies (Theowald, 1963), virus vector cicadae (*Laodelphax striatella* (Fallén)) and *Javesella pellucida* (Fabricius) (Homoptera, Areopidae) (Jászainé, 1969); European Grapevine Moth (*Lobesia botrana* Den. et Schiff.) and Vine Moth (*Eupoecilia ambiguella* Hbn.) (Voigt and Vojnits, 1970).

Extremely valuable conclusions come from a series of experiments by Járfás et al. (1975) and Járfás and Tóth (1977) in which comparisons were made among the catch results yielded by 125W (HgVE 27) ultraviolet, 125W (HgLSE27) mercury vapour, 100 W (OHP 220-230 VAO) crypton, 100W (F_3) 50cm neon, 250W (E 27 9043 IMP) infra ruby and 50cm germicidal lamps. Silver Y moths (*Autographa gamma* L.), Pine Chafers (*Polyphylla fullo* L.), Vine Chafers (*Anomala vitis* Fabr.) and Scarab Beetles (*Anoxia orientalis* Kryniczky) flew to the mercury vapour lamps in the highest numbers, while infra ruby light proved to be practically unsuitable for trapping. Járfás (1975, 1977) published the results of his experiments, in which he examined the efficiency of light traps with respect to different moth species with the application of different light-sources. The most suitable traps for catching were the following, in descending order: mercury lamp (HgW), BL and normal light, in the case of the following species: Silver Y (*Autographa gamma* L.) (Járfás et al., 1975), the Codling Moth (*Cydia pomonella* L.) (Járfás et al. 1977), the Pea Podborer (*Etiella zinckenella* Tr.) (Járfás and Viola, 1984) and the Beet Webworm (*Loxostege sticticalis* L.) (Járfás and Viola, 1991). Járfás (1977) reports that the Apple Peel Tortrix (*Adoxophyes reticulana* Hbn.), the Pear Moth (*Laspeyresia pyrivora* Pan.) and the Plum Fruit Moth (*Grapholita funebrana* Tr) can be caught effectively with the mercury vapour lamp (HgW), the Strawberry Tortricid (*Pandemis dumetana* Tr.) and the Dark Fruit-tree Tortrix (*Pandemis heparana* Den. et Schiff.) are more attracted to a normal light bulb. The European Corn Borer (*Ostrinia* *nubilalis* Hbn.) was collected by the HgW traps more successfully than by the normal and the BL traps (Járfás, 1978).

Skuhravý et al. (1993) found a BL trap much more effective than either yellow, green or red lights in collecting the Saddle Gall Midge (*Haplodiplosis marginata* von Roser) (Diptera: Cecidomydae).

In our earlier study (Nowinszky and Puskás, 1994), we compared the composition of species of five Macrolepidoptera families based on the normal and BL trap data collected at two light trap stations, by the Sorensen index. The results are as follows: Geometridae: 0.607 and 0.518; Sphingidae: 0.750 and 0.500; Notodontidae: 0.444 and 0.429; Arctiidae: 0.714 and 0.609; Noctuidae: 0.608 and 0.527.

Wallner et al. (1995) carried out experiments of three lymantriid species in the Russian Far East. There were significantly more moths in the fluorescent black light lamp than either in the phosphor mercury or the high-pressure sodium lamps, in case of all three species: Gipsy Moth (*Lymantria dispar* L.), Nun Moth (*Lymantria monaca* L.) and the Pink Gipsy Moth (*Lymantria matura* Moore).

Nabli et al. (1999) studied the efficiency of catching agriculturally benficial insects by using different light sources. The Coccinellidae (Coleoptera) species preferred BL, the Ophion sp. (Hymenoptera: Ichneumonidae) had a preference for blue BL. *Chrysopa* spp. (Neuroptera: Chrysopidae) could be trapped equally well with white and BL, while every source of light had the same impact on some broad damsel bugs (Hemiptera: Nabidae) and Hemerobius spp. (Neuroptera: Hemerobiidae).

Bürgés et al. (2003) found the following characteristics of those families (Geometridae, Sphingidae, Notodontidae, Arctiidae and Noctuidae) that are rich in species: most of their species fly to both normal and BL traps, but the BL one catches significantly more species. The number of specimen caught was also less in the normal light trap.

Fayle et al. (2007) examined three Robinson type light traps equipped with 125W mercury bulbs. One of these contained materials which absorb the visible light, so this lamp was a BL type trap. Their results showed that the least moth was caught by the BL trap.

Barghini (2008) tested four lighting systems. Most insects were caught in the high-pressure mercury lamp (Hg). A further order was as follows: high-pressure sodium (Na) without a BL filter and the same type with BL filter.

In the last decade most researchers found connection between body size of the insects (larger eyes or wingspan) and their light sensitivity. Insects with larger eyes and wingspan tend to have higher light sensitivity than those with smaller eyes. Over the last decade, published studies supported the finding that the vision of insects with greater body weight is more sensitive to light than that of the smaller species. Such a statement was published concerning desert ants (Cataglyphis) (Zollikofer et al. 1995); pollen foraging bees (Apoidea) (Jander and Jander, 2002); the bumblebees (*Bombus terrestris* L.) (Spaethe and Chittka, 2003) and Kapustjanskij et al. 2007); the nymphalid butterflies (Nymphalidae) (Rutowski et al. 2009).

Moser et al. (2004) found a connection between the size of eyes of 10 Atta species (Hymenoptera: Formicidae) and the time of nuptial flight using digital photography. The diameter of compound eyes of the night flying species was significantly larger.

Yack et al. (2007) reported similar results concerning the *Macrosoma eliconiaria* Walker (Lepidoptera: Hedyloidea) species.

Experiments of Kino and Oshima (1978) suggest that moth and butterfly emanations could cause allergy-induced bronchial asthma in certain people. Since moths are readily attracted to artificial light and often fly into houses, these insects are especially suspected as important factors in extrinsic asthma.

Barghini and Medeiros (2010) assumed that in developing countries the growing light pollution will affect the spread of vector-borne human diseases.

Van Langevelde et al. (2011) established that moths are attracted to artificial light with smaller wavelength in higher species richness and abundance than to light with larger wavelength. This attraction was correlated with the body mass, wingspan and eye size of moths. The size dependent attraction of the artificial light sources cause distortions to the ecosystems.

In the above mentioned studies the catch coming from parallelly operated regular and black light (BL) traps offered a unique possibility to answer the following questions.

- Is there a significant difference in species and families between the catch yielded by the two types of traps?
- Which of the two types is more suitable for trapping what species?
- Are there any species that can be collected by either regular or BL traps alone?
- Does either of the two types indicate the presence of more species than the other?
- To what extent do the materials yielded by the two types of trap at the same observation site differ in their composition by species?

In the present study we examined how the wingspan of Macrolepidoptera species can influence the catch result of normal light traps and BL ones based on data from the Hungarian Light Trap Network.

Material

To compare the differences between the practical use of normal and BL traps the Hungarian Plant Protection Research Institute of Keszthely has been carrying out experiments since 1962 with parallel operation of two light trap types, one with a regular bulb and the other with BL. In 1962 the Plant Protection Service added a BL trap in Nagytétény to the ones running with regular light and in 1963 equipped all its county plant protection stations with BL traps. The national network of normal and BL traps operated in parallel opened up the possibility to a comprehensive analysis of the catch results.

The normal and BL traps operated in the following cities and villages:

Baj (47.38N, 18.21E)	Mikepércs (47.26N, 21.37E)
Csopak (45.58N, 17.55E)	Miskolc (48.5N, 20.46E)
Fácánkert (46.26N, 18.44E)	Nagytétény (47.38N, 18.97E)
Gyöngyös (47.46N, 19.55)	Pacsa (46.43N, 17.0E)
Győr-Kismegyer (47.39N, 17.39E)	Szederkény (45.59N, 18.27E)
Hódmezővásárhely (46.25N, 20.19E)	Tanakajd (47.11N, 16.44E)
Kaposvár (46.22N, 17.46)	Tarhos (46.48N, 21.12E)
Kállósemjén (47.51N, 21.55)	Tass (47.1N, 19.2E)
Kenderes (47.13N, 20.45E)	Velence (47.14N, 18.38E)
Keszthely (46.46N, 17.15E)	

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The most valuable information was provided by the light traps at Nagytétény where, according to the station register entries, regular and BL traps were placed at a mere 10 metres distance from one another. The proximity of the two traps meant homogeneity of microclimate, vegetation and the distances from the habitats of other species and so the insects were practically offered the choice of two different light sources.

The complete Macrolepidoptera material of the above listed light traps was processed in our work. We processed the data of 378 species of the data of the 18 light trap sites belonging to the National Network and the data of 222 species collected by the light traps of Nagytétény.

The data of the wingspan of the different Macrolepidoptera species we collected from the websites of “Moths of Hungary” József Szalkai Hungarian Lepidopterist Association (www.macrolepidoptera.hu) and UK moths (www.ukmoths.org.uk).

Methods

We summarized in each light trap site and each trap type the number of the Macrolepidoptera species and individuals caught from all generations, however, we did not separate the individuals within generations. Then, using the Mann-Whitney’s test we checked the significance of the homogeneity of the number of individuals captured by normal and BL traps, separately for all species and recorded significantly ($p<0.05$) higher normal trap or BL trap catches marked as N or BL, respectively, while insignificant differences were marked as E (*Table 1*). Particular attention was paid to the data of Nagytétény's normal and BL traps, since the two trap types were set close enough to represent homogeneous microclimate, vegetation and species habitat ranges so the moths were supposed to be able to choose directly between different light sources.

We arranged all the species collected both by the national light trap network (NW) and by the Nagytétény (NT) traps in ascending order according to the wingspan sizes of insects. We calculated the percentages of species caught significantly more effectively by the black light traps (BL) and normal ones (N) and the percentages of the species caught insignificantly differently by the two types of traps (E) where the percentages were taken over the sum of all catches, separately for the data of National Light Trap Network (NW) and Nagytétény (NT).

The differences between the BL and N dominated results together with insignificantly different results for the species observed both in NW and NT sites were tested familywise by Z-tests at the 0.05 level (Moore et al. 2006).

For NW and NT results, separately, we compared the proportions BL, N and E familywise by Marascuillo’s test at the 0.05 level (National Institute of Standards and Technololgy, 2010).

As a next step, we pooled the species of all families into one data set and ordered them by their average wingspan.

First, splitting the total range of the observed wingspan sizes into categories, we took the ratio BL over BL+N and compared these by Marascuillo’s test.

Then, using the ordered, pooled data set, the moving averages with a window size of 7 days were calculated for BL, N and E proportions of the observations of NW and NT.

To represent the wingspan dependency of the BL, N and E proportions, we defined a joint regression model containing models of three subranges of the following formula:

$$Y = \chi[X < s_1] * Y_1 + \chi[s_1 \le X < s_2] * Y_2 + \chi[X \ge s_2] * Y_3 + \varepsilon \qquad \text{(Eq.1)}$$

where Y_1 , Y_2 and Y_3 are functions of the general formulas:

$$Y_1 = p_{11} + p_{12} * (1 - \exp(- p_{13} * (32 - X))) \qquad \text{(Eq.2)}$$

$$Y_2 = p_{21} + (p_{22} - p_{21}) / (1 + \exp(- p_{23} * (X - p_{24}))) \qquad \text{(Eq.3)}$$

$$Y_3 = p_{31} + p_{32} * (1 - \exp(- p_{33} * (X - p_{34}))) \qquad \text{(Eq.4)}$$

In the formulas Y denotes the moving average of the percentages of BL, N and E with window size 7 while X is for the wingspan size (mm) and ε is a normally distributed error term with expected value of zero;

s_1 and s_2 are wingspan values (mm) that indicate the borders of the wingspan subranges;

$\chi[X < s_1]$, $\chi[s_1 \le X < s_2]$ $\chi[X \ge s_2]$ are characteristic functions which take 1 if the conditions given in brackets $[X < s_1]$, $[s_1 \le X < s_2]$ or $[X \ge s_2]$ hold and zero else;

p_{ij} are the parameters of the functions Y_i ($i = 1, 2, 3$, $j = 1, 2, 3, 4$).

Y_1 and Y_3 are saturation functions with the following properties:

- $Y_1(32) = p_{11}$; $Y_3(p_{34}) = p_{31}$;
- The decrease of Y_1 and Y_3 from their values p_{11} or p_{31} are p_{12} or p_{32} as $X \to +\infty$, respectively. Obviously, if $p_{12} > 0$ then Y_1 is decreasing, otherwise it is increasing and if $p_{32} > 0$ then Y_3 is decreasing, otherwise it is increasing.
- $p_{13} > 0$ and $p_{33} > 0$ are the a velocity factors of the exponential term of Y_1 and Y_3, respectively.

Y_2 is a logostic function with the following properties:

- p_{21} is the limit Y_2 approaches as $X \to -\infty$;
- p_{22} is the limit Y_2 approaches as $X \to +\infty$;
- $p_{23} > 0$ is a velocity factor of the exponential term of Y_2;
- p_{24} is the inflexion point of Y_2.

Normality of the error terms was tested by Shapiro-Wilk's test (p > 0.05). Parameter estimations were calculated together with their t-values and significance levels. The regression models were tested by their F-values and their significance levels. Finally, the explained variances (R^2) were evaluated.

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Results and discussion

Table 1 summarizes the average wingspan data (mm) of all the 378 trapped species sorted into families and presents the numbers of species that were collected significantly more effectively by the normal (N) or black light (BL) traps of the Hungarian Light Trap Network (Network) and, separately, of Nagytétény. The significant differences are based on Mann-Whitney's test at the $p < 0.05$ level.

Comparing the normal light trap dominated proportions of Macrolepidoptera species of the National Light Trap Network sites and Nagytétény (*Table 2*) by Z-tests, we detected no significant differences ($p > 0.05$). The BL dominated results of *Geometridae*, *Arctiidae* and *Noctuidae* catches, however, were significantly higher in Nagytétény ($p < 0.001$) where the potential chance for the species to choose between the two types of trap was higher.

Table 1. *Numbers and average wingspan (mm) of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps of the Hungarian Light Trap Network (Network) and, separately, of Nagytétény. The significant differences are based on Mann-Whitney's test at the p < 0.05 level*

Family name	Average wingspan (mm)	Network				Nagytétény		
		No. of different species caught	No. of trap pairs	No. of different species caught significantly more by		No. of different species caught	No. of different species caught significantly more by	
				N	BL		N	BL
Nolidae	19.0	2	12	0	0	0	0	0
Syntominae	23.0	1	12	0	0	0	0	0
Geometridae	26.1	104	1122	17	7	58	13	38
Drepanidae	28.2	5	45	0	0	1	0	0
Thaumetopoidae	30.0	1	8	0	1	1	0	1
Noctuidae	34.4	194	2248	4	85	126	7	105
Arctiidae	34.5	22	267	0	6	15	1	12
Thyatiridae	37.3	3	16	0	1	0	0	0
Lymantriidae	38.8	7	65	0	2	3	0	2
Notodontidae	39.7	19	203	2	8	10	2	8
Lasiocampidae	42.2	8	85	0	3	2	0	1
Sphingidae	73.3	11	153	0	9	6	1	4
Saturniidae	82.5	2	12	0	2	0	0	0

Moreover, comparing those proportions of species the catches of which were significantly higher neither for the normal nor the BL light trap type (E) in Nagytétény or in other sites of the National Light Trap Network, we found that in Nagytétény these numbers were significantly lower ($p < 0.001$) for *Geometridae*, *Arctiidae* and *Noctuidae* families. These significant differences indicate that in case the species of *Geometridae*, *Arctiidae* and *Noctuidae* families can choose between the two light trap types, they prefer the BL type traps, while, in case the potential possibility of choice is low, then the trapping success of the two types of light traps is homogeneous.

Table 2. *Numbers of Macrolepidoptera species observed both in Network sites (NW) and Nagytétény (NT) with the numbers of species collected significantly more effectively by normal (N) or black light (BL) traps, or, insignificantly differently by the two types of traps (E) of the Hungarian Light Trap Network (NW) and, separately, Nagytétény (NT). The significant differences in boldface are based on Z-tests at the p < 0.05 level*

Family name	***Number of species observed both in NW and NT***	***Numbers of species collected insignificantly differently by BL and N***		***Numbers of species collected significantly more effectively by***			
		E		***BL***		***N***	
		NW	***NT***	***NW***	***NT***	***NW***	***NT***
Lasiocampidae	2	1	1	1	1	0	0
Drepanidae	1	1	1	0	0	0	0
Geometridae	58	**44 *****	**7**	**2**	**38 *****	17	13
Sphingidae	6	0	1	6	5	0	0
Notodontidae	10	**3 +**	**0**	5	8	2	2
Thaumetopoidae	1	1	0	0	1	0	0
Lymantriidae	3	1	1	2	2	0	0
Arctiidae	15	**10 *****	**2**	**5**	**12 *****	0	1
Noctuidae	126	**57 *****	**14**	**47**	**105 *****	**2**	**7 +**

+significant at the $p < 0.1$ level; *** significant at the $p < 0.001$ level; proportions are compared by Z-test

Table 3. *Numbers of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps, or, insignificantly differently by the two types of traps (E) of the Hungarian Light Trap Network (NW). The three proportions are compared, different letters are for significantly different proportions based on Marascuillo's test at the p < 0.05 level*

Family	***Average wingspan (mm)***	***Numbers of species collected insignificantly differently by BL and N***	***Numbers of species collected significantly more effectively by***	
		E	***BL***	***N***
Nolidae	19.0	**2 b**	0 a	0 a
Syntominae	23.0	**1 b**	0 a	0 a
Geometridae	26.1	**80 b**	7 a	17 a
Drepanidae	28.2	**5 b**	0 a	0 a
Thaumetopoidae	30.0	0 a	**1 b**	**1 *ab***
Noctuidae	34.4	**105 b**	**85 b**	4 a
Arctiidae	34.5	**16 b**	6 a	0 a
Thyatiridae	37.3	2 a	1 a	0 a
Lymantriidae	38.8	**5 b**	**2 *ab***	0 a
Notodontidae	39.7	9 a	8 a	2 a
Lasiocampidae	42.2	**5 b**	**3 *ab***	0 a
Sphingidae	73.3	2 a	**9 b**	0 a
Saturnidae	82.5	0 a	**2 b**	0 a

When we compared the proportions of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps, or, insignificantly differently by the two types of traps (E) of the Hungarian Light Trap Network (NW) by Marascuillo's test (*Table 3*), we saw that for families of smaller wingspan sizes (*Nolidae*, *Syntominae*, *Geometridae*, *Drepanidae*), the trapping success is typically rather homogeneous for the two trap types (E) while for families of greater wingspan sizes (*Lasiocampidae*, *Sphingidae, Saturnidae*), the BL trap types are significantly more preferred ($p < 0.05$).

Performing the same comparisons for the proportions recorded in Nagytétény (*Table 4*), we could state that independently from the wing size, the preference of the species is the BL type of trap. However, none of the families includes species that could be captivated by only one type of traps.

Table 4. *Numbers of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps, or, insignificantly differently by the two types of traps (E) in Nagytétény (NT). Different letters are for significantly different proportions based on Marascuillo's test at the p < 0.05 level*

Family	***Average wingspan (mm)***	***Numbers of species collected insignificantly differently by BL and N***	***Numbers of species collected significantly more effectively by***	
		E	***BL***	***N***
Geometridae	26.1	7 a	**38 b**	13 a
Drepanidae	28.2	**1 b**	0 a	0 a
Thaumetopoidae	30.0	0 a	**1 b**	0 a
Noctuidae	34.4	14 a	**105 b**	7 a
Arctiidae	34.5	2 a	**12 b**	1 a
Lymantriidae	38.8	1 a	2 a	0 a
Notodontidae	39.7	0 a	**8 b**	2 a
Lasiocampidae	42.2	**1 b**	**1 b**	0 a
Sphingidae	73.3	1 a	**4 b**	1 a

The results of the Marascuillo's tests for the BL/(BL+N) ratios calculated from the results of the Hungarian Light Trap Network for wingspan range categories (*Table 5*) show that above a wingspan of about 30 mm the preference of BL traps becomes obvious.

Table 5. *Numbers of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps of the Hungarian Light Trap Network (NW) with the BL ratio over (BL+N). The multiple ratios were compared, different letters indicate significantly different ratios based on Marascuillo's test at the p < 0.05 level*

Wingspan range (mm)	***Average wingspan (mm)***	***Numbers of species collected significantly more effectively by***		***BL/(BL+N) ratio***
		BL	***N***	
11 – 23	19.48	4	10	0.29 a
24 – 28	26.07	9	7	0.56 ab
29 – 31	30.17	11	3	0.79 ab
32 – 34	32.85	22	1	0.96 b
35 – 36	35.39	11	1	0.92 b
37 – 40	38.15	22	0	1.00 b
41 – 45	42.57	15	1	0.94 b
46 – 48	47.00	9	0	1.00 b
49 – 57	51.46	10	0	1.00 b
58 – 115	84.18	10	0	1.00 b

Performing the same comparisons for the BL/(BL+N) ratios recorded in Nagytétény (*Table 6*) we can conclude that the preference of BL type traps is independent from the wingspan size.

Considering the above results together with this, we can state that normal type light traps can be *at most* as successful as BL type traps, independently from the wingspan size. Over the wingspan of about 35 mm the BL/(BL+N) ratio is nearly 100 percent in all sites except for in Nagytétény, where the normal and the BL traps were close enough for moths to be able to choose between them, the BL/(BL+N) ratios of the species with even the smallest wingspan were over 75%.

Table 6. *Numbers of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps in Nagytétény (NT) with the BL ratio over (BL+N). The multiple ratios were compared, no significantl differences were detected by Marascuillo's test at the p < 0.05 level*

Wingspan range (mm)	***Average wingspan (mm)***	***Numbers of species collected significantly more effectively by***		***BL/(BL+N) ratio***
		BL	***N***	
11 – 23	19.48	24	8	0.75
24 – 28	26.07	21	6	0.78
29 – 29	29.00	7	1	0.88
30 – 35	32.51	50	2	0.96
36 – 40	37.74	31	2	0.94
41 – 44	42.07	15	2	0.88
45 – 48	46.29	5	1	0.83
49 – 57	51.46	5	1	0.83

The results of the regression joint model optimized for the BL, N and E proportions are summarized in *Table 7* for the Hungarian light Trap Network data and in *Table 8* for the data recorded in Nagytétény (see Eq.1 to Eq.4). The observed total wingspan range was split into three subranges cutted by $s_1 = 32$ and $s_2 = 36$ (*Figure 1*, black vertical lines or $s_2 = 39$ (*Figure 1*, blue vertical line) in case of the Hungarian Light Trap Network data and by $s_1 = 33$ and $s_2 = 40$ (*Figure 2*, black vertical lines) in case of the data recorded in Nagytétény.

Subrange 1

In the wingspan subrange below 32 mm (Network) or 33 mm (Nagytétény) the N and E proportions can be modelled by decreasing exponential (i.e. saturation) functions (Eq.2). The BL proportions can be modelled by increasing exponential (i.e. saturation) functions (Eq.2). In case of N proportions the functions of the Network and Nagytétény observations are very similar. In case of BL proportions, however, the values of Network model are much lower than the ones of Nagytétény while in case of E proportions the relation is reverse: the values of Network model are much higher than the ones of Nagytétény. Moreover, some species of wingspan size below 25 mm were trapped more effectively by normal light trap, compared to BL.

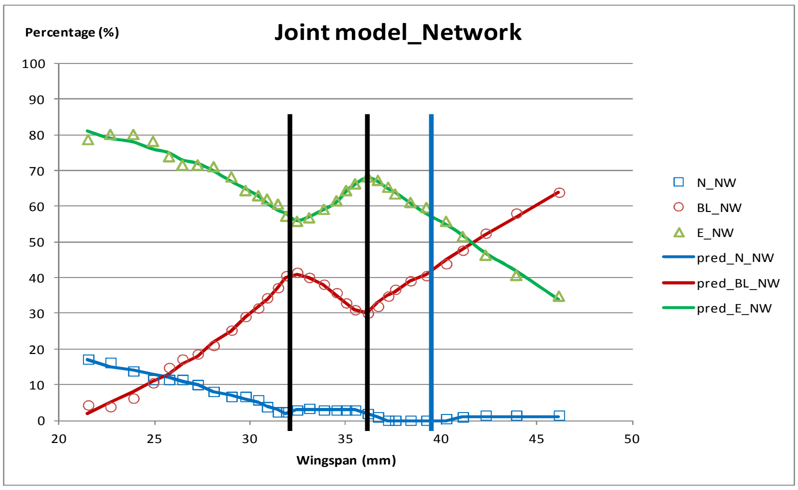

Figure 1. *Proportions of the numbers of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps or, insignificantly differently by the two types of traps (E) of the Hungarian Light Trap Network (NW) and their joint models containing the models of three subranges. The vertical lines represent the borders of the wingspan subranges (see also Table 7)*

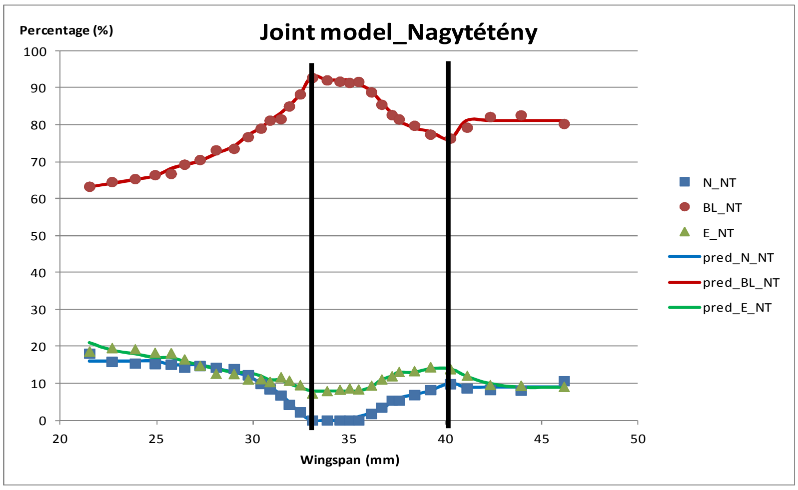

Figure 2. *Proportions of the numbers of Macrolepidoptera species collected significantly more effectively by normal (N) or black light (BL) traps or, insignificantly differently by the two types of traps (E) in Nagytétény (NT) and their joint models containing the models of three subranges. The vertical lines represent the borders of the wingspan subranges (see also Table 8)*

Subrange 2

The catch results of species of wingspan in Subrange 2 refer to a different trend of attraction of the moths and this surprisingly modified trend were detected both for the data of Network and Nagytétény.

In the wingspan subrange above 32 mm (Network) or 33 mm (Nagytétény) and below 36 mm (Network) or 40 mm (Nagytétény) the E proportions can be modelled by increasing, the BL proportions by decreasing logistic functions (Eq.3). The values of E proportions are much higher in case of Network data while the BL proportions are higher in Nagytétény.

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In the wingspan subrange above 32 mm (Network) or 33 mm (Nagytétény) and below 39 mm (Network) or 40 mm (Nagytétény) the N proportions can be modelled by logistic functions (Eq.3) differently for the data of Network and Nagytétény. The first is decreasing while the second one is increasing; nevertheless, the values of both functions are very small.

Table 7. *Results of the regression joint model optimized for the BL, N and E proportions of the Hungarian Light Trap Network: parameter estimations with their t-values and significance levels, the F-values of the models and their significance levels as well as the explained variances (R^2) with their significance levels*

	Subrange 1 $\chi[X<32]$,			**Subrange 2** $\chi[32\le X<36]$			**Subrange 3** $\chi[X\ge 36]$			**Joint Model**	
	Estimated parameters		***t***	**Estimated parameters**		***t***	**Estimated parameters**		***t***	***F***	R^2
E	p_{11}	0.57	62.78 ***	p_{21}	0.56	23.82 ***	p_{31}	0.66	93.33 ***	8023.60 ***	0.99 ***
	p_{12}	0.32	7.57 ***	p_{22}	0.70	13.31 ***	p_{32}	-6.32	0.21 n.s.		
	p_{13}	0.13	3.76 ***	p_{23}	1.28	2.38 ***	p_{33}	0.01	0.20 n.s.		
				p_{24}	34.82	65.08 ***	p_{34}	37.00	fixed		
	Subrange 1 $\chi[X<32]$,			**Subrange 2** $\chi[32\le X<39]$			**Subrange 3** $\chi[X\ge 39]$			**Joint Model**	
	Estimated parameters		***t***	**Estimated parameters**		***t***	**Estimated parameters**		***t***	***F***	R^2
N	p_{11}	0.02	5.12 ***	p_{21}	0.03	10.81 ***	p_{31}	-0.36	0.00 n.s.	376.17 ***	0.99 ***
	p_{12}	0.41	1.98 +	p_{22}	0.00	fixed	p_{32}	0.05	4.22 ***		
	p_{13}	0.04	1.59 n.s.	p_{23}	3.22	9.75 ***	p_{33}	7.03	5.27 ***		
				p_{24}	36.40	146.56 ***	p_{34}	40.00	fixed		
	Subrange 1 $\chi[X<32]$,			**Subrange 2** $\chi[32\le X<36]$			**Subrange 3** $\chi[X\ge 36]$			**Joint Model**	
	Estimated parameters		***t***	**Estimated parameters**		***t***	**Estimated parameters**		***t***	***F***	R^2
BL	p_{11}	0.40	57.10 ***	p_{21}	0.41	28.10 ***	p_{31}	0.34	59.72 ***	3749.06 ***	0.997 ***
	p_{12}	-0.60	9.34 ***	p_{22}	0.29	12.01 ***	p_{32}	7.77	0.19 n.s.		
	p_{13}	0.10	5.62 ***	p_{23}	1.54	1.97 +	p_{33}	0.004	0.19 n.s.		
				p_{24}	34.61	117.93 ***	p_{34}	37.00	fixed		

+ significant at the p < 0. 1 level; * significant at the p < 0.05 level
** significant at the p < 0.01 level; *** significant at the p < 0.001 level

Table 8. *Results of the regression joint model optimized for the BL, N and E proportions recorded in Nagytétény: parameter estimations with their t-values and significance levels, the F-values of the models and their significance levels as well as the explained variances (R^2) with their significance levels*

	Subrange 1 $\chi[X<33]$,			Subrange 2 $\chi[33\leq X<40]$			Subrange 3 $\chi[X\geq 40]$			Joint Model	
	Estimated parameters		***t***	**Estimated parameters**		***t***	**Estimated parameters**		***t***	***F***	R^2
E	p_{11}	0.10	20.94 ***	p_{21}	0.08	13.89 ***	p_{31}	0.15	11.41 ***	600.24 ***	0.99 ***
	p_{12}	0.44	0.63 n.s.	p_{22}	0.14	16.31 ***	p_{32}	-0.06	4.67 ***		
	p_{13}	0.03	0.55 n.s.	p_{23}	-1.79	1.97 +	p_{33}	0.64	1.65 n.s.		
				p_{24}	36.68	118.00	p_{34}	40.00	fixed		
	Subrange 1 $\chi[X<33]$,			**Subrange 2** $\chi[33\leq X<40]$			**Subrange 3** $\chi[X\geq 40]$			**Joint Model**	
	Estimated parameters		***t***	**Estimated parameters**		***t***	**Estimated parameters**		***t***	***F***	R^2
N	p_{11}	0.04	8.42 ***	p_{21}	-0.002	0.75 n.s.	p_{31}	0.14	fixed	393.29 ***	0.98 ***
	p_{12}	0.12	18.29 ***	p_{22}	0.07	9.21 ***	p_{32}	-0.02	3.56 ***		
	p_{13}	0.42	7.54 ***	p_{23}	1.62	4.22 ***	p_{33}	0.55	1.62 n.s.		
				p_{24}	38.85	208.55 ***	p_{34}	40.00	fixed		
	Subrange 1 $\chi[X<33]$,			**Subrange 2** $\chi[33\leq X<40]$			**Subrange 3** $\chi[X\geq 40]$			**Joint Model**	
	Estimated parameters		***t***	**Estimated parameters**		***t***	**Estimated parameters**		***t***	***F***	R^2
BL	p_{11}	0.86	13.61***	p_{21}	0.93	36.52 ***	p_{31}	0.74	22.86 ***	21435.19 ***	0.99 ***
	p_{12}	-0.25	24.61 ***	p_{22}	0.77	70.24 ***	p_{32}	0.81	125.61 ***		
	p_{13}	0.207	12.83 ***	p_{23}	1.50	4.40 ***	p_{33}	12.108	2523.38 ***		
				p_{24}	36.81	230.85 ***	p_{34}	40.00	fixed		

+ significant at the p < 0.1 level; * significant at the p < 0.05 level
** significant at the p < 0.01 level; *** significant at the p < 0.001 level

Subrange 3

In the wingspan subrange above 36 mm (Network) or 40 mm (Nagytétény) the E proportions can be modelled by decreasing, the BL proportions by increasing exponential (i.e. saturation) functions (Eq.4). The values of E proportions are much higher in case of Network data while the BL proportions are higher in Nagytétény.

In the wingspan subrange above 39 mm (Network) or 40 mm (Nagytétény) the N proportions can be modelled by exponential (i.e. saturation) functions (Eq.4) differently for the data of Network and Nagytétény. The first is increasing while the second one is decreasing; nevertheless, the values of both functions are very small.

These characteristics of the models correspond to the results of the comparisons of proportions (Z-tests and Marascuillo's tests) and can be reasoned by the fact that in Nagytétény the preference of the species can be more effectively observed and it is definitely BL, especially for the species of wingspan sizes above 39-40 mm.

When the normal and BL type traps were very close to each other, the BL traps were chosen by even the moths of small wingspans en masse. However, occasionally, such choices are suspected to be random and the proof of the preferences desires more observations.

We stress that the fact that the preference of the species of large wingspans is unambiguously BL does not mean that these species cannot be collected with a normal light trap successfully. We only state that the preference of BL type traps is significant and thus the Wolfram light bulb of 100 W is less effective.

When choosing a suitable light trap type for a special aim, the harmful effects of light traps should also be considered. Kollings (2000) has established that there is a definite difference in the composition of the catch from two neighbouring street lamps of different types. Our results coincide with the observations of Kolling as we also confirmed that the different light sources can damage different species and to different degrees. In an experiment by Eisenbei and Hassel (2000), the use of natrium vapour street lamps reduced the number of insects caught by 50%, including a 75% reduction in the number of moths. According to Frank (2006), if some moth species are more attracted to light than others, the traits related to this attraction could help us to predict effects of artificial light on communities of nocturnal species. Since the artificial light sources of different wavelengths attract different species to different degrees, thus this effect on the community can distract the balance of a local ecosystem.

Our results can be applied in plant protection and entomological research projects when the aim is to find the most effective type of light traps for special purposes and different targeted species. Before a responsible decision, the type and rate of damage risk, the targeted species with their wingspan sizes and also environmental aspects should be deliberately considered.

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Acta Phytopathologica et Entomologica Hungarica 37 (1–3), pp. 251–256 (2002)

Examination of Female Proportion of Light Trapped Turnip Moth (*Scotia segetum* Schiff.)

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The change of the number of turnip moth (*Scotia segetum* Schiff.) females was examined at 65 different light trap stations between 1957 and 1990. There are two generations of the examined species in Hungary, but the individual number of the first generation is low year by year, so we processed only the data of the second generation.

Only those generations were examined that had more than 100 samples because of the statistical reliability. Thirty-three light trap stations were suitable for this examination. The joint number of yearly caught male and female individuals and also separately the samples of females were summarised for each observing station. The change of female individual number as a function of total individual number was determined from the coherent pairs of value. The connection can be described by linear function. The proportion of females is 38%. The relative frequency of females was also determined in the function of the individual number. The shown point-mass is similar to the damped vibration known at technical systems. It was established that the female proportion was higher than the average if the individual number is low, but it showed average value when the individual number was high. It can also be established that the female proportion is significantly high in some cases before gradation years.

Keywords: turnip moth, *Scotia segetum* Schiff., female proportion, light-trap.

Light-trap is the most widely used sampling device to collect nocturnal insects. The operation is based on the behaviour of insects that they fly to – natural or artificial - light. There is a light trap network in Hungary, having been operated for more than 40 years, collecting material mainly for the purpose of making plant protection prognosis. Specialists determine the number of caught adults and specify the number of males and females of most important insect pests. The degree of probable damage can be estimated from the number of caught adults. In order to increase reliability of the prognosis, it is very important to determine general regularities from the data collected during 40 years.

It is well known since decades that the males and females of different insect species are caught by light trap in different rates. Williams (1939) examined the sex distribution of caught adults for each species. From the 51 species of Noctuidae family, the females of two species were not flying to the light at all. Females of 27 families gave 1–20% of the total number of specimen, in case of 16 species this rate was 20–46%. In case of 3 species the number of males and females was the same, and there were only 3 species where more females were flying to the light than males. Nanu and König (1968) were examining the rate of males and females flying to the light in case of 13 Lepidoptera families. In some families 0.2–30% of females were caught by the trap. Usseglio-Polatera (1987) examined the proportion of males and females flying to the light in case of 23 Trichoptera species. The differences in sex ratio observed in light trap collections must be due to behavioural differences in the activity of sexes rather than by one sex being

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more attracted to the light than the other. Schurr (1971) trapped mainly male specimen of grape berry moth (*Eupoecilia ambiguella* Hbn.) with his white light (560–610 nm) trap. Járfás et al. (1974) examined the sex ratio of turnip moth (*Scotia segetum* Schiff.) by the help of using different light sources, too. The proportion of male specimen was fluctuating in-between 48–66% in case of all light sources. According to El-Abdullah et al. (1984) only 10% of adults caught by the light trap were males in case of the striped stem borer (*Chilo suppressalis* Walker). Sex proportion of tiger beetles, *Dicindela melancholica* F. and *Cicindela nilotica* Dej., varied at different trapping levels (Hanna, 1973).

Observations during several decades did not provide too much of benefit for the plant protection practice. Authors of most of studies were satisfied by stating the numbers of caught males and females and possibly their percentage proportion but they did not draw any conclusions. True, it would be a hopeless attempt to make use of data of a light trap working for short time. It is important that if sex proportion of population living in the environment changes towards females this could be shown by the light trap; growth of the rate of caught females can show the gradation. Accordingly the knowledge of regularity of changes in sex ratio can also be used for prognostic purposes in case of such species where males and females are flying to the light equally well.

Some researchers are giving statements considered generally valid. Novák (1974) publishes sexual index data relating to 96 light trapped moth species. He divided the examined species into 5 categories depending on the rate of caught females, and he considered his results – within limits – constant. According to Malicky (1974) the sex proportion of a species is constant (specific for that species) in case of using identical light sources at different observation sites during several years. The average proportion of females of dog's tooth moth (*Mamestra sausa* Schiff.) was 33% according to Szarukán (1975). There was only minimal difference between the first and second generations. Proportion of light-trapped females of the one-population European corn borer *(Ostrinia nubilalis)* was found 47.3% by Cordillot and Duelli in Switzerland (1989). According to these authors the sex ratio is a species-specific static value though there are yearly differences in the sex ratio. These are not statistical scattering data without biological value but valuable results connected with the change of population (Szeőke and Szarukán, 1982).

According to Mohainé and Herczig (1979) and Lesznyák et al. (1993) with increasing or decreasing of the insect quantity the percent rate of females is also increasing or decreasing. The latter authors established that the rate of females is influenced mainly by minimum values of temperature. According to results of some authors both males and females are attracted to light sources only in certain physiological condition. Terszkov and Kolomiec (1966) are informing that the females of satin moth (*Stilpnotia salicis* L.) can be trapped before egg-laying while the females of gypsy moth (*Lymanthria dispar* L.) after egg-laying. This last publication is interesting because there is no publication on light attraction in case of gypsy moth females of European and American populations – the females of known populations are unable to flight. Females of gypsy moth native in East-Asia – differently from those of European populations – are able to fly (Mészáros, verbal notification). The females of European corn borer (*Ostrinia nubilalis* Hbn.) could fly at any time to the light after the outbreak of the chrysalis (Showers et al., 1974). There are few publications in the literature on similar studies though these could provide important knowledge for the practice. Unfortunately we cannot expect significant new results in this field due to high volume of time and work required by these studies.

If the sex ratio of a species shows significantly changing values at different observation sites in different years, it is worth to examine the regularity of changes. Mainly the time changes are important from prognostic point of view because these could be in connection with the hypercyclical movement. Nowinsky and Kiss (1981) found countrywide increase of the rate of females of turnip moth (*Scotia segetum* Schiff.) before the gradations in years 1962 and 1968.

Material and Methods

Presumably the rate of females has an influence on the number of individuals in the following generation. We examined the change of the number of females of turnip moth (*Scotia segetum* Schiff.) caught at 65 different observation sites in-between 1957 and 1990. Turnip moth has two generations in Hungary but the number of individuals in the first generation is decreasing year by year so we did not take into consideration and only the data of second generation were processed.

From the remaining data collection, the data of generations with more than 99 individuals were handled separately at each observation site in each year according to the requirements of statistical reliability, nevertheless generations where the number of individuals was in-between 5 and 99 were also examined. The number of yearly-trapped males and females was summarised at each observation site. From the value pairs belonging together we determined the changes in the number of females in the function of the total number of individuals.

Results and Discussion

The connection can be expressed as a linear function in all cases, the correlation coefficients are significant on 95% confidence level. It can be ascertained that in generations with more than 99 individuals the rate of females is 0.38 *(Fig. 1)* from the total number of adults. The range of total individuals above 99 was divided into further categories: in-between 100 and 499 the rate of females was 0.46, in-between 500 and 999 it was 0.38 while in-between 100 and 999 it was 0.40.

At each observation site the proportion of female individuals and the correlated 95% confidence level intervals were calculated. These were represented in the function of the total number of individuals. Above 99 individuals the fluctuation and frequency is decreasing to the same extent as the total number of them is increasing and it keeps to the earlier calculated 0.38 value *(Fig. 2)*. This phenomenon is similar to the damped vibration known at technical systems. The distribution of proportions is asymmetric. The fluctuation of

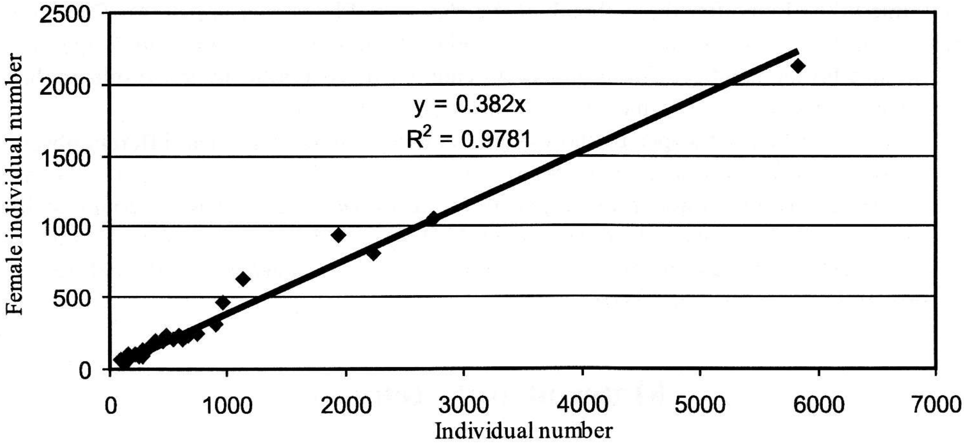

Fig. 1. Female individual number of turnip moth (*Scotia segetum* Schiff.), 2nd generation, for each observing station as a function of all individual number (33 observing stations, individual number > 99)

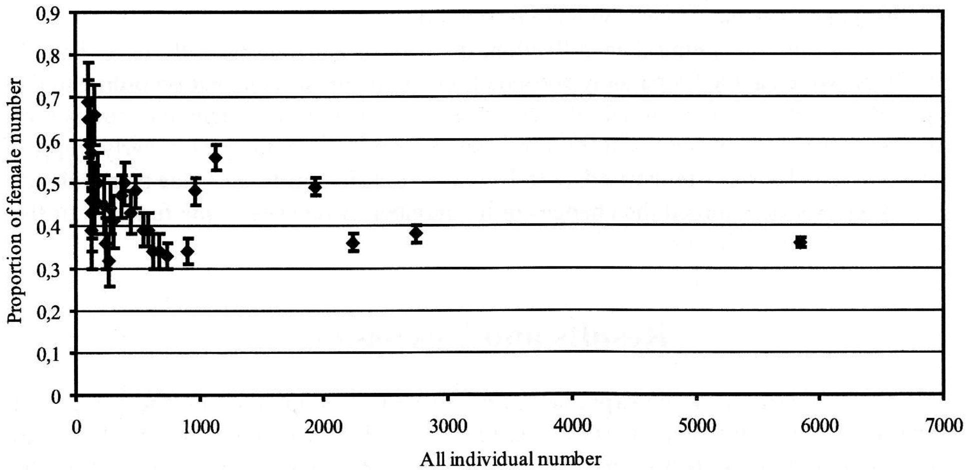

Fig. 2. Female individual number of turnip moth (*Scotia segetum* Schiff.), 2nd generation, for each observing station as a function of all individual number with 95% confidence intervals (33 observing stations, individual number > 99)

numbers of female individuals in case of 5–99 individuals in a generation is similar to the previous case, it keeps to the earlier calculated 0.44 value but the confidence intervals are bigger then the fluctuations. The distribution of proportions is asymmetric.

The average numbers of individuals were also calculated for each observation site. The changes of average numbers of female individuals were determined in the function of the average number of total individuals. The connection is linear here too, above 99 individuals in a generation the rate of females in comparison to the average number of total individuals: 0.40, in-between 5 and 99 is 0.47 *(Table 1)*.

Table 1

Proportions of females of turnip moth (*Scotia segetum* Schiff.) at all observing stations and years

	Proportion of females									
	For each observing station								Years	
	IN >99			1000 > IN > 99	500 > IN > 99	1000 > IN > 499	100 > IN ≥ 5		20 years	1962
	F/T	Av. F/T	F/M	F/T	F/T	F/T	F/T	Av. F/T	F/T	F/T
OS	33	33	33	28	21	7	59	59	33	19
B	0.38	0.40	0.61	0.40	0.46	0.38	0.44	0.47	0.42	0.38
R^2	0.9781	0.9568	0.9431	0.9662	0.9779	0.9741	0.9331	0.9372	0.999	0.9767

Notes: IN = Individual numbers, F = Female numbers, T = Total numbers, Av. = average, M = Male numbers, OS = Observing stations, B = female proportion, R^2 = square of correlation coefficients.

The connection and changes of number of female individuals was determined at each observation site also in the function of total number of male individuals. The connection is linear, above 99 individuals in a generation the female – male proportion is 0.61 *(Fig. 3)*. The distribution is the same way asymmetric as the proportion of female individual numbers.

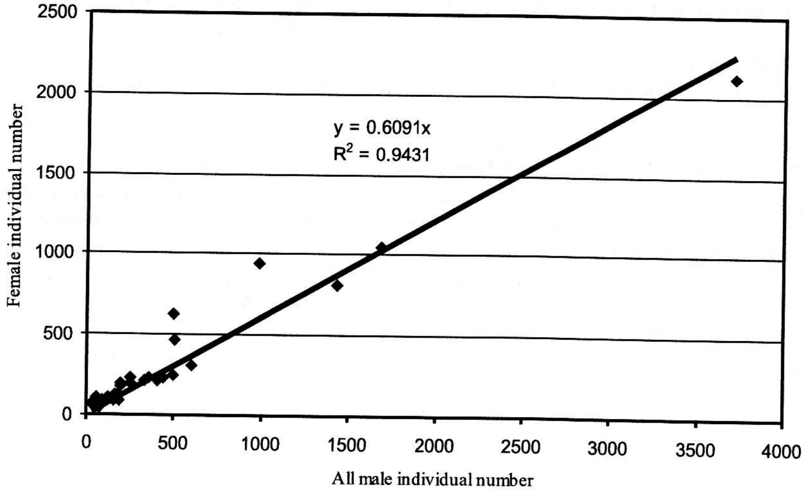

Fig. 3. Female individual number of turnip moth (*Scotia segetum* Schiff.), 2nd generation, for each observing station as a function of all male individual number (33 observing stations, individual number > 99)

According to observations the rate of females many time was extremely high in years preceding the gradations.

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DOI: 10.1515/aslh-2015-0008 Acta Silv. Lign. Hung., Vol. 11, Nr. 2 (2015) 99–110

Sex Ratio Analysis of Some Macrolepidoptera Species Collected by Hungarian Forestry Light Traps

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Abstract – We analysed the sex ratio of 32 macrolepidopteran species caught by Hungarian forestry light traps**.** That the ratio of males and females collected by light trap varies by species has been known for decades; however, the sex ratio found in the natural population is not known. All 32 species were processed separately, but by the same method. Both males and females were counted throughout the whole swarming. We calculated these figures and inspected the difference in the level of significance with the χ^2 test. For each swarming we calculated the percentage of males and females. We also calculated the values of the variation coefficients, which express the deviations in average percentages.

Males make up the majority of the moths captured in the trap; this result was mirrored by 29 of the 32 species investigated. One of the exceptions was the *Pelosia muscerda* Hfn. where we observed a male to female ratio that was equal. In addition to that *Watsoniana cultraria* Fabr. is the only one species captured by light traps that showed a significant female majority.

Our results confirm that the majority of moths captured in traps are males. However, the proportion of males and females of each species, and even within the same species, tended to differ greatly with each swarming. Yet, it must be noted that these results speak only for those specimens captured by light traps and cannot be related directly to the actual sex ratio of populations living in the natural environment.

Macrolepidoptera / sex ratio / forestry light-trap / Hungary

Kivonat – A magyar erdészeti fénycsapdák által gyűjtött néhány macrolepidoptera faj ivar-arányának elemzése. Évtizedek óta ismert, hogy fénycsapdával gyűjtött hímek és nőstények aránya fajonként változik. Nem ismert azonban, hogy milyen a nemek aránya a természetes populációban. 32 fénycsapdával gyűjtött Macrolepidoptera faj hím és nőstény arányát elemeztük**.** Minden fajt külön-külön dolgoztunk fel, de azonos módszerrel. Mind a hímeket, mind nőstényeket megszámoltuk egész rajzás során. Ezeket összeadtuk és az eltérések szignifikancia szintjét χ^2 próbával ellenőriztük. Kiszámítottuk a variációs koefficiens értékeket is, amelyek az eltéréseket az átlag százalékában fejezi ki.

Megállapítottuk, hogy a vizsgált 32 fajból 29 rajzásban magasabb volt a befogott hímek száma, mint a nőstényeké. Kivétel volt a hamvas zuzmószövő (*Pelosia muscerda* Hfn.), amelynél a hím és nőstény arány egyenlő és egyetlen faj bükkfa sarlósszövő (*Watsoniana cultraria* Fabr.), amelynél a nőstények voltak többségben.

Eredményeink szerint a legtöbb faj esetében több a fénycsapdával befogott hím mint nőstény, azonban ez az arány az egyes fajoknál, de még ugyanazon faj, más és más rajzásában is nagyon különböző. Ezek az eredmények azonban nem vonatkoznak közvetlenül a természetben élő populációk valós hím-nőstény arányaira, hanem csak a fénycsapdás fogásokra.

Macrolepidoptera / hím nőstény arány / erdészeti fénycsapda / Magyarország

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1 INTRODUCTION

That the proportion of males and females captured by light trap varies by species has been known for decades; however the sex ratio within the natural population is unknown.

Within the various orders of insects, Williams (1939) studied the sex ratio by species of the specimens caught. Of the 51 species of the Noctuidae family, the females of 2 species were not attracted to light at all. The females of 27 species represented 1–20% of the total number of specimens: this ratio was 20–46% with 16 species: the number of males and females was identical in the case of 3 species and there were only 3 species where more females than males were attracted to light. There is also a behavioural dimorphism: in 2 samples of 37 individuals of ghost moth **(***Hepialus humuli* L.) only 22% males flew to light traps even though sweep net samples gave an approximately 50:50 sex-ratio (Williams 1939). According to Mallet (1984), in the case of *Hepialus humuli* L. more females than males are attracted to light, which suggests that the females are the more mobile gender.

Nanu – König (1968) examined 13 Lepidoptera families to establish the ratio of males and females attracted by light. The females of the various families represented 0.2–30% of the catch. Schurr (1971) captured mostly male specimens of the vine moth (*Eupoecilia ambiguella* Hbn.) with his trap running on white light (of 510–610 nm). Járfás et al. (1974) used different sources of light to study the sex ratio of the turnip moth (*Agrotis segetum* Den. et Schiff.). Whatever the light source, the proportion of males was between 48–66%. Czencz (1973) holds that the males of the diamondback moth (*Plutella xylostella* L.) are more drawn to light than the females (75–25%). She does not provide any explanation for this, however.

Bürgés – Gál (1980), with a 125W mercury light trap, found that with the nut fruit tortrix (*Cydia splendana* Hbn.), males appear 3–4 days earlier than females. The male to female ratio is 1.9:1. This was almost the same as the male to female ratio of the European chestnut weevil (*Curculio elephas* Gyllenhal), which was 1.83:1.

Egyptian Bollworm (*Earias insulana* Boisduval) moths were collected by Yathom (1981) from mercury vapour light traps operating in Israel between 1974 and 1980. He concludes that the sex ratio generally favoured males.

El-Abdullah et al. (1984) report on a mere 10% of the trapped specimens of the Asiatic rice borer (*Cilo suppressalis* Walker) being males. Skuhravý et al. (1993) caught male specimens of the saddle gall midge (*Haplodiplosis marginata* von Roser) almost exclusively, both with a Minnesota-type and a UV light trap.

Itämies et al. (1986) employed a light trap to examine the flight pattern of grey mountain carpet (*Entephria caesiata* Den. et Schiff.) between 1978 and 1982 in the Finnish forest areas of Lapland. With the exception of 1978, males dominated the catch, although this dominance was not overwhelmingly high.

Some researchers have published statements of general validity. Novák (1974) has published sex index data relating to 96 species of moths trapped. Depending on the ratio of females, he arranged the species examined into five classes and, within certain limits, he regarded his results as constant. Malicky (1974) also believes that the sex ratio of a captured species is the same over many years through the use of the same source of light at different places of observation; in other words, sex ratio is value specific to a given species. Szarukán (1975) claims that the average proportion of female specimens of the dog's tooth (*Lacanobia suasa* Schiff.) is 33%. He found minimal difference between the first and second generations. A study in Egypt (Sadek 2001), found that 8.04% of the female mediterranean brocade (*Spodoptera littoralis* Fabr.) specimens that had been trapped had not been fertilized, while the ratios of those fertilized once or more than once were 37.25% and 54.76%. The sex ratio of the sulphur knapweed moth (*Agapeta zoegana* L.) was equal when examined at daytime, but at night the overwhelming majority of the specimens caught by light trap were male. The difference may be explained by the dissimilar reaction of the two sexes to light (Story et al. 2001). In Switzerland Cordillot – Duelli (1986) noticed that the ratio of females captured by light trap in one generation of European corn-borer (*Ostrinia nubilalis* Hb.) was 47.3%. The above mentioned authors regard sex ratio as a static value specific to a species, despite the fact that the annual differences in sex ratio are valuable results related to population changes and not statistical deviation data without a biological value (Szeőke – Szarukán 1982). According to Mohai – Herczig (1979) and also to Lesznyák et al. (1993), the proportion in percentage of females rises and falls in harmony with the rise and fall of the amount of insects caught in light traps. The latter of the abovementioned authors have found that the ratio of females is affected first of all by the minimum values of temperature. El-Deeb (1992) established that the number of European corn-borer (*Ostrinia nubilalis* Hbn.) females captured by light trap surpassed that of the males. However, the ratio was affected positively by maximum and minimum temperature, and negatively by relative vapour content.

Some authors have found that both males and females have to be in a certain physiological state to be attracted to sources of light. Terskov – Kolomiec (1966) report that females of the white satin moth (*Leucoma salicis* L.) can be trapped before egg laying, while those of the gypsy moth (*Lymantria dispar* L.) in Siberia are more prone to be trapped after egg-laying. This latter bit of information is of special interest because there are no data in literature about how gypsy moth females of the European and American populations fly to light considering that the females there are incapable of flight. In contrast to that females of the gypsy moth (*Lymantria dispar* L.) population in East Asia do fly (Wallner et al. 1995; Reineke – Zebitz 1998; Charlton et al. 1999). Females of the European corn-borer (*Ostrinia nubilalis* Hbn.), on the other hand, may fly to light any time following their emergence from the pupal state (Showers et al. 1974). Then again, Elliott – Dirks (1979) claim they are trappable in the largest numbers 3.2 – 4.4 days after mating.

Sathiyanandam – Baskaran (1999) observed that the ratio of females of the groundnut leaf miner (*Aproaerema modicella* Deventer) in India changed during different periods in the night. The ratio of mated to unmated females also changed. The number of males and females of some caddis fly (Trichoptera) species caught by light traps in New Zealand displayed a definite change in swarming. Males were the majority at the start of the swarming, while females made up the majority at the end (Ward et al. 1996). Dickler – Steuerwald (1997) found significant differences from one year to the next in the number of specimens as well as in the sex ratio of noctuids (Noctuidae) captured by light traps in apple orchards in Germany.

In the study of Myers et al. (1998) the sex ratio of gypsy moth (*Lymanrtia dispar* L.) pupae varied strikingly between low-density and high-density populations.

Altermatt et al. (2009) experimentally studied the flight to light behaviour of two moth species – the small ermine moth, *Yponomeuta cagnagella* (Hbn.), and the scorched carpet moth, *Ligdia adustata* (Den. et Schiff.). They found that male moths were significantly more (about 1.6 times more frequently) attracted to light than female moths. It was established that there is a sexual dimorphism in the flight to light behaviour of moths.

Garris – Snyder (2010) investigated and recorded the sex ratio of 28 southern species in the USA. They tested the well-known view that UV light-trap collections of moths are considerably skewed toward males. Twelve species demonstrated a statistically notable male preponderance, but a wide range of sex ratios was found. Two of the 28 species demonstrated significant bias for both males and females during different observation periods, illustrating the need to collect over the entire flight period. Since the sex ratio of collected organisms varies by species and by time, this knowledge must be taken into consideration when using light trap collection to make population estimates and to gather information for conservation or control of any particular species.

According to Tabadkani et al. (2013) appreciation of the proportion of genders of arthropods is a pertinent issue not only in ecological studies and in biological programs, but also in plant protection. In this study, they continued to examine the factors leading to erroneous estimates of sex ratios of insect species. They examined the predatory gall midge, *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae), and the results explicitly suggest that direct estimation of the sex ratio in natural populations may be affected by some secondary factors such as differential mortality of sexes, protandry, and differential distribution of males and females over time and/or across habitat.

While they could provide us with important, useful information for everyday practice, there are very few publications reporting on research of this kind. Unfortunately, this kind of research is both time consuming and energy consuming; thus, in the foreseeable future, we cannot expect any major breakthrough in this area.

Researchers have been studying the sex ratio of the insects trapped for decades, but their observations had little practical value for plant protection prognostics. The authors of most studies confine themselves to releasing the figures recording the number of males and females, perhaps even their ratio in terms of percentage of the captured specimens, but they refrain from drawing any conclusions. Admittedly, any such attempt would be a vain endeavour, especially in the case of the data provided by light traps operating for short periods. Whereas if the sex ratio of the populations in the environment shifts in the direction of a preponderance of females and that change is reflected in the catch, a growth in the number of the females trapped might indicate the start of gradation. Therefore, awareness of the regularity of sex ratio transformation may also be used for the purposes of prognosis in the case of species where both sexes fly well to light. Some researchers have published general statements concerning this.

When the sex ratio of an observed species at different observation sites and in different years produces decidedly different values, it would be useful to examine regularities in changes. From the point of view of prognosis, the differences in time have main importance, because they might be related to hypercyclic movement. Our own research revealed a rise of the number of turnip moth (*Agrotis segetum* Den. et Schiff.) females in the years which were followed by gradation (in years 1962 and 1968) (Nowinszky – Kiss 1981). It is assumed that the proportion of females affects the number of individuals of future generations. In the year prior to the years of gradation, the number of females increased.

We examined the changes of the number of the females in the turnip moth (*Agrotis segetum* Den. et Schiff.) population between 1957 and 1990. The light-trap catches of 65 observing stations were used (Kiss et al., 2003).

It is concluded that over 99 specimens in each generation the ratio of females is 0.38 from all individual number. If the number of individuals is between 5 and 99, the proportion is 0.44. The proportion of females is 0.46 if the number is between 100 and 499; it is 0.38 between 500 and 999. Between 100 and 999 this value is 0.40. For all observing stations, we calculated the female individual proportions and the 95% confidence intervals for them. We established that higher female proportion belongs to the lower individual numbers, but this proportion is close to the feature if individual numbers are high. It was observed that in the year before gradations begin, the rate of females was extremely high in many cases.

2 MATERIAL

The development of a light trap network began in 1952 in Hungary. The traps were used in research institutes, for plant protection, and for forestry purposes. The three-type light trap network is still working and works with uniformly Jermy-type traps. Over the past decades, the national light-trap network has provided an enormous and inestimable amount of scientific insect material for entomological research and plant protection practice (Nowinszky 2003).

The Jermy-type light trap (Jermy 1961) consists of a frame, a truss, a cover, a light source, a funnel, and a killing device. All the components are painted black, except for the funnel, which is white. A metal ring holding the funnel and a zinc-plated tin joins the steel frame. The cover is 100 cm in diameter. The distance between the lower edge of the cover and the higher edge of the funnel is 20–30 cm. The light source is a 100W normal electric bulb with a colour temperature of 2900°K. The lamp is in the middle of the trussing, 200 cm above ground. The upper diameter of the funnel is 32 cm, while the lower one is 5 cm, and its height is 25 cm. In each case chloroform was used as a killing agent.

The forestry light traps are operational from 6 p.m. (UT) to 4 a.m. every night of the year, regardless of weather, or the time of sunrise and sunset. The operation is suspended only on days when the temperature is below 0 C^{o} and the ground is covered by an unbroken layer of snow. All the insects trapped during the course of a night go into the same collecting jar and so a single set of data will represent the nightly catch result at the given observation site.

In this study we used the catch data of the Hungarian Forestry light trap network of the Forest Research Institute. The light traps were operating in 16 light trap stations across the whole territory of Hungary. The light trap stations, geographic coordinates and years of operation are presented in *Table 1*.

Table 1. The light trap stations, geographic coordinates and years of operation

Light-trap stations	*Geographic coordinates*	*Years of operation*
Budakeszi	47º30′83″N 18º56′03″E	1962–1970
Erdősmecske	46º10′51″N 18º30′80″E	1970
Felsőtárkány	47º58′44″N 20º25′07″E	1961–1970
Gerla	46º42′01″N 21º11′07″E	1962–1970
Gyulaj	46º30′51″N 18º17′76″E	1970
Makkoshotyka	48º21′52″N 21º31′17″E	1961–1970
Mátraháza	47º46′87″N 19º55′69″E	1961–1970
Répáshuta	48º02′90″N 20º31′70″E	1962–1970
Sopron	47º41′01″N 16º34′79″E	1962–1970
Szakonyfalu	46º55′45″N 16º13′71″E	1967–1970
Szentpéterfölde	46º37′02″N 16º45′64″E	1968–1970
Szombathely	47º14′01″N 16º37′22″E	1962–1970
Tolna	46º25′60″N 18º46′95″E	1962–1970
Tompa	46º12′28″N 19º38′08″E	1962–1970
Várgesztes	47º28′52″N 18º23′91″E	1962–1970
Zalaerdőd	47º03′44″N 17º03′30″E	1970

For our study, 32 forest phytophagous Macrolepidoptera species were selected from the national forestry light trap network material dating back to the years between 1961 and 1970.

The species were selected based on data available from several light traps over many years.

Table 2. Catching data of caught species

Families and species	Light-traps	Years	Σ ♂	Σ ♀	χ^2 P<
	Number of				
Lasiocampidae					
December Moth *Poecilocampa populi* (Linnaeus, 1758)	2	9	2,817	317	0.01
Autumn Eggar *Eurigaster rimicola* (Denis et Schiffermüler, 1775)	1	9	2,027	40	0.01
Barred Hook-tip *Watsonalla cultraria* (Fabricius, 1775)	3	5	818	1,484	0.01
Scarce Hook-tip *Sabra harpagula* (Esper, 1786)	2	5	888	134	0.01
Thyatiridae					
Popular Lutestring *Tethea or* (Denis et Schiffermüller, 1775)	3	8	2,353	929	0.01
Geometridae					
Maiden's Blush *Cyclophora punctaria* (Linnaeus, 1758)	1	4	1,197	1,331	0.01
Clay Triple-lines *Cyclophora linearia* (Hübner, 1799)	4	7	4,005	4,864	0.01
November Moth *Epirrita dilutata* (Denis et Schiffermüller, 1775)	3	2	1,216	114	0.01
Dingy Shell *Euchoeca nebulata* (Scopoli, 1763)	8	8	2,656	427	0.01
Sharp-angled Peacock *Macaria alternata* (Denis et Schiffermüller, 1775)	5	9	3,018	1,990	0.01
Featheres Thorn *Colotois pennaria* (Linnaeus, 1761)	9	7	4,561	567	0.01
Peppered Moth *Biston betularia* (Linnaeus, 1758)	5	8	4,359	34	0.01
Pale Oak Beauty *Hypomecis punctinalis* (Scopoli, 1763)	9	9	12,715	2,938	0.01
The Engrailed *Ectropis bistortata* (Goeze, 1781)	12	9	17,815	1,517	0.01
Notodontidae					
Buff-tip *Phalera bucephala* (Linnaeus, 1758)	3	4	495	7	0.01
Plumed Prominent *Ptilophora plumigera* (Denis et Schiffermüller, 1775)	1	4	2,118	275	0.01
Small Chocolate-tip *Clostera pigra* (Hufnagel, 1766)	1	10	886	12	0.01
Chocolate-tip *Clostera curtula* (Linnaeus, 1758)	1	10	699	7	0.01

Table 2. Catching data of caught species (continuation)

Families and species	Light-traps	Years	Σ ♂	Σ ♀	χ2 P<
	Number of				
Lymantriidae					
Pale Tussock *Calliteara pudibunda* (Linnaeus, 1758)	4	7	1,411	72	0.01
Yellow-tail *Euproctis similis* (Fuessly, 1775)	2	9	540	38	0.01
White Satin Moth *Leucoma salicis* (Linnaeus, 1758)	1	5	157	18	0.01
Arctiidae					
Dotted Footman *Pelosia muscerda* (Hufnagel, 1766)	3	10	1,791	1,762	NS
Scarce Footman *Eilema complana* (Linnaeus, 1758)	6	10	8,244	6,156	0.01
Common Footman *Eilema lurideola* (Zincken, 1817)	5	9	15,980	12,252	0.01
Noctuidae					
Small Quaker *Orthosia cruda* (Denis et Schiffermüller 1775)	5	7	6,820	3,201	0.01
Hebrew Character *Orthosia gothica* (Linnaeus, 1758)	8	9	4,565	727	0.01
The Satellite *Eupsilia transversa* (Hufnagel, 1766)	7	10	2,974	2,911	NS
The Chestnut *Conistra vaccinii* (Linnaeus, 1761)	11	10	11,479	5,428	0.01
Pale-lemon Sallow *Xanthia ocellaris* (Borkhausen, 1792)	3	8	542	886	0.01
The Dun-bar *Cosmia trapezina* (Linnaeus, 1758)	6	8	2,097	1,483	0.01
Lesser Belle *Colobochyla salicalis* (Denis et Schiffermüller, 1775)	2	9	2,056	614	0.01
Jubilee Fan-foot *Zanclognatha lunalis* (Scopoli, 1763)	4	10	12,077	8,234	0.01

The flying period and primary food plants of caught moths are shown in *Table 3.*

3 METHODS

All species were processed separately, but by the same method. The number of captured males and females was counted for the entire swarming. These were summarized and the difference in level of significance was calculated with χ^2 test.

For each swarming we calculated the percentage of males and females. We also calculated the values of the coefficients of variation, which express the deviations in average percentages.

Table 3. The flying period and primary food plants of caught moths

Families and species	*Flying period of moths*	*Primary food plants*
Lasiocampidae		
P. populi L.	October-November	Quercus, Betula, Populus, Tilia
E. rimicola Den. et Schiff.	September-October	Quercus
W. cultraria Fabr.	May-June; July-August	Fagus
S. harpagula Esp.	May-June; July-August	Tilia, Betula, Quercus
Thyatiridae		
T. or Den. et Schiff.	April-May; August	Populus
Geometridae		
C. punctaria L.	April-May; July-August	Quercus, Betula
C. linearia Hbn.	May-June; July-August	Fagus, Quercus, Betukla
E. dilutata Den. et Schiff.	September-November	Quercus, Acer, Betula, Ulmus
E. nebulata Scop.	June-August	Alnus Quercus, Acer, Betula
M. alternata Den. et Schiff.	April-May; July-August	Salix, Alnus, Prunus
C. pennaria L.	September-November	Carpinus, Quercus, Tilia, Salix
B. betularia L.	May-June; July-August	Betula, Ulmus, Salix, Fraxinus
H. punctinalis Scop.	May-July	Quercus, Betula
E. bistortata Gze.	April-May	Polyphagous (Acer, Alnus)
Notodontidae		
Ph. bucephala L.	May-June ; July-August	Quercus, Tilia, Salix
P. plumigera Den. et Schiff.	October-December	Acer, Fagus, Prunus
C. pigra Hfn.	April-June; July-August	Salix
C. curtula L.	April-May; June-August	Populus, Salix
Lymantriidae		
C. pudibunda L.	May-June	Fagus, Carpinus, Ulmus, Tilia,
E. similis Fuesl.	June-July	Qurcus-, Ulmus-, Tilia, Salix
L. salicis L.	June-July	Populus
Arctiidae		
P. muscerda Hfn.	July-August	Lichenes
E .complana L.	July-August	Lichenes
E. lurideola Znck.	July-August	Lichenes
Noctuidae		
O. cruda Den. et Schiff.	March-April	Quercus, Betula, Acer, Carpinus
O. gothica L.	March-April	Quercus, Tilia, Ulmus, Betula
E. transversa Hfn.	September-April	Quercus, Betula
C. vaccinii L.	September-April	Quercus, Betula
X. ocellaris Brkh.	September-April	Quercus, Tilia, Acer, Ulmus,
C. trapezina L.	June-September	Quercus, Fagus, Betula, Acer
C. salicalis Den. et Schiff.	May-August	Populus, Salix
Z. lunalis Scop.	May-September	Fagus

4 RESULTS AND DISCUSSION

The results are shown in *Table 4*.

Table 4. The percentage of males and females, deviations and coefficients of variation.

Families and species	Σ Moths	Mean ♂%	♂s	♂CV	Mean ♀%	♀s	♀CV
Lasiocampidae							
Poecilocampa populi L.	2,134	0.83	0.177	0.21	0.17	0.177	1.04
Eriogaster rimicola Den. et Schiff.	2,067	0.98	0.018	0.02	0.02	0.018	0.90
Drepanidae							
Watsonalla cultraria Fabr.	2,308	0.37	0.111	0.30	0.63	0.106	0.17
Sabra harpagula Esp.	1,022	0.88	0.042	0.05	0.12	0.042	0.37
Thyatiridae							
Tethea or Den. et Schiff.	3,292	0.75	0.092	0.12	0.25	0.106	0.42
Geometridae							
Cyclophora punctaria L.	2,528	0.61	0.179	0.29	0.39	0.179	0.46
Cyclophora linearia Hbn.	8,862	0.48	0.102	0.21	0.52	0.092	0.18
Epirrita dilutata Den. et Schiff.	1,340	0.89	0.040	0.04	0.11	0.034	0.31
Euchoeca nebulata Scop.	3,083	0.86	0.141	0.16	0.12	0.141	1.17
Macaria alternata Den. et Schiff.	5,004	0.75	0.114	0.15	0.25	0.115	0.46
Colotois pennaria L.	5,128	0.91	0.086	0.09	0.09	0.086	0.96
Biston betularia L.	4,393	0.99	0.011	0.01	0.01	0.011	1.10
Hypomecis punctinalis Scop.	15,553	0.88	0.076	0.09	0.12	0.076	0.63
Ectropis bistortata Goeze	19,443	0.97	0.048	0.05	0.03	0.045	1.50
Notodontidae							
Phalera bucephala L.	502	0.98	0.019	0.02	0.02	0.019	0.95
Ptilophora plumigera Den. et Schiff.	2,393	0.90	0.054	0.06	0.10	0.054	0.54
Clostera pigra Hfn.	886	0.99	0.013	0.01	0.01	0.008	0.80
Clostera curtula L.	699	0.99	0.009	0.01	0.01	0.009	0.90
Lymantriidae							
Calliteara pudibunda L.	1,183	0.95	0.039	0.04	0.05	0.039	0.78
Euproctis similis Fuesl.	578	0.94	0.037	0.04	0.06	0.036	0.60
Leucoma salicis L.	175	0.89	0.073	0.08	0.11	0.074	0.67
Arctiidae							
Pelosia muscerda Hfn.	3,553	0.53	0.108	0.20	0.47	0.108	0.23
Eilema complana L.	13,400	0.56	0.129	0.23	0.44	0.129	0.29
Eilema lurideola Zinck.	28,232	0.68	0.174	0.26	0.32	0.174	0.54
Noctuidae							
Orthosia cruda Den. et Schiff.	10,021	0.66	0.105	0.16	0.34	0.105	0.31
Orthosia gothica L.	5,292	0.88	0.071	0.08	0.12	0.071	0.59
Eupsilia transversa Hfn.	5,885	0.51	0.083	0.16	0.49	0.083	0.17
Conistra vaccinii L.	16,907	0.69	0.123	0.18	0.31	0.123	0.40
Xanthia ocellaris Borkh.	1,428	0.39	0.194	0.50	0.61	0.194	0.32
Cosmia trapezina L.	3,580	0.58	0.082	0.14	0.42	0.082	0.19
Colobochyla salicalis Denis et Schiff.	2,670	0.81	0.085	0.10	0.19	0.085	0.45
Zanclognatha lunalis Scop.	20,311	0.62	0.130	0.21	0.38	0.130	0.34

Notes: Mean ♂% and Mean ♀% = averaged percentage of males and females,
♂s and ♀s = deviations, ♂CV and ♀CV = coefficient of variations.

We found the majority of moths collected in light traps are males. This result is true of 29 species from the investigated 32 species. However, the proportion of males and females of each species, and even within the same species, differed greatly during each swarming.

One probable explanation may be the protandry for greater number of males. Cordillot (1989) established that occurrence of the male of the European corn-borer (*Ostrinia numilalis* Hbn.) in the light trap preceded the females' occurrence by 3.8 ± 1.5 days on average. This phenomenon was named "protandry" by Stockel and Peyelut (1984). That the females of some species are attracted to light in greater number after mating may be the cause of this.

Yathom (1981) found the most frequently light trapped Egyptian bollworm (*Earias insulana* Boisduval) females mated once. Lopez et al. (2000) found that the overwhelming majority of the females of *Mythimna unipuncta* (Haworth) flew to light after egg-laying. We also observed the "protandry" phenomenon in the case of the dotted footman *Pelosia muscerda* Hfn. in Tompa 1970; the male and female ratio is equal with this species. Males and females of both species (*Pelosia muscerda* Hfn. and *Eupsilia transverse* Hfn.), are captured nearly in similar number. Cordillot (1989) found that the overall ratio of European corn-borer (*Ostrinia nubilalis* Hbn.) was found almost the same; of the captured moths, 52.7% were males and 47.3% were females.

Watsoniana cultraria Fabr. is the only one species captured by light traps that showed a significant female majority. We examined 8 swarmings; females outnumbered males in 7 of them. The males of this moth also fly in the sunlight and they can usually be seen among the higher branches of beech trees. This may be a reason why fewer males of this species are captured at night.

For decades it has been known that the proportion of male and female individuals of various insect species caught by light trap tends to differ. This fact proves that the ratio of the various species represented the catch are not the same as the ratio that appears in nature (Kiss et al. 2003). The reasons for this fact may be many. Flight is difficult for females because of their increased weight due to developing eggs. The males may be more active as they visit the females with the aim of the mating. It is also possible that the males have a greater affinity to light (Waringer 2003).

Acknowledgement: We thank Dr. Pál Szontagh who gave the light trap data of Forest Research Institute to Dr. Sándor Szabó and Dr. László Nowinszky in the 1970s. These data were used in our study.

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Cent. Eur. J. Biol. • 9(4) • 2014 • 417-430
DOI: 10.2478/s11535-013-0272-z

VERSITA

Central European Journal of **Biology**

Swarming patterns of light trapped individuals of caddisfly species (Trichoptera) in Central Europe

Research Article

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Received 04 July 2013; Accepted 11 October 2013

Abstract: This study is on the light trapping of caddisfly species (Insecta: Trichoptera) related to the proportion of males and females and the moon phases. The data collected includes 24 species in 9 light-trap stations, for 49 swarming events between the years 1980 and 2000. We found the massive emergence of adults happens fractionally in swarming intervals. This is connected with the phenology and life cycle of each species. The percentage of males and females of the same species during different swarming events cannot be considered equal. The proportion of males and females are different in the swarming of different species. We found that the number of male and female individuals is substantially synchronized with each other within the swarming, but it can be different in the case of each species. The duration of the swarming, even in the same species, are not always uniform. The effect of the Moon cannot be clearly identified in any species, even if data from several swarmings are available. The swarming peaks appear near different Moon quarters.

Keywords: *Sex ratio • Light-trap • Moon Quarters*

1. Introduction

The caddisflies (Trichoptera) are one of the most important groups of aquatic insects, which include 13,574 species [1]. Their seasonal activity is therefore essential to understanding the ecological impacts [2].

The caddisflies imagos generally are active at night and they are attracted to artificial light. Therefore according to prior investigations [2-8], light trapping is one of the most suitable methods of identifying their swarming patterns and abundance. This includes the beginning and end of swarming, and the length and peaks of activities. This research is important for the characterization of caddisflies species and their function in nature conservation research.

Thousands of adults were collected in the study [9,10]. This trapping method has been extensively used by trichopterologists from temperate areas [9,11-16] through Mediterranean aquatic habitats [17,18] to subtropical/tropical regions [10,19,20].

By 'swarming' we mean the length of the flight-period of the imagos. The caught caddisflies are short-lived, thus observed flight by light-trap can be considered as a time series of the different emerging and dying specimens. Accordingly, the swarming reflects the hatching of imagos from the pupae, with some probably negligible delay [21].

The daily distribution of flight activity is an important aspect in the study of potential moonlight effects on caddisflies, because the nightly duration of the moon staying above the horizon is changing during the moon phases [21,22].

The caddisflies may have very different types of daily activity patterns. Many trichopteran species fly exclusively in daylight [23,24]. Most of the caddisflies are active during evening or night, but some species have a daily bimodal activity pattern [25]. Other studies reported that the swarming of caddisfly adults starts mainly after dusk and peaks before midnight at early or late evening, but the flying of many species continues until dawn [26].

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According to Harris [27], Trichoptera species were not caught by light trap when solar light level was greater than sixteen cd. The swarming of caddisflies started when the light intensity decreased below four cd.

Jackson and Resh [28] monitored the daily flight pattern of three caddisfly species using female sex pheromones to attract males: *Dicosmoecus gilvipes* (Hagen) (Limnephilidae), *Gumaga nigricula* (McL.) (Sericostomatidae) and *Gumaga griseola* (McL.). They established that the light intensity strongly influenced the flight activity of these species but not their flight periodicity. Although many studies have communicated the proportion of males and females of the light trapped caddisfly species: [18,29-38], only a few authors examined the drawing synchrony of them during swarming.

Adult Trichoptera were caught by Waringer [15] in May 1986 to June 1987 on the banks of the Danube at Altenwörth, Lower Austria, using a set of 3 Jermy-type light traps. Waringer found that in 17 species the sex ratio was significantly different from 1:1 and it changed during the night but did not disclose any of later study. Waringer [39] wrote that in nine out of the eleven most abundant species the sex ratios significantly differed from 1:1, with an excess of females.

Schmera [41] found that at the beginning of the flight period (May and June) the ratio of males was significantly higher compared to the expected 50% and towards the end of the flight period there was no significant difference.

Urbanovič [42] found the males of the most abundant species *Potamophylax cingulatus* (Steph.) which belonged to two subspecies, showed different distributional pattern in Slovenia.

Monson [43] carried out detailed studies of Lake Itasca (Minnesota, USA) and he published results for 126 caddisflies species. Unfortunately, his results cannot be compared to our results, because they are not of the same species collected.

Only few observations have been published on reactions of caddisflies to moonlight. Mackay [44] reported that the number of caddisflies (*Pycnopsyche* spp, Limnephilidae) caught by BL trap was low on nights of Full Moon, especially, when the moon disc was above the horizon. The daily distribution of flight activity is an important aspect in the study of potential moonlight effects on caddisflies, because the nightly duration of the moon disc staying above the horizon is changing during the various quarters [21].

Corbet [19,45], by use of Robinson-type light traps equipped with 125 W mercury vapour bulbs, collected Plecoptera, Ephemeroptera, Chaoborus and Trichoptera species on one hundred consecutive nights on the shore of Lake Victoria. In four of the 37 species examined, the number of individuals showed a periodical change corresponding to the changes of the lunar phases. He proposed that these catching peaks reflect the emergence pattern of adults influenced by moonlight rather than changes in the catching ability of light-traps [19,44].

Detailed studies discussing the effects of various moon phases on the light-trapping effectiveness of caddisflies are rare in the literature. Therefore, it is important to extend the tests to potential moonlight effects on caddisflies.

2. Experimental Procedures

Our catching data were collected from registers (between 1980 and 2000) and studies of Kiss [2,30,32,33,45,48], Kiss *et al.* [49,50].

Jermy-type light traps were used to collect caddisflies. The light source of the applied Jermy-type light-traps was a 100 W normal white light electric bulb hung under a metal cover (Ø: 1m) 200 cm above the ground. The traps were operated every night throughout the season from April until October.

The name of the species caught, number of individuals, the trapping sites and years are shown in Table 1 and Table 2.

We determined the four typical phases of the moon (the first- and last quarter, full moon and new moon), and all the swarming periods of time (UT) by our own computer program. This program was created by astronomer György Tóth for our earlier studies [40].

We calculated catch value using number of males and females separately for each species and swarming for one trap over one night.

We examined the question: does the percentage of males and females differ from the expected ratio (50-50%) in each swarming? The χ^2 test was used to determine this. Schmera [41] used this test for this purpose. We also investigated the case of the same species; can the male and female ratio be considered to be constant or are they modified by environmental factors?

We established the duration of all swarming events and sorted them by month. We also determined the percentage of males for those swarming where the number of caught specimens was over a thousand.

The number of specimens were plotted and the swarming pattern was determined, so that the one- (unimodal), two- (bimodal), three or more (polymodal) distribution was involved. With correlation analysis, we found that two or more species are not in synchronized

Species and light-trap station	*Geographic coordinates*	*Number of individuals*	*Number of nights*
Rhyacophilidae			
Rhyacophila tristis Pictet 1834			
Zemplén Mountains, Kemence brook, 1998	48°45'N, 21°48'E	566	100
Rhyacophila nubila Zetterstedt 1840			
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	461	123
Rhyacophila fasciata Hagen			
Szilvásvárad, Szalajka stream 1980	48°64'N; 20°23'E	110	158
Szilvásvárad, Szalajka stream 1981	48°64'N; 20°23'E	103	143
Szarvaskő, Eger brook, 1989 Eger brook, 1989	47°59'N, 20°51'E	441	174
Ecnomidae			
Ecnomus tenellus Rambur			
Nagy-Eged, Csomós farm-stead, Eger, 1981	47°54'N; 20°22'E	239	81
Glossosomatidae			
Glossosoma conformis Neboiss 1963			
Zemplén Mountains, Kemence brook, 1998	48°45'N, 21°48'E	504	99
Hydropsychidae			
Hydropsyche instabilis Curtis 1834			
Nagy-Eged, Csomós farm-stread, Eger, 1980	47°54'N; 20°22'E	76	146
Dédestapolcsány, Bán stream, 1988	48°08'N, 20°25'E	837	68
Polycentropodidae			
Plectronemia conspersa Curtis 1934			
Szarvaskő, Eger brook, 1989	47°59'N, 20°51'E	137	91
Limnephilidae			
Ecclisopteryx madida Mc Lachlan 1867			
Nagyvisnyó, Nagy brook, 1981	48°08'N, 20°25'E	54	78
Nagyvisnyó, Nagy brook, 1984	48°08'N, 20°25'E	502	102
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	431	98
Limnephilus lunatus Curtis 1834			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	341	98
Limnephilus flavicornis Fabricius 1787			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	99	125
Limnephilus rhombicus Linaeus 1758			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	249	126
Potamophylax rotundipennis Brauer 1857			
Dédestapolcsány Bán stream, 1988	48°08'N, 20°25'E	717	75
Halesus digitatus Schrank 1781			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	839	90
Bükk Mountains, Vöröskő-Valley, 1981	48°34'N; 20°27'E	104	70
Dédestapolcsány Bán stream, 1988	48°08'N, 20°25'E	837	68
Szarvaskő, Eger brook, 1989	47°59'N, 20°51'E	714	108
Goeridae			

Table 1. The name of the species caught, the trapping sites and years, and the number of individuals and nights. The number of individuals is fewer than 1,000.

Species and light-trap station	Geographic coordinates	Number of individuals	Number of nights
Silo pallipes Fabricius 1781			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	199	110
Szilvásvárad, Szalajka stream, 1981	48°64'N; 20°23'E	641	110
Nagyvisnyó, Nagy brook, 1984	48°08'N, 20°25'E	86	106
Dédestapolcsány, Bán stream, 1988	48°10'N, 20°29'E	442	109
Silo pallipes Fabricius			
Szarvaskő, Eger brook, 1989	47°59'N, 20°51'E	296	118
Sericostomatidae			
Sericostoma personatum Kirby & Spence 1862			
Bükk Mountains Vöröskő-Valley, 1982	48°34'N; 20°27'E	983	143
Odontoceridae			
Odontocerum albicorne Scopoli 1763			
Szilvásvárad, Szalajka stream, 1980	48°64'N; 20°23'E	316	120
Szilvásvárad, Szalajka stream, 1981	48°64'N; 20°23'E	451	114
Bükk Mountains, Vöröskő-Valley, 1982	48°34'N; 20°27'E	618	112
Bükk Mountains , Vöröskő-Valley, 1983	48°34'N; 20°27'E	845	131
Nagyvisnyó, Nagy brook, 1984	48°08'N, 20°25'E	65	59

continued **Table 1.** The name of the species caught, the trapping sites and years, and the number of individuals and nights. The number of individuals is fewer than 1,000.

with each other's swarmings. Level of significance of the correlation quotient was also calculated.

Then, we adopted the model of two sexes swarming synchronized if the correlation quotient was less than the level of significance $P < 0.05$.

They also demonstrated the existence of a relationship. Therefore, if there was more swarming of the same species available, we investigated whether the same swarming peaks can be found in the same months or not; are the numbers of swarming peaks the same?

We calculated catch value using number of males and females separately for each species and swarming for one trap over one night.

Since most of the caddisfly species swarm more or less permanently in the summer season, the total number of individuals was used in the relative catch (RC) calculations. The application of relative catch allows us to work with catching data from different swarming periods.

The number of basic data exceeded the number of sampling nights because in most collecting years more light-traps operated synchronously. In order to compare the differing sampling data of a species, relative catching values were calculated from the number of individuals. We calculated for investigated species the relative catch (RC) value for each day per light-trap station per year. The RC was defined as the quotient of the number of individuals caught during a sampling period (1 night) per the average catch (number of individuals) within the same generation relating to the same time unit. For example when the actual catch was equal to the average individual number captured in the same generation/swarming, the RC value was 1. Because most of caddisflies species are more or less permanently swarming in the summer season, the total number of individuals was used in the calculations.

We listed our collecting data - separately for males and females - as four moon quarter surroundings. Moonlight during the four quarters of the moon was divided into by photometric characteristics of the moonlight thus gathering a number of different phase angles. The total lunar month, angle of 360 months (approximately 30 days) included. To First- and Last Quarter – when seen positively polarized moonlight - 72–72 phase angles (7–7 days) are listed below. To Full Moon – this time in the negative and low-polarized moonlight - 48 phase angle (5 days) belongs. New Moon period – when there is no measurable moonlight – 168 phase angle (11 days) belongs.

Our relative catch data is averaged and divided into four moon quarters. In those moon quarters where an apparently higher number of catches was observed, the difference of average value between the level

Species, trap sites and years	Specimens	May ♂%	June ♂%	July ♂%	Au-gust ♂%	Septem-ber ♂%
				Percentages		
Glossosomatidae						
Agapetus orchipes Curtis 1834						
Zemplén Mountains, 1998	2 485	24.3**	11.9**	15.6**	33.3	
Hydropsychidae						
Hydropsyche contubernalis Mc Lachlan						
Uppony Mountains, 1992	4 047		40.0**	47.8	38.6**	76.5**
Hydropsyche instabilis Curtis						
Szilvásvárad, 1980	1 761		33.3**	12.1**	30.5**	45.2
Bükk Mountains, 1981	2 656	17.1**	9.1**	9.1**	7.2**	
Bükk Mountains, 1982	7 169	10.0**	42.7**	24.3**	21.5**	
Bükk Mountains, 1983	11 483	32.8**	35.3**	43.6**	33.4**	14.3**
Szarvaskő, Eger stream, 1989	2 273	65.8**	58.3**	62.7**	66.7**	
Hydropsyche bulgaromanorum Malicky, 1977						
Szolnok, Tisza River, 2000	22 343		42.3**	43.7**	44.2**	35.9**
Polycentropodidae						
Neureclipsis bimaculata Linnaeus						
Bükk Mountains, 1983	15 636	51.4	54.1**	54.3**	50.0	
Limnephilidae	1 049	47.0	53.1**	49.8	43.3	
Limnephilus rhombicus Linaeus						
Zemplén Mountains, 1982						
Potamophylax nigricornis Pictet	3 708		54.3	66.4**	57.3**	58.2**
Bükk Mountains, 1982						
Bükk Mountains, 1983	3 666		43.3**	56.8**	60.0**	
Halesus digitatus Schrank	5 866		48.9	55.7**	62.0**	
Bükk Mountains, 1982						
Bükk Mountains, 1983	1 287				63.5**	75.6**
Goeridae	1 049				73.0**	76.0**
Goera pilosa Fabricius						
Uppony Mountains, 1992						
Silo pallipes Fabricius	1 037	1.9	36.9**	31.0**	0.6	0.1
Zemplén Mountains, 1998						
Sericostoma personatum Kirby & Spence	1 204		55.4	64.0**	56.9*	78.8**
Bükk Mountains, 1983	1 272		73.8**	69.1**	63.3**	72.1**

Table 2. The name of the species, trapping sites and years and percentages of males per month. Number of individuals is more than 1,000. Notes = Significance levels are * = P <0.01, ** = P < 0.001. Geographical coordinates: Szolnok 47°10'N, 20°11'E

of significance was tested by t-test. We arranged the days of each swarming of each species by the days of swarming and those points are plotted. By the figures we calculated in which ten days are the peaks of swarming. We arranged all swarming of all species in four lunar quarters (First Quarter, Full Moon, Last Quarter and New Moon) and depicted them as well. According to the figures, it was determined that the peak of the swarming happens during quarter moon.

May it be hypothesized whether the male and female ratio is approximately constant, or whether environmental factors modify it?

Is the number of male and female individuals caught synchronized during each swarming days of the

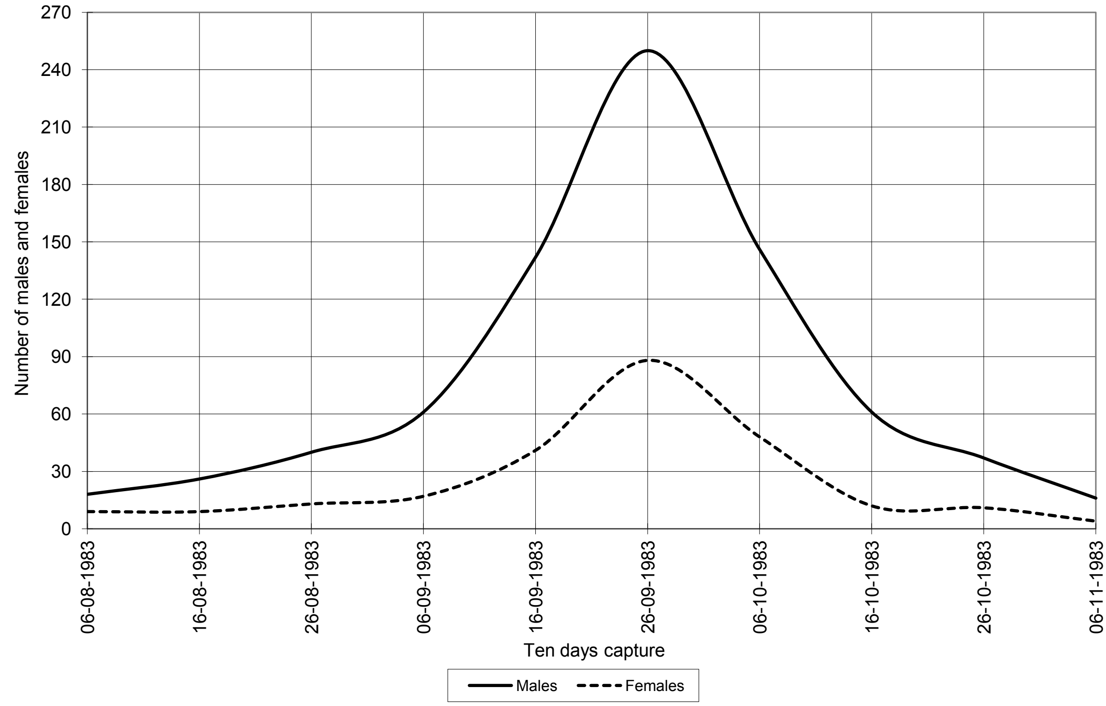

Figure 1. Swarming pattern of light trapped males and females of *Halesus digitatus* Schrank over ten days in1983 (Bükk Vöröskő-Valley).

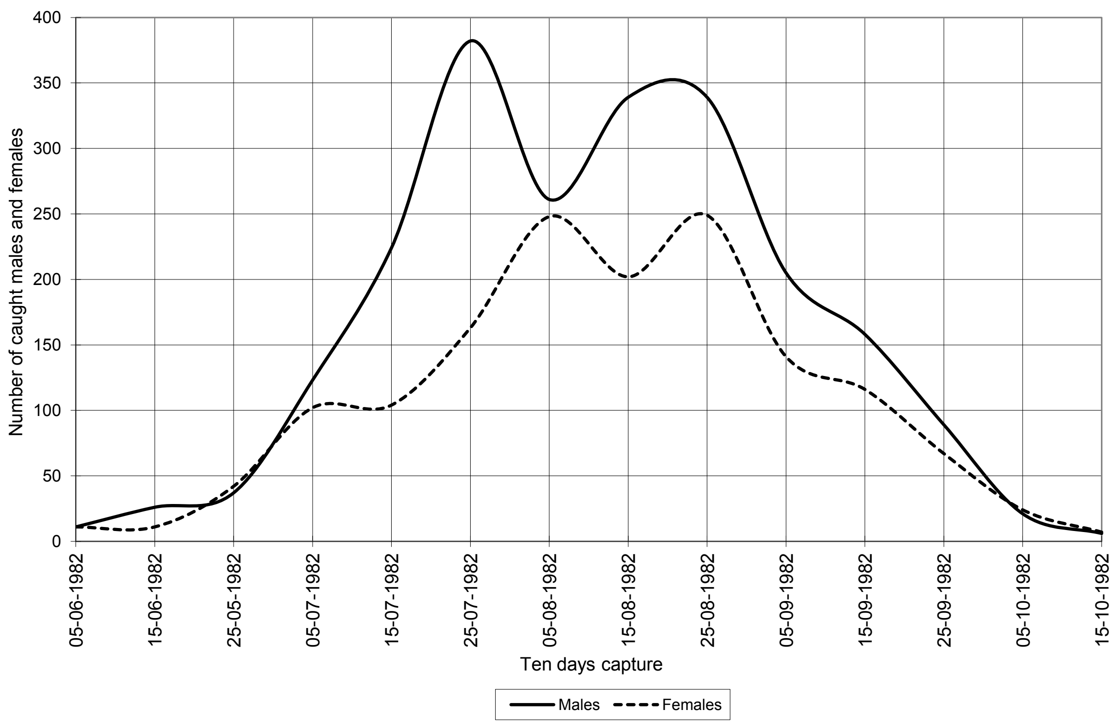

Figure 2. Swarming pattern of light trapped males and females of *Limnephilus rhombicus* Linnaeus over the ten days of 1982 (Zemplén Mountains Kemence brook)

lunar month? Correlation analysis was carried out to determine this and determine its level of significance. We adopted the model of two sexes swarming synchronized if the correlation quotient was less than the level of significance P <0.05.

If there was more swarming of the same species available, we investigated if the swarming peaks can be found in the same months or not.

We arranged and plotted the days of each swarming of each species by the days of swarming. By the figures, we calculated which ten days are the peaks of swarming.

We hypothesized that the swarming of the species is modified by environmental effects. Therefore, if there was more swarming of same species available, we investigated whether the same swarming peaks can be found in the same months or not; are the numbers of swarming peaks the same?

3. Results

The percentage of males and females of different swarming events, even in the same species, cannot be considered equal (Tables 2 and 3). The swarming pattern observed are as follows: unimodal 20, bimodal 12, polymodal 9 and atypical 8.

Our results regarding some species were compared with the results of other researchers (Table 4). We found

Species and light-trap stations and years	♂%	♀%	*Pattern*	*r*
Rhyacophilidae				
Rhyacophila fasciata Hagen 1859				
Szilvásvárad Szalajka stream, 1980	77.5 **	22.5	Polymodal	0.433
Nagyvisnyó Nagy brook, 1981	77.3 **	22.7	Polymodal	0.647 **
Szarvaskő Eger brook, 1989	66.4 **	33.6	Polymodal	0.604 **
Rhyacophila tristis Pictet 1834				
Zemplén Mountains, Kemence brook, 1998	53.5	47.6	Polymodal	0.527 *
Rhyacophila obliterata McLachlan 1863				
Szilvásvárad Szalajka stream, 1980	95.0 **	0.5	Bimodal	0.508
Rhyacophila nubila Zetterstedt 1840				
Uppony Mountains Csermely stream 1992	60.0 **	40.0	Polymodal	0.795 **
Ecnomidae				
Ecnomus tenellus Rambur 1842				
Nagy-Eged Csomós farm-stead Eger, 1981	24.3	75.7 **	Bimodal	0.369
Glossosomatidae				
Agapetus orchipes Curtis 1834				
Zemplén Mountains, Kemence brook, 1998	19.9	80.1 **	Atypical	0.843 **
Glossosoma conformis Neboiss 1963				
Zemplén Mountains, Kemence brook, 1998	49.2	50.8	Atypical	0.504 *
Hydropsychidae				
Hydropsyche contubernalis Mc Lachlan 1865				
Uppony Mountains Csermely stream 1992	45.0	55.0**	Bimodal	0.846**
Hydropsyche instabilis Curtis 1834				
Szilvásvárad Szalajka stream, 1980	29.7	70.3 **	Unimodal	0.875**
Nagy-Eged Csomós farm-stead Eger, 1980	26.3	73.7 **	Polymodal	0.482 *
Bükk Vöröskő-Valley, 1981	8.3	91.7 **	Unimodal	0.609 **
Bükk Vöröskő-Valley, 1982	28.2	71.8 **	Unimodal	0.032
Bükk Vöröskő-Valley, 1983	37.7	62.3 **	Unimodal	0.869 **

Table 3. The name of the species caught, the trapping sites, years, percentage of males and females and the swarming pattern (continuity) Notes: * = P < 0.01;** = P < 0.001 Significance level between actual percentages of males and females and their prospective values (50%) and correlation quotients of synchronization the patterns of individuals captured of males and females.

Species and light-trap stations and years	♂%	♀%	*Pattern*	*r*
Dédestapolcsány Bán stream, 1988	14.1	85.9 **	Unimodal	0.655 **
Szarvaskő Eger brook, 1989	63.8 **	36.2	Unimodal	0.903 **
Hydropsyche bulgaromanorum Maliczky, 1977				
Szolnok Tisza River, 2000	43.8	56.2 **	Unimodal	0.985 **
Polycentropodidae				
Neureclipsis bimaculata Linnaeus 1758				
Bükk Vöröskő-Valley, 1982	53.7**	46.3	Unimodal	0.981 **
Bükk Vöröskő-Valley, 1983	76.0 **	24.0	Unimodal	0.976 **
Plectronemia conspersa Curtis 1934				
Szarvaskő Eger brook, 1989	70.1 **	29.9	Polymodal	0.829 **
Limnephilidae				
Ecclisopteryx madida Mc Lachlan 1867				
Nagyvisnyó Nagy brook, 1981	69.2 **	30.8	Unimodal	0.987 **
Ecclisopteryx madida Mc Lachlan 1867				
Nagyvisnyó Nagy brook, 1984	63.5 **	36.5	Unimodal	0.801 **
Uppony Mountains Csermely stream 1992	65.3 **	34.7	Bimodal	0.517 *
Limnephilus lunatus Curtis 1834				
Szilvásvárad Szalajka stream, 1980	73.5 **	36.5	Unimodal	0.799 **
Limnephilus flavicornis Fabricius 1787				
Szilvásvárad Szalajka stream, 1980	52.5	47.5	Polymodal	0.843 **
Limnephilus rhombicus Linaeus 1758				
Szilvásvárad Szalajka stream, 1980	31.3	68.7 **	Bimodal	0.718 **
Zemplén Mountains, Kemence brook, 1998	59.9 **	40.1	Bimodal	0.910 **
Potamophylax rotundipennis Brauer 1857				
Dédestapolcsány Bán stream, 1988	74.2**	24.8	Atypical	0.258
Potamophylax nigricornis Pictet 1834				
Bükk Vöröskő-Valley 1982	55.6 **	44.4	Bimodal	0.874 **
Bükk Vöröskő-Valley 1983	55.9 **	44.1	Unimodal	0.927 **
Halesus digitatus Schrank 1781				
Szilvásvárad Szalajka stream, 1980	63.8 **	36.2	Unimodal	0.962 **
Bükk Vöröskő-Valley, 1981	58.6	41.4	Atypical	0.418
Bükk Vöröskő-Valley, 1982	68.8 **	31.2	Bimodal	0.852 **
Bükk Vöröskő-Valley, 1983	76.0 **	24.0	Unimodal	0.989 **
Szarvaskő Eger brook, 1989	69.2 **	30.8	Atypical	0.587 **
Goeridae				
Goera pilosa Fabricius 1775				
Uppony Mountains Csermely stream 1992	60.5 **	39.5	Bimodal	0.625 **
Silo pallipes Fabricius 1781				
Szilvásvárad Szalajka stream, 1980	79.9 **	20.1	Unimodal	0.519 *
Szilvásvárad Szalajka stream, 1981	77.7 **	22.3	Bimodal	0.481 *

continued **Table 3.** The name of the species caught, the trapping sites, years, percentage of males and females and the swarming pattern (continuity) Notes: * = P < 0.01;** = P < 0.001 Significance level between actual percentages of males and females and their prospective values (50%) and correlation quotients of synchronization the patterns of individuals captured of males and females.

Species and light-trap stations and years	*♂%*	*♀%*	*Pattern*	*r*
Nagyvisnyó Nagy brook, 1984	45.3	54.7	Polymoda	0.639 **
Dédestapolcsány Bán stream, 1988	50.0	50.0	Unimodal	0.945 **
Szarvaskő Eger brook, 1989	69.6 **	30.4	Atypical	0.733 **
Sericostomatidae				
Sericostoma personatum Kirby & Spence 1862				
Bükk Vöröskő-Valley, 1982	75.4 **	24.6	Unimodal	0.797 **
Bükk Vöröskő-Valley, 1983	69.5 **	30.5	Unimodal	0.965 **
Odontoceridae				
Odontocerum albicorne Scopoli 1763				
Szilvásvárad Szalajka stream, 1980	89.2 **	10.8	Bimodal	0.527 *
Szilvásvárad Szalajka stream, 1981	77.2 **	22.8	Bimodal	0.934 **
Bükk Vöröskő-Valley, 1982	77.2 **	22.8	Atypical	0.832 **
Bükk Vöröskő-Valley, 1983	21.8	78.2 **	Atypical	0.777 **
Nagyvisnyó Nagy brook, 1984	63.1 **	36.9	Unimodal	0.880 **

continued **Table 3.** The name of the species caught, the trapping sites, years, percentage of males and females and the swarming pattern (continuity) Notes: * = P < 0.01;** = P < 0.001 Significance level between actual percentages of males and females and their prospective values (50%) and correlation quotients of synchronization the patterns of individuals captured of males and females.

Species and researchers	*Waringer, 1989*	*Waringer, 2003*	*Waringer & Graf, 2008*	*Schmera, 2005*	*Our own present study*
Agapetus orchipes Curtis		30.8			19.9
Ecnomus tenellus Rambur			13.9		75.7
Hydropsyche bulgaromanorum Malicky			58.6		53.7 and 76.0
Hydropsyche contubernalis Mc Lachlan			43.1		45.0
Neureclipsis bimaculata Linnaeus			52.8		43.8
Goera pilosa Fabricius	82.0			70.0	60.4
Silo pallipes Fabricius				71.0	59.9

Table 4. Comparison of the percentages of males (%) by different researchers.

that rates proportion of males and females are different and cannot be species specific.

The influence of the Moon on swarming peaks of caddisflies is not identified clearly with the little number of swarming (Table 5). Probably the appearance of the swarming peaks is primarily timed by meteorological factors such as rain, wind, temperature, humidity, and *etc*.

We made a comparative investigation about some researcher's former results with ours (Table 6).

4. Discussion

The massive emergence of adults swarming happens fractionally in swarming intervals. The percentage of males and females of the same species during different swarming events cannot be considered equal. Certain species the male predominate, but the ratio varies (51.7 to 76.0%). This may be due in part to morphological differences, and part to differences of characteristics of life. In other species, however,

Species, trap sites and years	*FQ*	*FQ*	*FM*	*FM*	*LQ*	*LQ*	*NM*	*NM*
Males and females	♂	♀	♂	♀	♂	♀	♂	♀
Hydropsyche contubernalis Mc Lachlan								
Uppony Mountains, 1992	0.967	0.975	0.913	1.084	1.156	1.102	0.995	0.932
Hydropsyche instabilis Curtis								
Szilvásvárad, 1980	0.676	0.260	0.063	0.842	1.181	2.188*	0.169	1.059
Bükk Mountains, 1981	0.845	0.335	0.358	0.456	1.486	1.702	1.123	1.268
Bükk Mountains, 1982	0.845	0.917	1.233	1.605	0.837	0.549	1.165	1.153
Bükk Mountains, 1983	1.053	0.958	0.628	1.061	1.186	0.937	1.044	1.033
Szarvaskő, Eger stream, 1989	0.723	0.687	0.637	0.688	0.590	0.661	1.554*	1.513*
Neureclipsis bimaculata Linnaeus								
Bükk Mountains, 1982	1.170	0.902	0.581	0.619	0.777	0.898	1.245	1.365
Bükk Mountains, 1983	1.588*	1.778*	1.066	0.872	0.753	0.775	0.844	0.835
Hydropsyche bulgaromanorum Malicky, 1977								
Szolnok, Tisza River, 2000	1.009	1.072	0.960	1.004	1.181	1.119	0.921	0.885
Limnephilus rhombicus Linaeus								
Zemplén Mountains, 1982	1.131	1.232	0.745	1.149	0.965	0.716	1.068	0.940
Potamophylax nigricornis Pictet								
Bükk Mountains, 1982	0.910	0.980	0.826	0.967	0.978	0.976	1.154	1.044
Bükk Mountains, 1983	0.989	1.162	1.183	0.894	1.031	0.908	0.918	1.016
Halesus digitatus Schrank								
Bükk Mountains, 1982	1.019	0.899	1.169	1.449	0.867	0.846	0.975	0.896
Bükk Mountains, 1983	0.985	0.719	1.146	1.161	1.400*	1.655*	0.766	0.820
Silo pallipes Fabricius								
Zemplén Mountains, 1998	0.989	1.054	0.880	1.009	0.933	0.775	1.139	1.100
Sericostoma personatum Kirby & Spence								
Bükk Mountains, 1983	0.858	0.965	1.004	1.053	1.000	0.855	1.076	1.081
Agapetus orchipes Curtis								
Zemplén Mountains, 1992	1.689*	1.506*	1.553	1.087	0.670	0.877	0.424	0.721
Goera pilosa Fabricius								
Uppony Mountains, 1992	0.933	1.100	0.634	0.696	1.196	1.367	1.065	0.766

Table 5. The name of the species, trapping sites and years and relative catch in Moon Quarters.

the females are significant majority (55.0 to 99.9%).

It is known the Hydropsyche species have a generally high proportion of females (proterogyny). This phenomenon may be due to an uneven sex ratio because of the higher mortality rate for males in the larval or pupal stages according to Waringer [39].

Müller-Peddinghaus [52] and Müller-Peddinghaus and Hering [53] found strong linear relationships between forewing length and body length (r^2=0.88), wing width (r^2=0.96), and wing area (r^2=0.88). Sexual dimorphism was species-specific. The wing of imagos was bigger in males than in females at important species. However, the results only partially confirm this conclusion.

The flight of females developing eggs is more difficult because of their increased weight, thus flight is slower. Males in flight may be more active, because they are looking for females to mate. The differences of sex ratios could be caused by location differences or due to (1) higher female mortality in instars, (2) the male potential for greater dispersion, (3) or greater affinity for the males to a light source [39]. Waringer [39] also found that the proportion of males of 9 species increased from sunset to sunrise.

According to Crichton and Fisher [54] the preponderance of males probably results from their greater activity at night and their wider dispersal.

Species and light-trap station	*Season*	*Length*	*Other research*	*Season-Length*
Rhyacophilidae				
Rhyacophila tristis Pictet 1834	Summer	Long		
Rhyacophila nubila Zetterstedt 1840	Summer	Long		
Rhyacophila fasciata Hagen	Summer-Autumn	Long		
Ecnomidae				
Ecnomus tenellus Rambur	Summer	Medium	Waringer & Graf [58]	Long
Glossosomatidae				
Glossosoma conformis Neboiss 1963	Summer	Medium		
Agapetus orchipes Curtis 1834	Summer	Long		
Hydropsychidae				
Hydropsyche instabilis Curtis 1834	Summer-Autumn	Long	Schmera [57]	Summer-Long
Hydropsyche contubernalis Mc Lachlan	Spring	Long	Waringer & Graf [58]	Long
Hydropsyche bulgaromanorum Malicky, 1977	Summer	Long	Waringer & Graf [58]	Long
Polycentropodidae				
Plectronemia conspersa Curtis 1934	Summer	Medium		
Neureclipsis bimaculata Linnaeus 1758	Summer	Long	Waringer & Graf [58]	Short
Limnephilidae				
Ecclisopteryx madida Mc Lachlan 1867	Autumn	Medium		
Limnephilus lunatus Curtis 1834	Autumn	Medium		
Limnephilus flavicornis Fabricius 1787	Autumn	Long		
Limnephilus rhombicus Linaeus 1758	Summer	Long		
Potamophylax rotundipennis Brauer 1857	Summer-Autumn	Long		
Potamophylax nigricornis Pictet 1834	Summer	Medium		
Halesus digitatus Schrank 1781	Summer	Long	Schmera [57]	Authum - Short
Goeridae				
Goera pilosa Fabricius 1775	Summer	Long	Schmera [57]	Summer-Medium
Silo pallipes Fabricius 1781	Spring-Summer	Long	Schmera [57]	Summer-Medium
Sericostomatidae				
Sericostoma personatum Kirby & Spence 1862	Summer	Long		
Odontoceridae				
Odontocerum albicorne Scopoli 1763	Summer-Autumn	Long		

Table 6. The name of the caught species, the swarming season and swarming length.

According to Pianka [55], cited by Monson [43], a higher number of females can be a strategy allowing males to mate with more females. Corbet [56] also reported parthenogenesis in some caddisflies species.

A single swarms swarming pattern or that of a single species cannot be determined unequivocally. The swarming peaks even in the same species in different months can appear in either the same number of peaks and swarming events.

We observed differences in swarming, where the number of males and females are not synchronized with each other, swarms where the number of specimens taken were less than 150, and in the swarming where swarming pattern were atypical. Therefore for our conclusions we used data only from the swarming in which the number of individuals captured were at least 150.

According to Schmera [57] the length of the flight of studied caddisfly species is determined as follows: The lengths of the flight activities were listed into 3 artificial groups: long if the length of the flight activity is longer than 14 weeks. Medium long is the activity if the length of the flight activity is between 8 and 14 weeks, and short if the interval is smaller than 8 weeks. The spring, summer or autumn species are defined on the occurrence of the highest percentage of the individuals collected in those periods.

There are some differences between our present results and other researcher's former ones. It may be because of different environmental circumstances.

The imagos as the appearance of a mass of swarming during different moon phases occurred. This is confirmed by *e.g.* the five swarming events of *Hydropsyche instabilis* Curtis. Furthermore, there is no significant difference in swarming to catch all the males and the females, but there is a difference in one of the Moon phases. Current results seem to contradict our previous ones [59], when we found that there was a significantly higher catch of *Ecnomus tenellus* Rambur in the first and last moon quarters than in any other moon phases. In the previous study, the results of 4 light trap stations were obtained from sampling data over 3 years and 16,206 observational dates was available for 834 individuals. In the present study, however, we only have data on about 239 individuals of 81 species. Current results do not confirm the results of previous studies' [60]. In a former study we used data of 9 years (although not all years for all species), nine species were unique and used 1798 of a total of 39695 observation data points. Our results showed that of the five studied species' (*Ecnomus tenellus* Rambur, *Hydropsyche instablis* Curtis, *Odontocerum albicorne* Scopoli, *Limnephilus lunatus* Curtis and *Halesus digitatus* Schrank) light-trap catch was high in the First- and the Last moon quarter, and two species' (*Rhyacophila fasciata* Hagen and *Psychomya pusilla* Fabricius) light-trap catch was the same during a Full Moon. The only species is *Agraylea sexmaculata* Curtis, when the peak was at New Moon.

Both the previous and the present results showed that the light trapping of caddisflies (Trichoptera) does not yet have a clear relationship with different moon phases. We therefore conclude that further investigation is necessary in order clarify the question.

Acknowledgements

We are grateful for the financial support of OTKA T:026479 and AMFK: 310/98 programs, and we also appreciate the support of our research by management of the Bükk National Park.

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ISSN 2278 –1358

Original Article

Protandry and protogyny in swarmings of caddisflies (Trichoptera) species in Hungary (Central Europe)

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Received 24 July 2016; accepted 10 March 2016

Abstract

The paper deals with the light-trapping of caddisfly species (Insecta: Trichoptera), caught in Hungary (Central Europe), in connection with the protandry and protogyny. 13 species were investigated in 9 years, the catch data of 7 light-trap stations for 22 swarmings from the years 1980 and 2000. We attempted to quantify the concept of the protandry and protogyny. It was considered to protandry or protogyny if the number of male or female insect was significantly higher to the other in the first two ten days of swarming. We established in four cases protandry and eight times protogyny in 22 swarmings. We could determine neither-protandry nor protogyny in ten cases.

Key words: - caddisflies, light-trap, protandry, protogyny.

1 Introduction

Most of the researchers, deal with caddisflies, register the number of captured males and females in working up daily light-trap catch data. However, studies generally give only the number of all males and females and also their percentage.

Although many studies have communicated the proportion of males and females of the light-trapped caddisfly species: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12], only a few authors examined the drawing synchrony of them during swarming.

Several publications deal with the fact that at the beginning of the swarming what kind of characteristics has the proportion of males and females of different insect groups. Hoffman [13] wrote that males of *Lasiocephala basalis* Koleneti sprouted earlier with 2 hours than the females. The protandry was observable both in the laboratory and outdoors.

Muralimohan and Srinivasa [14] found that the *Opisina arenosella* Walker (Lepidoptera: Crytophasidae) males appeared average 3-5 days earlier in every generation than females. Uyi et al. [15] found that although the *Pareuchaetes insulata* Walker (Lepidoptera: Erebidae) female larva state longer than the males, they appear yet as the imago (protogyny).

Cordillot [16] stated that the appearance of male European corn borer (*Ostrinia nubilalis* Hübner) is average of 3.8 ± 1.5 days in light-traps than females. This phenomenon was named protandry by Stockel and Paypelut [17]. This may be the reason at some species, which only greater number females fly onto the light after mating.

According to Farkas [18] the timing of fledging of the riverine dragonflies may differ between males and females within a species. However, mostly none has precedence over the other [19]. If there is difference in the take-off time of the genders the protandry is frequent [20], but protogyny also can appear [21]. It may be protandry reason that the males appearing earlier and they are sooner ready for insemination, while the protogyny be due that the females longer larva state development results bigger weight and fertility.

Bürgés and Gál [22] found with 125 W mercury lamp that the acorn moth (*Cydia splendana* Hbn.) males appear 3-4 days earlier than females. The male and female ratio is 1.9:1. The chestnut weevil (*Curculio elephas* Gyllenhal) males were also ahead than females on the beginning of swarming.

There can be found in the literature works dealing with the caddisflies, but only a few authors examined their distribution on the time of swarming and especially during the first days in swarming.

Adult Trichoptera were caught by Waringer [23] between May 1986 and June 1987 on the banks of the Danube at Altenwörth, Lower Austria, using a set of 3 Jermy-type light-traps. He found that in the case of 17 caddisfly species the sex ratio differed from the 1:1 ratio and it changed during the night but did not disclose why? None of later study Waringer [24] wrote that in nine out of the eleven most abundant species the sex ratios significantly differed from 1:1, with an excess of females.

Ward et al. [25] found with light-trap that a number of caddisfly species has a strong change in the flight season; there is a majority of males at the beginning and females later. In case of *Costachorema xanthopterum* McFarlane (Hydrobiosidae) the ratio of genders can change sinusoidal in the whole year. The males are predominant in winter (March-August), but females are predominant in summer (September-February). Males are slightly more pronounced in females throughout the year *Oxyethira albiceps* McLachlan (Hydroptilidae).

Males dominated at the beginning of the flight season, in mid-September, but the rate decreases linearly (with two exceptions), at the end of the flight season in April *Aoteapsyche tepoka* Mosely in Mosely and Kimmins (Hydropsychidae). Males are predominantly like at the start of the season in December, the females at the end of March *Pycnocentrodes aeris* Wise (Conoesucidae).

Protandry can be determined in the study of Terra [26] about the figure of the trapped *Hydropsyche lobara* McLachlan.

Singh et al. [27] collected caddisflies with emergence traps. They found protandry at five species from 11 common ones. It was 1-3 weeks. However, neither this paper nor others have been able to predict the sex ratios for Trichoptera species.

Mendez and Resh [28] studied with emergence traps appearance of Trichoptera adults, the sex ratio and the protandry in two autumn seasons (2003 and 2005). The appearance of males was 1-2 weeks earlier than females.

According to Li et al. [29] the male *Psychoglypha bella* Banks appearance was on October 19. This occurred 23 days earlier than the first females.

We present a method, which seems to be suitable for numerical expression of the concept of protandry and protogyny. We think this method is suitable for the similar research.

2 Material and Method

The selected caddisfly species and their all swarming were used to our investigation, originated from our light-trap collections.

There was the most important point of view at the selection of species and swarming the total number of male and female specimens exceeds one thousand. The second important aspect was that the duration of a swarming reach at least three months (90 days).

The collection sites, their geographical coordinates and the years of collection are shown in Table 2.1

Jermy-type light-traps were used in catch of caddisflies.

These light-traps consist of a 125 W mercury lamp and a saving lid with a diameter of 1 metre. There was a collecting funnel under the lamp. Its diameter was 40 cm and this collector drove into a container. We used clear chloroform as killing material. Our light-traps operated in all years and on all settlements between 1st April and 31st October on all nights.

We mean a generation's flying period by swarming. The lifetime of trapped imagos is usually short, so the observed swarming can be viewed as the difference between individuals born and dying in time series. According to this swarming image at least partly reflects the leaving of the puppets [30].

We mean protandry or protogyny that the percentage of male or female ratio was higher in the first two ten days of swarming, than in all the other ten days.

So we tried to express these two concepts in numerical form.

We counted the number of caught males and females in the first two of swarming and also in the whole swarming period.

Protandry was established if the percentage of males was significantly higher (at least $P < 0.05$ level) in the first two ten days than the rest of ten days. If the females were in majority in the first two ten days under the same conditions, it was the protogyny.

We have examined the question, the percentage of males and females differ in the expected 50-50 % ratio in all swarming? The χ^2 test was used to define it.

3 Results and Discussion

There are shown in Table 3. 2 the investigated species, the number of the caught individuals and the percentile proportion of the males and females in each swarming. We show if there can be found significant protandry or protogyny.

We found that in the swarming of 22 examined species the protandry can be found only four times, but in eight cases there was the protogyny. There was no significant difference in the number of genders.

The results were as follows within individual families:

There was protandry in 1-1 swarming of 1-1 species in Glossosomatidae and Hydroptilidae families. One of the species of Hydropsychidae family had three swarmings. We found protogyny in two of them, but neither protandry nor protogyny was observed in the third one. There was also no significant difference in the number of captured males and females in all three swarming of 1-1 species. The same was found in two swarming of one species in Polycentropodidae family. There were six swarming of three species of Limnephilidae family. Protogyny occurred four cases, but there was not any protandry. Protogyny was justified in case of two species among four ones in Goeridae family, and two had no significant difference.

The sexual asynchronous and the protandry is a presumption, that these are answers given to the incalculable disturbing circumstances [26]. The caddisflies can indicate the quality of living waters, and its changes, also can give information about the potential changes in aquatic ecosystems due to pollution. Therefore it is not only important for researchers if outcomes any new results in researches which deals with the phenomena of caddisfly species life. This little-researched topic is very important for the environmental protection researchers and all readers.

More important conclusions can be established from our results. It was a lucky circumstance, that we could examine five swarmings of *Hydropsyche instabilis* Curtis (Hydropsychidae family) from five years and from three sites. We could recognise protandry in two swarmings and also twice protogyny in other two swarmings, but there was one period without them.

The result is not the same in different years even on the same site. From these facts, we can conclude that the ecological claims of males and females of this species differ significantly perhaps the earlier stages of development and imago state as well.

This diversity is more important than the racial conditions. These conclusions can be relevant also in case of *Hydropsyche contubernalis* Mc Lachlan, although we could investigate only two swarmings.

The third member of this family is Hydropdsyche bulgaromanorum Malicky having a swarming tested. We could not establish any protandry and protogyny at this one.

We found only protogyny at the races of Polycentropodidae family, but there were some swarmings where this phenomenon cannot be experienced. It is possible the racial characteristics of the family may be more strongly prevail, such as environmental influences. We could examine only 1-1 swarming in other families.

It would not be right to make assumptions from these examinations. Of course, laws cannot be said of our results, we may have made assumptions, to verify or refute them requires further research.

We present a method, which seems to be suitable for numerical expression of the concept of protandry and protogyny. We are

Table 1. The name of the species, trapping sites, years, number of collected individuals and observing nights

Species and light-trap stations	*Geographic coordinates*	*Number of* Σ♂	Σ♀	Nights
Glossosomatidae				
Agapetus orchipes Curtis, 1834				
Zemplén Mountains, Kemence brook, 1998	48°45'N, 21°48'E	494	1991	94
Hydroptilidae				
Agraylea sexmaculata Curtis, 1834				
Szolnok, Tisza River, 2000	47°10'N, 20°11'E	1173	552	136
Hydropsychidae				
Hydropsyche contubernalis Mc Lachlan, 1865				
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	1922	2225	102
Szolnok, Tisza River, 2000	47°10'N, 20°11'E	120	12182	194
Hydropsyche instabilis Curtis, 1834				
Szilvásvárad, Szalajka stream 1980	48°64'N, 20°23'E	523	1238	88
Bükk Vöröskő Valley, 1981	48°34'N, 20°27'E	203	2453	123
Bükk Vöröskő Valley, 1982	48°34'N, 20°27'E	2024	5145	91
Bükk Vöröskő Valley,1983	48°34'N, 20°27'E	4227	7156	122
Szarvaskő, Eger stream, 1989	48°34'N, 20°27'E	2273	1288	102
Hydropsyche bulgaromanorum Malicky, 1977				
Szolnok, Tisza River, 2000	47°10'N, 20°11'E	9795	12548	102
Polycentropodidae				
Neureclipsis bimaculata Linnaeus, 1758				
Bükk Vöröskő Valley, 1982	48°34'N, 20°27'E	8403	7233	96
Bükk Vöröskő Valley,1983	48°34'N, 20°27'E	6871	6411	103
Limnephilidae				
Limnephilus rhombicus Linnaeus, 1758				
Zemplén Mountains, Kemence brook, 1998	48°45'N, 21°48'E	2221	1487	132
Potamophylax nigricornis Pictet, 1834				
Bükk Vöröskő Valley, 1982	48°34'N, 20°27'E	2041	1625	89
Bükk Vöröskő Valley,1983	48°34'N, 20°27'E	3277	2589	96
Halesus digitatus Schrank, 1781				
Bükk Vöröskő Valley, 1982	48°34'N, 20°27'E	886	401	92
Bükk Vöröskő Valley,1983	48°34'N, 20°27'E	797	252	102
Szolnok, Tisza River, 2000	47°10'N, 20°11'E	934	314	105
Goeridae				
Goera pilosa Fabricius, 1775				
Uppony Mountains, Csernely brook, 1992	48°13'N, 20°25'E	627	410	123
Silo pallipes Fabricius, 1781				
Zemplén Mountains, Kemence brook, 1998	48°45'N, 21°48'E	721	483	109
Sericostoma personatum Kirby & Spence, 1962				
Bükk Vöröskő Valley,1983	48°34'N, 20°27'E	886	386	123
Setodes punctatus Fabricius, 1759				
Szolnok, Tisza River, 2000	47°10'N, 20°11'E	1052	796	113

Table 2. The name of the species, trapping sites, years, number of collected individuals and observing nights

Species and light-trap stations	*First two ten days — Other ten days* ♂ %	♂ %	♀ %	♀ %	χ^2 P <
Glossosomatidae					
Agapetus orchipes Curtis, 1834					
Zemplén Mountains, Kemence brook, 1998	27.98*	13.55	72.02	85.45	0.01
Hydroptilidae					
Agraylea sexmaculata Curtis, 1834					
Szolnok, Tisza River, 2000	78.24*	67.57	21.74	32.43	0.01
Hydropsychidae					
Hydropsyche contubernalis Mc Lachlan, 1865					
Uppony Mountains, Csernely brook, 1992	42.69	45.41	57.31*	54.59	0.05
Szolnok, Tisza River, 2000	79.17*	59.27	20.83	40.73	0.01
Hydropsyche instabilis Curtis, 1834					
Szilvásvárad, Szalajka stream 1980	16.67	30.11	83.33*	69.89	0.01
Bükk Vöröskő Valley, 1981	18.13*	5.92	81.87	94.08	0.01
Bükk Vöröskő Valley, 1982	35.73*	26.77	64.27	73.23	0.01

Bükk Vöröskő Valley,1983	30.37	39.26	69.63*	60.74	0.01
Szarvaskő, Eger stream, 1989	65.78	63.65	34.22	36.36	
Hydropsyche bulgaromanorum Malicky, 1977					
Szolnok, Tisza River, 2000	42.31	43.84	57.69	56.16	
Polycentropodidae					
Neureclipsis bimaculata Linnaeus, 1758					
Bükk Vöröskő Valley, 1982	50.94	53.96	49.06*	40.03	0.05
Bükk Vöröskő Valley,1983	51.40	51.73	48.60	48.27	
Limnephilidae					
Limnephilus rhombicus Linnaeus, 1758					
Zemplén Mountains, Kemence brook, 1998	62.71	59.85	37.29	40.18	
Potamophylax nigricornis Pictet, 1834					
Bükk Vöröskő Valley, 1982	47.50	56.35	52.50*	43.65	0.01
Bükk Vöröskő Valley,1983	45.24	56.95	54.76*	43.05	0.01
Halesus digitatus Schrank, 1781					
Bükk Vöröskő Valley, 1982	63.37	69.31	36.63*	30.69	0.01
Bükk Vöröskő Valley,1983	70.97	76.29	29.03*	23.71	0.01
Szolnok, Tisza River, 2000	33.33	66.67	75.04*	24.96	0.01
Goeridae					
Goera pilosa Fabricius, 1775					
Uppony Mountains, Csernely brook, 1992	56.70	60.95	43.30*	39.15	0.01
Silo pallipes Fabricius, 1781					
Zemplén Mountains, Kemence brook, 1998	56.62	60.30	43.38*	39.70	0.05
Sericostoma personatum Kirby & Spence, 1962					
Bükk Vöröskő Valley,1983	78.85*	69.26	21.15	30.74	0.01
Setodes punctatus Fabricius, 1759					
Szolnok, Tisza River, 2000	55.32	57.16	43.40	42.84	

Note: * denotes the protandry or protogyny

aware that there are many other possible answer for it, indeed would be desirable.

Researchers can use these according to their goals, considering characteristics of the available examination material. In any case, it will be essential to define exactly what the researchers mean on these two concepts in the investigation.

We believe that our study is a contribution to the better understanding the phenomenon of protogyny and protandry.

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Source of support: Nil; Conflict of interest: None declared

Jermy type light-trap Photo: Dr. Zsuzsanna Kúti PhD

Becse type light-trap Photo: Prof. Dr. Zoltán Mészáros DSc

Recommendation

During the Iron Curtain period, many people tried to flee from Hungary into Austria across Lake Fertő (Neusiedler See). Few managed it; most were caught. Almost all those captured had with them some printed map or hand-drawn sketch map. These had it in common that they all showed a landmark, drawn to help the user find north. The landmark was a light trap by the lake, used by Hungarians researching its moths.

I am not saying the light trap's main function was as a landmark, merely that it helped a great many refugees.

Since then the Iron Curtain has been drawn back and the programme of examining the Lepidoptera of Fertő is over. The light trap has regained its original entomolo-gical function of assisting Hungarian researchers, particularly the research group headed by László Nowinszky in recent decades.

Lighting and light traps have been helping with night-time moth collection for over two centuries. But night-time light sources can be used not only for collection, but to study insect's behaviour. Hungary was first in the world in 1952, when Tibor Jermy and his team began setting up their network of light traps. The details of their captures still represent a vast database, of note to researchers with a wide range of interests.

Both the types of light trap and the knowledge obtained through them increased to a marked extent over the half-century. The findings fill fat books and periodi-cals. This volume holds a selection of that material, across the full spectrum of information the research group obtained. Among the authors are an entomologist, a meteorologist, an astronomer and a geophysicist, which gives an idea of how many sciences can put questions that analysis of the captured insect material may be able to answer.

Although most of the articles treat expressly narrow scientific issues, readers of average knowledge will also find matters of interest in them. The most important message concerns the huge volume of remarkable discoveries and unanswered questions about the world's wildlife that still await us in the early 21st century. This can be considered a flourishing period for insects, and all enquiries that bring us nearer to understanding them help to refine and perfect our view of the world.

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