The Light Trapping of Insects Influenced by the Sun and Moon in Europe, Australia and the USA

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CONTENTS

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CHAPTER 1

SOLAR ACTIVITY

NOWINSZKY L., PUSKÁS J., KISS M., KISS O., HILL L., BARTA V., HIRKA A., CSÓKA GY., SZENTKIRÁLYI F.

1. 1 Introduction

The activity of the Sun is the common name for 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 in the appearance of a terrestrial phenomenon depends on whether electromagnetic or corpuscular radiation is the cause. Such events include 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 precede changes in the biosphere's phenomena. Schowalter (2011) suggested that solar activity, such as solar flares, may cause irregular departures from typical climatic conditions.

The electromagnetic and corpuscular radiations of the Sun are regarded as factors that have a general modifying effect for weather and climate. In turn, the weather influences the insects and, of course, their multiplication and flight activity. The influences affect large areas at a given time modifying first of all the numbers of insects in an area and also their temporal processes. This justifies the investigation of the change of the catches of insects in light-traps as a function of solar activity.

The relationship of solar physics and meteorology has been investigated by numerous researchers. Wilcox (1975) pointed out a strong correlation between the solar wind and cyclones in the northern hemisphere. Roberts and Olson (1973) as well as Hines and Halevy (1977) demonstrated that solar activity influences the electric conditions in the magnetosphere of the Earth, which influences the formation of weather.

Cohen and Sweetser (1975) found a negative correlation between the sunspot numbers and tropical cyclones and their duration in the Atlantic Ocean. Similar results were found by Vibert (1976) with the help of modern mathematical methods. His results verify that solar periodicity has greater influence than weather phenomena on the amount of precipitation. Dyer (1975) compared the solar activity with the precipitation measured at 157 meteorological stations in South Africa between 1810 and 1912. He showed that the amount of precipitation was 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.

Solar flares precede intensive X-ray, gamma and corpuscular radiation, which after reaching the upper atmosphere of Earth change the electromagnetic environment (Smith and Smith 1963). Flares can be observed that persist for a maximum of 10-20 minutes. They are provisional lights in the colour sphere near sunspots. Observation of flares is done in the 656.3 μm, red wavelength of light of the alpha line of hydrogen. The corpuscular (energetic particle) emission is about one thousand times greater at the time of intensive flares than during the Sun's undisturbed condition. Corpuscles are mainly electrons and their speed is a maximum of 1500 km per second in space into all directions including to the Earth. These corpuscles with electric charge are the so-called solar wind, which reaches Earth in 26-28 hours, in contrast to electromagnetic radiation, which arrives in 8.5 minutes (Tóth and Nowinszky 1983). The energetic particles cross the interplanetary space but do not reach the Earth's upper atmosphere because they propagate only along the magnetic field lines of the magnetosphere of the Earth. The impact of the energetic particles on the atmosphere depends on the directions of the interplanetary magnetic field and its connection to the Earth's magnetic field.

The intensity of solar flares is classified by their area in comparison to the area of the Sun’s sphere. Flares with a classification of importance 1 are less than 250 times one half of a millionth part of the spherical sun surface. If the area of a solar flare is 250-600 times greater than this unit, the flare has importance 2. Flares with importance 3 have an area 600 times greater than this unit. Because of their greater energy radiation, the cosmic influence of flares with intensity classifications of 2 and 3 have the most important effects.

Previously, we demonstrated the influence of hydrogen alpha flares of importance levels 2 and 3 on light-trap catches (Tóth and Nowinszky 1983).

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

Blunck and Wilbert (1962) assumed that insect gradations may be related to the solar activity. Black and Thomson (1978) showed the importance of two maxima of solar activity for agriculture in that the second peak often causes droughts from the end of the first peak.

Polgár (1966) found that the dry and the wet years coincided with the maxima or minima of sunspot activity. Manninger (1975) analysed observations about the gradation of harmful insects spanning several decades. He found a relationship between the gradation and the wet and dry periods, which have a connection to solar activity. He proved that in the second half of the dry periods the drought-loving species increased but in the second part of the wet periods moisture-loving species increased.

The solar activity contains information about the Sun's surface observed through several methods. Among them, the most important is the appearance of sunspots, which have been continuously observed since the 18th century. The sunspots can be seen from the sun-facing hemisphere of the Earth. They peak approximately every 11.2 years.

Richmond (1938) suggested that sunspots affect the weather, which in turn affects the abundance of insects. However, the abundance of Hemlock Looper *Lambdina fiscellaria* Guenée in British Columbia was apparently not related to the sunspot cycle. Klimetzek (1976) examined several pest gradations between 1810 and 1970. He found that strong gradation occurs mainly during minima and maxima of sunspot activity. In later years, many researchers developed an index that takes into consideration the intensity of flares and also their duration. Many investigators searched for some connections between the solar activity and mass reproduction of insects. Their data for outbreaks derived from non-uniform observations, which prevented fundamental conclusions. Benkevich (1968, 1984, 1988, 1990) investigated several solar activity cycles and gradations of Gipsy Moth *Lymantria dispar* Linnaeus. Using data from long periods, he found that across vast areas of the Soviet Union the gradations we re related to Wolf's relative numbers, which are explained later. Martinek (1972) concluded that peaks of abundance of European Pine Sawfly *Neodiprion sertifer* Geoffroy occur every 11 years coincident with maxima of sunspots.

We previously completed three studies of the effects of sunspot numbers using a uniform method (Nowinszky *et al.* 2017, Nowinszky *et al.* 2018a, Nowinszky *et al.* 2018b). We examined whether annual sunspot numbers modified the numbers of certain moths collected in the different years because the daily values of the sunspot numbers showed significant differences in the various years.

Three groups were formed from the years in accordance to the average number of sunspots in the swarming periods, namely less than 30, 30-100, or more than 100 sunspots.

We found no significant deviations in the group in which the sunspot numbers were below 30 so we did not publish the results. In the groups of 30-100 and higher than 100 we found that both the low and high values of sunspot activity depressed the flight activity of European Corn-borer *Ostrinia nubilalis* Hübner. In contrast, the moderate values of sunspot activity increased flight activity as measured by the number of individuals caught in light-traps (Nowinszky *et al.* 2017).

Our results showed that during the swarming periods of the composite taxon called “Microlepidoptera species indeterminate” flight activity was high when the number of sunspots was the same as the average. Both smaller and higher number of sunspots reduced the flight activity of this group of moths (Nowinszky *et al.* 2018a).

Our results demonstrated that when there was low solar activity (less than 30 sunspots) there was no verifiable effect on the efficiency of light trapping of Scarce Bordered Straw *Helicoverpa armigera* Hübner. However, in other years, when the number of sunspots was greater than 30 the catches were elevated (Nowinszky *et al.* 2018b).

An index of solar activity can show all the information about the Sun's surface measured by several methods. The most important component is the number of sunspots, which has been continuously examined since the 18th century. The generally accepted index-number of sunspots is the Wolf relative number (Rw), which is calculated according to the formula:

$$Rw = \text{constant}\ (10\ g + f)$$

where: g = the number of observed sunspot groups, f = the number of all sunspots.

The Wolf relative numbers are collated in the Zurich observatory, as the global network centre, and they publish the data one year later.

Features of instruments used in the detection of sunspots determine the value of the constant. By this formula sunspot relative numbers determined in any of the world's solar physics observatories can be compared in a uniform scale. The use of Wolf relative numbers significantly progressed in meteorology in the second half of the 20th century.

In an earlier study, we found a correlation between Wolf relative numbers and forest insect damage (Kiss and Nowinszky 1988).

An index for chromospheric hydrogen alpha (Hα) flare activity was introduced by Örményi (1966). To simplify the calculations, he adopted the proportions 1:2:4 for the characterization of the intensities of various flares. This procedure is expressed by the formula:

$$\mathrm{FAN} = \frac{1}{1440} \frac{\Sigma}{n} I_n \Delta t_n$$

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 in minutes.

In an earlier study (Nowinszky and Puskás 2017) we examined the light-trap catches of three moth (Lepidoptera) species from the data of the Hungarian agricultural observation stations in connection with the Flare Activity Numbers numbers. It was found that these numbers could be used by entomological researchers.

The daily activity of the flares is characterized by the so-called Q-index that considers both the intensity and period of prevalence of the flares. It has been used by several researchers.

Kleczek (1952) devised the Q-index to rank the daily flare activity using the formula:

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

where i = flare intensity, t = the time length of its existence in minutes. This index is characteristic of a whole day.

He thought this formula described the whole energy that arises from the flares. The flare intensity (i) index is based on the area covered by the flare on the Sun's surface (S,1,2,3,4) and the brightness of the flare, namely F (Faint), N (Normal) and B (Bright) (Lepreti *et al.* 2000).

Some researchers used the method of Kleczek in connection with flare activity which is determined for every day (Kleczek 1952, Knoška and Petrásek 1984).

Turkish astronomers (Özgüç and Ataç 1989) characterised the daily flare activity for several decades by using the Q-index (Ataç 1987, Ataç and Özgüç 1998).

The Sun has low, moderate and high-activity years during its 11.2-year cycle and Q-index values change accordingly (Lepreti *et al.* 2000). This presented a difficulty in our investigations for which we adopted two solutions. Initially, we (Nowinszky and Puskás 2001, 2013) compared the Q-index value of a given day with the average of the drawing period (Q / Q average). In later work (Nowinszky *et al.* 2014, 2015), the calculations were performed separately in the years of low, moderate, and high activity.

No other researchers have examined the connection between insect activity and Q-index data.

Nowinszky *et al.* (2015) examined numbers of 30 moth species caught by a Mészáros type light-trap near Becej (Serbia) in connection with the Q-index. Three catching trends were found: ascending, descending and ascending then descending. The different responses were not linked to the taxonomic position of the 30 species.

Nine species showed an increasing trend with the high values of the Q-index while decreasing trends were observed in fourteen species. In the other seven cases the catches increased after decreasing when the values of the Q-index were high.

The results of our research on the relationship between the Q-index and light trapping were also published in a book (Puskás *et al.* 2021, 1-119).

The Sun's radio frequency radiation has been measured since 1948 in Ottawa at 2800 MHz (10.7 cm) wavelength (Tapping 2013). This integrates both the thermal radiation of the Sun at rest and the contribution of intermittent solar flares per day. Radio flux measurement data (F10.7 index) are reported in 10^{-22} Wm^{-2} Hz^{-1} flux units and are closely correlated with Wolf relative numbers.

The F10.7 Index has proven very valuable in specifying and forecasting space weather. It is an excellent indicator of solar activity that correlates well with the sunspot number as well as a number of ultraviolet (UV) and visible light solar irradiance records. The F10.7 index has been measured consistently in Canada since 1947, first at Ottawa, Ontario, then at the Penticton Radio Observatory in British Columbia. Unlike many solar indices, the daily F10.7 radio flux can be easily and reliably measured in alltypes of weather from the Earth's surface. Because it is a long record, it provides climatology of solar activity over six solar cycles. Because it comes from the chromosphere and corona of the sun, it tracks other important emissions that form in the same regions of the solar atmosphere. The extreme ultraviolet (EUV) emissions that impact the ionosphere and modify the upper atmosphere track well with the F10.7 index. Many UV emissions that affect the stratosphere and ozone also correlate with the F10.7 index. It is a very robust data set with few gaps or calibration issues (Space Weather Prediction Center, 2020)

The aim of our work was to investigate the trapping results of hundreds of nocturnal insect species flying on three continents (Europe, Australia and North America) in relation to solar activity. The influence of these factors on light trapping of insects has rarely or not been investigated up to now. Our goal was to analyse the results of catching numerous species using different types of light-traps in different geographical environments on three continents in relation to solar indexes.

1. 2 Material

In our study we used the data of mean magnetic field of the Sun published by the Wilcox Solar Observatory (WSO) from 1975 to 2020. The solar mean magnetic field is the average field as observed over the entire visible disk of the Sun. A solar telescope was built in 1975 at Stanford University to study the organization and evolution of large-scale magnetic fields of the Sun. The WSO made daily observations of the solar mean magnetic field using a Babcock-type magnetograph that is connected to a 22.9 m vertical Littrow spectrograph (Scherrer *et al.* 2017). This is the Stanford mean in microTesla units given in Figures 1. 4. 1 to 1. 4. 28.

The Q-index data used in this book were calculated by T. Ataç and A. Özgüç from Boğaziçi University Kandilli Observatory, Istanbul, Turkey (Ataç 1987, Özgüç and Ataç 1989).

The sunspot data were taken from the World Data Center of the Royal Observatory of Belgium in Brussels (World Data Center n.d.).

F10.7 solar radio flux data that we use was published by the British Geological Survey on their website (British Geological Survey n.d.).

The Flare Activity Numbers can be found in the study of Örményi (1966).

Several light-trap stations collected insects in Australia (Tasmania, Stony Rise), in Central Europe (Hungary) and in two states in the USA (Nebraska and North Carolina). For many years, moth (Lepidoptera) species were trapped at those places. In addition, in Hungary many caddisflies (Trichoptera) were collected over many years by Ottó Kiss and Ferenc Szentkirályi.

In Hungary the systematic scientific collection of the research institute started a light trapping initiative by academician Tibor Jermy (Jermy 1961). Once various initial problems of technology and operation were solved, Jermy-type traps were set up at every county plant protection station from 1958 onwards. The number of observation posts rose sharply as plant protection stations established additional regional traps. In 1970, the backbone of the national network was comprised of the 20 central, 87 regional and 18 specific light-traps of the National Plant Protection Service.

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. 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 100 cm in diameter and 14 cm in height. 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 the ground. The upper diameter of the funnel is 32 cm, the lower one is 5 cm, and its height is 25 cm. The female thread of the killing device joins the male thread of the 5 cm appendage at the lower part of the funnel. The killing jar of the device modified by Bozai (1966) is a glass lamp globe of 1.5 - 2 litres in volume. At the lower edge of the appendage tube a frame made of steel wire holds the evaporating vessel, which is fitted with a protective cap made of haircloth to prevent insects from falling into the vessel. The insects caught must not get in contact with the chloroform used for killing because of its strong fat-dissolving action. Before it is put into operation, some wadding is placed in the bottom of the vessel to reduce the danger of the collected material becoming damaged. The evaporating vessel is filled with a generous amount of chloroform to get the maximum killing power so that the material does not become unidentifiable (Kovács 1957). The lamp is turned on before dusk and is switched off after sunrise. The material collected over one night gets into the one vessel, making one sample.

Balogh (1962) modified the Jermy-type trap by fixing a reflecting surface to the rear part of the funnel's edge. This mirror not only kept the insects from flying over the trap, but also projected the light in a given direction. He placed a cotton-wool layer coated in plaster to the bottom of the killing jar. Through the plaster two short glass tubes lead to the cotton wool. He injected killing material into these tubes: equal portions of ethyl acetate and chloroform. The catching data of studied species were taken from this light-trap network which is still in operation.

Modified Jermy type light-traps operated for the catching of caddisflies between years of 2001 and 2005 at Fülöpháza and Maroslele. These traps had compact fluorescent bulbs (Philips PL-T 42W/830/4p). The trap at Fülöpháza was equipped with three baffles around the bulb to increase the catch of caddisflies. The traps were used continuously throughout the night, from April to the end of October, during the flight period of caddisflies.

The Tasmanian data derive from decades of near-continuous (1992-2019) operation of a 160W Rothamsted-design light-trap at Stony Rise in Tasmania, Australia. This trap was the last of several long-term Rothamsted-design traps operated at several sites from 1953 until various dates by the Tasmanian state agricultural agency, currently known as the Department of Natural Resources and Environment (DNRE). A history of the Tasmanian program was published by Hill (2013). The trap at Stony Rise was similar to the Rothamsted-design traps operated for decades in the United Kingdom (Rothamsted Research 2012). It was located at the edge of the small city of Devonport, which is on the north coast of Tasmania. The trap was at

41º11’29” S, 146°19’24” E, at a site 69 m above sea level and 5 km south of Bass Strait, which separates the island state of Tasmania from mainland Australia.

Data from the network of 15W black light (BL) traps in the USA States of North Carolina and Nebraska were downloaded from the website of the North Carolina Cooperative Extension Service including the archival North Carolina Pest News (North Carolina Cooperative Extension Service n.d., North Carolina Pest News n.d.). The data of Nebraska State spanned from 2000 to 2017 and the North Carolina State data spanned from 1994 to 2010. The data collection was published several times each year. These light-traps supplied much material for basic entomological research and plant protection prognostic work for the farmers. We investigated five species from the USA because only these had sufficient data.

The name of the captured species, the number of catching years, captured individuals and the nights are seen in Table 1. 2. 1.

Table 1. 2. 1
The name of the trapped species with the taxonomic authority, the numbers of catching years, caught individuals, data (observations unique to site and night) and the nights.

Species	Years	Number of individuals	Number of data	Number of nights
TRICHOPTERA (EUROPE, HUNGARY)				
Ecnomidae				
Ecnomus tenellus Rambur, 1842	6	26,521	1,149	616
Polycentropodidae				
Neureclipsis bimaculata Linnaeus, 1758	9	4,389	943	740
Hydropsychidae				
Hydropsyche instabilis Curtis, 1834	5	9,405	507	464
Hydropsyche contubernalis McLachlan, 1865	8	38,402	585	579
Hydropsyche bulgaromanorum Malicky, 1977	7	39,226	574	512

Table 1. 2. 1
The name of the trapped species with the taxonomic authority, the numbers of catching years, caught individuals, data (observations unique to site and night) and the nights (Continuation).

Species	Years	Number of individuals	Number of data	Number of nights
LEPIDOPTERA (EUROPE, HUNGARY)				
Microlepidoptera species indeterminate.	9	699,825	26,211	1,705
Gracillariidae, Lithocolletinae				
Horse Chestnut Leaf Miner *Cameraria ochridella* Deschka and Dimić, 1986	4	3,148	399	399
Crambidae, Pyraustinae				
European Corn-borer *Ostrinia nubilalis* Hübner, 1796	47	321,801	80,367	6,100
Lasiocampidae, Lasiocampinae				
The Lackey *Malacosoma neustria* Linnaeus, 1758	21	28,059	1,616	1,091
Geometridae, Larentiinae				
Winter Moth *Operophtera brumata* Linnaeus, 1758	15	6,577	638	357
Erebidae, Arctiinae				
Autumn Webworm *Hyphantria cunea* Drury, 1773	45	71,557	18,448	3,690
Noctuidae, Heliothinae				
Scarce Bordered Straw *Helicoverpa armigera* Hübner, 1808	18	6,616	1,972	514
Noctuidae, Noctuinae				
Setaceous Hebrew Character *Xestia c-nigrum* Linnaeus, 1758	34	1,972	54,757	7,040

Table 1. 2. 1
The name of the trapped species with the taxonomic authority, the numbers of catching years, caught individuals, data (observations unique to site and night) and the nights (Continuation).

Species	Years	Number of individuals	Number of data	Number of nights
LEPIDOPTERA (AUSTRALIA, TASMANIA)				
Plutellidae				
Diamond-back Moth *Plutella xylostella* Linnaeus, 1758	23	15,909	2,095	2,095
Oecophoridae, Oecophorinae				
Pasture Tunnel Moth *Philobota productella* Walker, 1864	6	3,477	231	231
Crambidae, Pyraustinae				
Tree Lucerne Moth *Uresiphita ornithopteralis* Guenée, 1854	21	1,850	1,053	748
Crambidae, Glaphyriinae				
Cabbage Centre Grub *Hellula hydralis* Guenée, 1854	22	1,905	759	331
Crambidae, Glaphyriinae				
Ptochostola microphaeellus Walker, 1866	17	2,839	989	653
LEPIDOPTERA (USA, NEBRASKA and NORTH CAROLINA				
Crambidae, Pyraustinae				
European Corn-borer *Ostrinia nubilalis* Hübner, 1796	13	81,101	3,675	1,185
Erebidae, Arctiinae				
Yellow Wolly Bear *Spilosoma virginica* Fabricius, 1798	5	25,536	631	446
Erebidae, Erebinae				
Forage Looper *Coenutgina erechtea* Cramer, 1790	6	14,309	1,142	566

Table 1. 2. 1
The name of the trapped species with the taxonomic authority, the numbers of catching years, caught individuals, data (observations unique to site and night) and the nights (Continuation).

Noctuidae, Heliothinae				
Corn Earworm *Heliothis zea* Boddie, 1850	18	75,630	2,205	1,444
Noctuidae, Noctuinae				
Western Bean Cutworm *Striacosta albicosta* Smith, 1888	7	61,851	955	469

1. 3 Methods

Basic data were the number of individuals and species caught in one night. In order to compare the differing sampling data, relative values were calculated. The relative catch value (RC) was defined as the quotient of the number of specimens caught during a sampling time unit (one night) per the average nightly catch of individuals within the relevant sampling period. The RC equals one when the catch for one particular night equals the average nightly catch (Nowinszky 2003).

Relative catches were grouped into classes. The number of these classes was calculated using the formula of Sturges (Odor and Iglói 1987):

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

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

It is not reasonable to have big differences in the number of data across classes. Therefore, the classes at the two extremities are wider than those in the middle. Within each group we used our own method and calculated three point weighted moving averages from the values of the dependent variable. In preceding studies, the use of moving averages meant that the first and last values, which often carry valuable information on the most important biological impacts, were lost. In elaborating our method, we considered the work of Urmantsev (1967). He came up with a solution to ensure that no data is lost, with every initial data being accompanied by a moving average value. The new method assigns differing weights to the middle, previous and following values. Thanks to this method, our moving averages get weighted with the number of initial data. The three point moving average is calculated on the basis of the following formulae:

The first value: $$\frac{7\Sigma x_1 + 4\Sigma x_2 - 2x_3}{7n_1 + 4n_2 - 2n_3}$$

The last value: $$\frac{7\Sigma x_h + 4\Sigma x_{h-1} - 2\Sigma x_{h-2}}{7n_h + 4n_{h-1} - 2n_{h-2}}$$

The remaining values: $$\frac{\Sigma x_{i-1} + 2\Sigma x_i + \Sigma x_{i+1}}{n_{i-1} + 2n_i + n_{i+1}}$$

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. The dividing line between these classes is always drawn more or less arbitrarily. 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 partly eliminates the disturbing influence of other environmental factors that are not being examined in the analysis (Nowinszky 2003). In this work, we chose a slightly different solution. Separately, all catch data by species were considered as a single sample and thus relative catch values were calculated. This solution also made it possible to determine the effectiveness of trapping from the relative catch values of each year and to compare the effectiveness of the years.

1. 4 Results and Discussion

Our results are shown in Tables 1. 4. 1 to 1. 4. 4 and Figures 1. 4. 1 to 1. 4. 28.

Table 1. 4. 1
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the solar magnetic field in Hungary, Australia and the USA.

Caught species	Ascending	Descending	Ascending then Descending	Descending then Ascending
TRICHOPTERA (HUNGARY)				
Ecnomus tenellus Rambur, 1842		X		

Table 1. 4. 1
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the solar magnetic field in Hungary, Australia and the USA (Continuation)

Neureclipsis bimaculata Linnaeus, 1758		X		
Hydropsyche instabilis Curtis, 1834			X	
Hydropsyche contubernalis McLachlan, 1865			X	
Hydropsyche bulgaromanorum Malicky, 1977	X			
LEPIDOPTERA (HUNGARY)				
Cameraria ochridella Deschka and Dimič, 1986				X
Ostrinia nubilalis Hübner, 1796		X		
Malacosoma neustria Linnaeus, 1758			X	
Hyphantria cunea Drury, 1877				X
Helicoverpa armigera Hübner, 1808				X
LEPIDOPTERA (AUSTRALIA)				
Plutella xylostella Linnaeus, 1758				X
Philobota productella Walker, 1864			X	
Uresiphita ornithopteralis Guenée, 1854			X	
Ptochostola microphaeellus Walker, 1866			X	
Proteuxoa tortisigna Walker, 1857				X
LEPIDOPTERA (USA)				
Ostrinia nubilalis Hübner, 1796		X		
Spilosoma virginica Fabricius, 1798			X	
Caenurgia erechtea Cramer, 1780	X			
Heliothis zea Boddie, 1850				X
Striacosta albicosta Smith, 1888	X			

We found that different species had different responses to the strength of solar activity. Their relative catch peaks were associated with different solar magnetic field values.

Four types of change in relative catch with changing solar magnetic field were identified: ascending, descending, ascending then descending, descending then ascending. Only the ascending, descending, and ascending and then descending catch responses occurred in relation to sunspots, Q-index, and the F10.7 cm solar radio flux.

The decreasing and then increasing type is observed only in the case of the solar magnetic field and not with other solar factors. Based on our current knowledge, we cannot interpret this response to solar magnetic field. To do this, we would need to know what changes in the Earth's atmosphere are caused by different values in the solar magnetic field.

The increase or decrease of the catch is explainable by our previous hypotheses (Nowinszky 2003). The divergent responses of species have many reasons reflecting their diverse ecological strategies. The significance of and tolerance to environmental factors of the species vary. Environmental factors interact with each other to exert their effects. Thus the same factor can express differently. The species have different survival strategies in response to adverse effects such as passivity, or hiding versus increased activity, to ensure their survival. Therefore, the insects seek, "to carry out their duties in a hurry".

Table 1. 4. 2
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the sunspot numbers in Hungary, Australia and the USA.

Caught species	*Ascending*	*Descending*	*Ascending then Descending*	*Descending then Ascending*
TRICHOPTERA (HUNGARY)				
Ecnomus tenellus Rambur, 1842			X	
Neureclipsis bimaculata Linnaeus, 1758	X			
Hydropsyche instabilis Curtis, 1834		X		

Table 1. 4. 2
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the sunspot numbers in Hungary, Australia and the USA (Continuation)

Caught species	*Ascending*	*Descending*	*Ascending then Descending*	*Descending then Ascending*
Hydropsyche contubernalis McLachlan, 1865	X			
Hydropsyche bulgaromanorum Malicky, 1977	X			
LEPIDOPTERA (HUNGARY)				
Microlepidoptera spec. indet.		X		
Ostrinia nubilalis Hübner, 1796			X	
Hyphantria cunea Drury, 1877			X	
Helicoverpa armigera Hübner, 1808			X	
Xestia c-nigrum Linnaeus, 1758			X	
LEPIDOPTERA (AUSTRALIA)				
Plutella xylostella Linnaeus, 1758			X	
Philobota productella Walker, 1864		X		
Hellula hydralis Guenée, 1854	X			
Ptochostola microphaeellus Walker, 1866			X	
Proteuxoa tortisigna Walker, 1857			X	
LEPIDOPTERA (USA)				
Ostrinia nubilalis Hübner, 1796		X		
Spilosoma virginica Fabricius, 1798	X			
Caenurgia erechtea Cramer, 1780			X	
Heliothis zea Boddie, 1850	X			
Striacosta albicosta Smith, 1888			X	

According to our hypothesis, our results have the following explanation. The low relative catch values always reflect situations in which the flight activity of the insects diminish. However, high values are not so simply interpreted. Major environmental changes bring about physiological transformation in insects. The imago is short-lived. Therefore an unfavourable environment influences the survival of not just the individual, but also the population as a whole. In our hypothesis, the individual may adopt either of two opposite strategies to evade the impacts hindering its normal functions. It may either display more liveliness, by increasing the intensity of its flight, copulation and oviposition or take refuge in passivity to weather an unfavourable situation. And so by the present state of our knowledge we might say that high relative catch can accompany favourable and unfavourable environmental effects (Nowinszky 2003).

The explanation of the increasing and then decreasing type, according to our hypothesis, may be as follows. Initially, solar activity enhances insect activity, whether favourable or unfavourable to the state of the environment.

Table 1. 4. 3
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the Q-index values in Hungary, Australia and the USA.

Caught species	*Ascending*	*Descending*	*Ascending then Descending*	*Descending then Ascending*
TRICHOPTERA (HUNGARY)				
Ecnomus tenellus Rambur, 1842			X	
Neureclipsis bimaculata Linnaeus, 1758	X			
Hydropsyche instabilis Curtis, 1834		X		
Hydropsyche contubernalis McLachlan, 1865	X			
Hydropsyche bulgaromanorum Malicky, 1977	X			
LEPIDOPTERA (HUNGARY)				
Microlepidoptera spec. indet.		X		

Table 1. 4. 3
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the Q-index values in Hungary, Australia and the USA (Continuation)

Caught species	*Ascending*	*Descending*	*Ascending then Descending*	*Descending then Ascending*
Ostrinia nubilalis Hübner, 1796		X		
Hyphantria cunea Drury, 1877	X			
Helicoverpa armigera Hübner, 1808		X		
Xestia c-nigrum Linnaeus, 1758			X	
LEPIDOPTERA (AUSTRALIA)				
Plutella xylostella Linnaeus, 1758	X			
Philobota productella Walker, 1864		X		
Hellula hydralis Guenée, 1854	X			
Ptochostola microphaeellus Walker, 1866		X		
Proteuxoa tortisigna Walker, 1857	X			
LEPIDOPTERA (USA)				
Ostrinia nubilalis Hübner, 1796		X		
Spilosoma virginica Fabricius, 1798			X	
Caenurgia erechtea Cramer, 1780			X	
Heliothis zea Boddie, 1850		X		
Striacosta albicosta Smith, 1888		X		

However, stronger solar activity subsequently forces insects into passivity. These types of responses by species are independent of the continent and taxonomic classification.

Table 1. 4. 4
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the 10.7 cm solar radio flux in Hungary, Australia and the USA

Caught species	*Ascending*	*Descending*	*Ascending then Descending*	*Descending then Ascending*
TRICHOPTERA (HUNGARY)				
Ecnomus tenellus Rambur, 1842			X	
Neureclipsis bimaculata Linnaeus, 1758	X			
Hydropsyche instabilis Curtis, 1834		X		
Hydropsyche contubernalis McLachlan, 1865	X			
Hydropsyche bulgaromanorum Malicky, 1977	X			
LEPIDOPTERA (HUNGARY)				
Microlepidoptera spec. indet.		X		
Ostrinia nubilalis Hübner, 1796			X	
Operophtera brumata Linnaeus, 1758			X	
Helicoverpa armigera Hübner, 1808			X	
Xestia c-nigrum Linnaeus, 1758			X	
LEPIDOPTERA (AUSTRALIA)				
Plutella xylostella Linnaeus, 1758			X	
Philobota productella Walker, 1864		X		
Hellula hydralis Guenée, 1854			X	
Ptochostola microphaeellus Walker, 1866			X	
Proteuxoa tortisigna Walker, 1857			X	

Table 1. 4. 4
Light-trap catch of caddisfly (Trichoptera) and moth (Lepidoptera) species in connection with the 10.7 cm solar radio flux in Hungary, Australia and the USA (Continuation)

Caught species	*Ascending*	*Descending*	*Ascending then Descending*	*Descending then Ascending*
LEPIDOPTERA (USA)				
Ostrinia nubilalis Hübner, 1796		X		
Spilosoma virginica Fabricius, 1798			X	
Caenurgia erechtea Cramer, 1780			X	
Heliothis zea Boddie, 1850	X			
Striacosta albicosta Smith, 1888			X	

Note to Table 1. 4. 4:
The result of *Hyphantria cunea* Drury cannot be interpreted, therefore the result of *Operophtera brumata* L. is included in this table.

Even if we process a huge amount of catch data, we cannot get significant results in two cases. One case is when we only have data from a single or a few light-traps. Then the standard deviations are large due to the significantly different catch data on different days.

In the other case, some species, especially migrants, appear intermittently in time and patchily across observation sites. Occasionally there are many migrants flying but often there are few or none. The standard deviations are extremely large in this case as well.

In our opinion, results that meet two conditions can be considered real. One is that those from several independent samples are essentially the same. The other condition is that the results can be interpreted based on our prior knowledge.