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Light-Trap Catch of Insects in Connection with Environmental Factors

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Additional information is available at the end of the chapter

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Abstract

This chapter deals with the connection between the light-trap collection of insects and the environmental factors that influence the trapping. These factors are as follows: the solar activity and its effects on the Earth (solar activity featured by *Q*-Index and the 2800 MHz radio flux, ionospheric storms and atmospheric radio noises, the interplanetary magnetic field sector boundaries, UV-B radiation of the Sun and geomagnetic indices), the moon phases and the polarized moonlight, the weather (macrosynoptic weather situations, weather fronts and air masses, weather events, weather elements), and air pollutants. The presented results show that these all modify the volume of captured insects.

Keywords: light trapping, solar activity, Moon, weather, air pollutants

1. Introduction

Since the mid-1930s, following Williams' [1] experiments, known now as classical experiments, light trapping developed into the most general method of collecting nocturnal insects throughout the world.

In Hungary, this was followed from 1952, by the introduction of an internationally unique network of traps established on an initiative by academician Jermy [2].

The Hungarian national network is uniformly outfitted with Jermy-type light-traps. The traps of the research and plant protection institutions work from 1 April to 31 October, while those of the forestry establishments are operational from 7 p.m. to 5 a.m. every night of the year, regardless of weather, or the time of sunrise and sunset.

After the beginning of the regular light-trap collections the researchers experienced that the fluctuations of the daily catch results do not follow exactly the swarming of species. These fluctuations are obviously caused by environmental impacts. First, the influences of meteorological elements were studied. These research studies continued soon with the examination of the influence of the moonlight as well. The essence of light trapping comes from the fact that the moonlight reduces the efficiency of the light source.

There was a light-trap network in operation in Hungary since the last six decades. This network gave an inestimable substance with a scientific value to the entomology researches. Nowinszky and his colleagues examined the influence of the environmental factors onto the light trap catch since the last four decades. This enormous amount data made it possible to study the influence of more environmental factors that were not examined by researchers or only some of them made such examinations. The results of this work are discussed in this chapter.

Researchers have examined the influence of the various weather elements on collection by light-trap all over the world. Williams [3] published a fundamental study.

Williams [1] found a lower catch at a Full Moon. He thought it was because of the smaller gathering distance or because moonlight had a direct influence on activity and reduced the number of insects in flight. After several decades, there is still no valid answer to this question.

Williams et al. [4] offered two possible explanations:

- Moonlight reduces insect activity.
- Accompanied by moonlight, lamplight collects from a smaller area.

The collecting distance as a function of changing moonlight has been calculated by a number of researchers [5–8].

Baker and his coworkers verified that the tethered and free-flying moths of the Large Yellow Underwing (*Noctua pronuba* Linnaeus) and Heart and Dart (*Agrotis exclamationis* Linnaeus) fly to the artificial light from the close quarters vicinity of lamp, only a few meters found that the insects reacted to artificial light from the amazingly short distance of 3–17 m, depending on the height of the light source. These authors ruled out the possibility of moonlight exerting any influence on the collecting distance. They hold that the growing intensity of light slackens flight activity.

In an earlier study [9], we detected the abundance of catch in the First and Last Quarters can be explained with the high ratio of polarized moonlight.

In clear moonlit nights, a band of highly polarized light stretches across the sky at a 90° angle from the Moon, and it was recently demonstrated that nocturnal organisms are able to navigate based on it [10].

In Hungary, the geomagnetic data measured at one single observatory supply sufficient information for the whole country [11].

Tshernyshev [12] found a high positive correlation between the horizontal component and the number of trapped insects.

Our study [13] deals with the modification of the catch of a dozen Caddisfly (Trichoptera) species by light trap in the region of the Tisza and Danube rivers in connection with the H -index (geomagnetic horizontal component). It demonstrates that in parallel to increasing values of the H -index the catch of 9 of the 12 species increased as well, but that of two species declined instead.

We did not find any previous studies in the literature dealing with those environmental factors that were investigated in our study. Therefore, we can cite only our own studies.

2.The Solar activity and its influence on the Earth

2.1. Solar activity featured by Q -index

Kleczek [14] was the first researcher, who introduced the concept of Q -index ($Q = i \times t$), to use the daily flare activity through quantification of the 24 h of the day.

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 [15, 16]. 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 assess the daily flare index [17]. Most authors have used Q -index to characterise daily flare activities, which also expresses the significance of flares by their duration. It is calculated by the following formula:

$$Q = (i \times t) \quad (1)$$

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

2.2. Solar activity featured by 2800 MHz radio flux

Solar flux from the entire solar disk at a frequency of 2800 MHz has been recorded routinely by radio telescope near Ottawa since February 1947.

2.3. Solar activity featured by ionospheric storms and atmospheric radio noises

The ionospheric disturbances caused by corpuscular radiation appear during the solar flares when the Sun emits a large amount of electrically charged and uncharged particles that enter the atmosphere of the Earth and change the conditions of the ionospheric layers. Among them, the most important is F_2 layer at night.

2.4. Interplanetary magnetic field sector boundaries

Besides studies of the longer cycles, emphasis has more recently shifted to research on the short-term atmospheric phenomena that also result from changes in the solar activity. These include the passing of the Earth through interplanetary magnetic field boundaries roughly once in every 8 days [18].

2.5. UV-B radiation of Sun

The UV-B range is especially detrimental in large quantities to living organisms. Our studies could not be related with the studies of other authors, dealing with the effect of the Sun's ultraviolet radiation and light and pheromone trapping of insects. Therefore we studied light-trap catch of insect species and pheromone trap catch of moth (Lepidoptera) species on the nights following days with a different solar activity. Low sunspot activity leads to a thinner ozone layer and thus higher surface ultraviolet (UV)-B radiation [19].

The light-trap success of European Corn-borer (*Ostrinia nubilalis* Hbn.) was examined by Puskás et al. [20] at those nights when during the previous day the UV-B radiation had a different intensity.

2.6. Geomagnetic indices

Becker [21] has found that certain species of Isotermes, Coleoptera, Diptera, Orthoptera and Hymenoptera are guided in their orientation by the natural magnetic field. Mletzko [22] carried out his experiments with specimens of ground beetles in the Moscow botanical garden. The insects flew in a given direction with an accuracy of $+5^\circ$ at daylight and $+60^\circ$ at night. The author assumes that orientation is guided by geomagnetism. Iso-Ivari and Koponen [23] studied the impact of geomagnetism on light trapping in the northernmost part of Finland. 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 Spotted Ermel (*Yponomeuta rorella* Hbn.), Pristavko and Karasov [24] revealed a correlation between the C and ΣK values and the number of individuals caught. In a later study [25], they also established that at the time of magnetic storms ΣK has a greater influence on the flying activity of the above species. Tshernyshev [26] found a high positive correlation between the horizontal component and the number of trapped insects. 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 [27].

Examinations over the past few decades have also confirmed that in the case of some Lepidoptera species, such as Large Yellow Underwing (*Noctua pronuba* L.) [15], both the Moon and geomagnetism guide their orientation and they can even integrate these two different types of information [28]. We have investigated the light trapping of Turnip Moth (*Agrotis segetum* Den. et Schiff.) Heart and Dart (*Agrotis exclamationis* L.) and Fall Webworm (*Hyphantria cunea* Drury) in relation with the *H*-index of the geomagnetic field strength using hourly data from the Kecskemét fractionating light trap [29].

2.7. The moon phases and the polarized moonlight

We summarize the known facts from the literature about the relationship between the Moon and light-trap catch, without our own results.

Williams [3] has published fundamental studies in this field. According to Williams [3] and El-Ziady [4], the smaller catch can be explained by the following reasons.

- The activity of the insects may be reduced by the light of the Moon; therefore, the active proportion of the population affected by the light trap can be smaller.
- It is possible that insects like to fly rather at shady places, than at clear areas, and probably in higher altitudes at a Full Moon.

No scientist could give a provable answer to this question in recent decades, most have not even tried. Some authors find an explanation by accepting the theory of the impact of a collecting distance, others refer to decreased activity.

2.8. Moonlight decreases the distance of collecting

Luminous intensity of the artificial light source (candela) is theoretically constant. Theoretical collecting distance has been calculated by several authors, for different light trap types and lunar phases [5, 7, 9]. The authors cited above did not as yet have considered light pollution. The actual collection distance may differ significantly from the theoretical one, because much abiotic and biotic factors influence it. These are summarized in Nowinszky's [8] work.

2.9. Moonlight inhibits flight activity

Bowden and Morris [7], discovered that the catch of most taxa changes in a 2:1 or 3:1 ratio between New Moon and Full Moon. However, for some taxa the trap catches more at a Full Moon. Thus, this study confirms both hypotheses, also the one asserting that insects are more active at a Full Moon, because the catch [30] is higher than what could be expected due to the decreased efficiency of the trap. From their studies [31–33], it is hypothesised that moonlight cannot have an influence on the collecting distance.

2.10. Height of flight

El-Ziady [34] believes in the likelihood of insects flying higher at the time of a Full Moon. Danthanarayana [30] came up with a theory that the three-peak lunar periodicity of the flight of insects might be related to migration. In these periods, insects fly in the higher layers of the atmosphere, reaching heights where they are further transferred by streams of air in a horizontal motion.

In a Macrolepidoptera material caught at heights of 2 and 10 m, respectively, by light traps working with 125 W mercury lamps as the light source in a forest environment the authors determined the number of species and individuals in connection with migration and moon phases [35].

3. The weather

3.1. Macrosynoptic weather situations

We can mention our own studies only in this topic.

We examined the effectiveness of the light trap catch in connection with Péczely- and Hess-Brezowsky macrosynoptic weather types in our previous studies [36].

3.2. Weather fronts and air masses

We examined from these factors the influences of the weather fronts and air masses.

3.3. Weather events

The light-trap collecting results—showing its flight activity—of Turnip Moth (*Agrotis segetum* Den. et Schiff.) were examined in connection 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 [37].

3.4. Weather elements

In Szombathely (47°14'01"N; 16°37'22"E), within the premises of the Kámon Botanic Garden, the Forestry Research Institute kept a Jermy-type light-trap in operation between 1962 and 1970, which has about 2 km in a straight line the local weather observatory, which operated in airport. As the insects are poikilotherm creatures, therefore it is understandable; their body temperature is always the same as the temperature of the environment.

4. Material

The data of environmental factors were downloaded from yearbooks other publications and NASA's website.

The collecting data of investigated Lepidoptera, Coleoptera and Heteroptera species were copied off the light-trap diaries. The Trichoptera individuals were collected by Ottó Kiss and we processed them in our previous joint studies.

4.1. Solar activity featured by Q-index

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

4.2. Solar activity featured by 2800 MHz radio flux

Data used in this study were from the Quarterly Bulletin of Solar Activity (Zürich-Tokyo) and the Journal of Geophysical Research.

4.3. Solar activity featured by ionospheric storms and atmospheric radio noises

The data we needed for our calculations (border frequency of the F_2 layer of the ionosphere (f_oF_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.

4.4. Interplanetary magnetic field sector boundaries

Data for the transition of interplanetary magnetic field sector boundaries have been taken from the studies of Wilcox [18].

4.5. UV-B radiation of Sun

UV-B data used for the study come from measurements in the Keszthely observatory of the Hungarian Meteorological Service [38]. Daily totals given in MED/day are calculated by totaling hourly values.

4.6. Geomagnetic indices

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 Tihany Geophysical Observatory:

$$H = \sqrt{x^2 + y^2} \quad (2)$$

We used the values of H -index over 2150 nT.

Catch effectiveness was examined in connection with the H -index and Quarters of the Moon.

4.7. The moon phases and the polarized moonlight

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 during our joint study [39]. The software was transcribed for modern computers by assistant professor Miklós Kiss. The illumination of the sky with stars, the moonlight and the Sun at dusk—all in lux—on any day and time, summarized or separately, for any given geographical location. Cloudiness is also calculated, and data were provided by the Annals of the Hungarian Meteorological Service Data are recorded on every third hour in okta. We used the value obtained in a given hour for the following 2 h.

4.8. The weather

4.8.1. Macrosynoptic weather situations

The Péczeley-type macrosynoptic weather situations was worked out by Péczeley [40] who identified and characterized 13 types of daily macrosynoptic weather situations for the Carpathian Basin taking into account the surface baric field. Since 1983, typifying has been continued and Károssy [41] has published the daily code numbers.

The catalogue of Hess-Brezowsky [42] based on baric circumstances of Central Europe, distinguishes four zonal, 18 meridional and seven mixed types of weather situations, maintaining one type for unclassified baric areas. The codes which were necessary for these investigations are taken from publication of Hess and Brezowsky [42].

4.8.2. Weather fronts and air masses

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 [43]. We determined the upper air masses according to the measuring of radiosondes giving information about the cross-section in time. We used for our examinations the data of the Heart and Dart (*Agrotis exclamationis* L.) adults getting from the light-trap network in Hungary. The different air masses were classified into 22 classes, the weather fronts in turn into 20 classes [44].

4.8.3. Weather events

We used the meteorological data that was published in 'Calendar of weather phenomena' between 1967 and 1990 by Hungarian Meteorological Service for the examination of weather events.

4.8.4. Weather elements

The measurements of the weather elements made every 3 hours were collected from the 'Yearbook of the Central Meteorological Institution of the National Meteorological Service'. We used the whole Macrolepidoptera data for the investigation of the number of species and individuals in connection with daily temperature range [45]. The caught individuals and species were investigated separately according to each aspect: spring, early- and late- summer and autumn [46]. Our study [47] deals with the effect of weather conditions on the light-trap catch of two Caddisfly (Trichoptera) species.

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.

4.9. The air pollutants

We analysed the ozone data registered at K-pusztá between 1997 and 2006 (<http://tarantula.nilu.no/projects/ccc/emepdata.hzml/>) for the examinations of light-trap catch in connection with the ozone pollution.

We have downloaded the ozone content data ($\mu\text{g}/\text{m}^3$) from the website of Norsk institutt for luftforskning (Norwegian Institute for Air Research (NILU)) (<http://tarantula.nilu.no/projects/ccc/emepdata.hzml/>).

For the recent study, the values of the chemical air pollutants: SO_2 , NO, NO_2 , NO_x , CO, PM10 and O_3 (in milligram per cubic meter) were measured in nearest automatic measurement station at Székesfehérvár (47°17'45"N and 18°19'59"E).

5. Methods

The number of individuals of a given species in different places and years is not the same. Therefore, we calculated 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. RC values were placed according to the features of the given day, and then were summed up and averaged. We arranged the catch and environmental data pairs of in classes, and then averaged them. Regression equations were calculated for RC of examined species and environmental factors data pairs.

Data on the environmental factors were arranged into classes according to the Sturges' method [48]. The relative catch values were assigned into the classes of the environmental factors belonging to the given day and then they were summarized and averaged.

6. Results

6.1. The solar activity and its influence on Earth

6.1.1. Solar activity featured by *Q*-index

The paper of Nowinszky and Puskás [49] deals with connections between the solar flare activities and light-trap collection of Horse Chestnut Leaf Miner (*Cameraria ohridella* Deschka et Dimić 1986). It was confirmed from their data that the *Q*-index significantly modified the daily catches, thus expressing the different intensities and duration of the solar flares. It was noticed that some of the Caddisfly species (Trichoptera) collected by Nowinszky et al. [50] showed the increase of the high values of the *Q*-index, but in other species there was a decrease in the *Q*-index. In case, the value of the *Q*-index is high, there is an increase of the catch after a decrease, which can be observed in some cases. We found an increasing tendency in nine species, if the *Q*-index value was in an increasing period. A decrease could be seen in the case of 14 species and increases after decreasing in the case of seven species if *Q*-index was increasing.

6.1.2. Solar activity featured by 2800 MHz radio flux

Tóth and Nowinszky [51] found that a moderate increase of solar radio flux measured at 2800 MHz in the preceding day coincided with an increase, however, a slight decrease or marked increase of the radio flux with a decrease in the light-trap catches of the Turnip Moth (*Agrotis segetum* Den. Et Schiff.) on nights following the solar H-alpha flares of importance (class) 2 and 3, the yield of light-trap catches also decreased.

6.1.3. Solar activity featured by ionospheric storms and atmospheric radio noises

We found in one of our previous study [52] that at the time of negative ionospheric storms ($\Delta K_f F_2$) the light-trap catch of Winter Moth (*Operophtera brumata* Linnaeus) and Scarce Umber (*Agriopsis aurantiaria* Hübner) decrease. However, during positive ionospheric storms the catch of these two species was low. The catch of Turnip Moth (*Agrotis segetum* Denis et Schiffermüller) increases in connection with the strengthening atmospheric radio noises (SEA).

6.2. Interplanetary magnetic field sector boundaries

Light-trap catches of all the six pestilent species decrease in the neighbourhood of the sector boundaries of the interplanetary magnetic field. The minimum catch of the four winter geometrid moth species (Winter Moth (*Operophtera brumata* L.), Mottled Umber (*Erannis defoliaria* Cl.), Scarce Umber (*Agriopis aurantiaria* Hbn.) and Feathered Moth (*Colotois pennaria* L.) occur on or following the day of the event [53]. It is remarkable, however, that in contrast to the results reported by Wilcox et al. [54] confirming a fallback of the vorticity area index 2 days prior to the event, in the case of winter moths collected by light-trap, there is a significant decrease in the number of individuals only on or 1 day after the event. This fact contradicts the findings of Wilcox et al. [54] who could not prove a modification of the cyclone activity in connection with the sector boundaries in the summer half-year.

6.2.1. UV-B radiation of Sun

In the majority of examined swarming, the solar UV-B radiation increases the catch initially; at higher values of UV-B radiation the catch is lower. Ten of all swarming was obtained in this result, regardless of the trapping method and location of the taxonomic classification of species. Three times we experienced continuous elevation in swarming, though a decrease in one case decrease when the value of UV-B radiation was increasing. In our recent study (in press), we show the catch increases earlier and afterwards a decrease can be found in two Caddisfly (Trichoptera) species at higher UV-B radiation values. There was an increase at the catch of the third species, but there was decrease in case of the fourth one at higher values of UV-B radiation [55].

6.2.2. Geomagnetic indices

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 an increase in relative catch. In the First Quarter and the Last Quarter, growing values of the horizontal component (*H*-index) are accompanied by a decreasing catch [56].

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 (*H*) component. 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. During New Moon when insects cannot get any light from the Moon for their orientation for the whole night, it can be supposed the increasing geomagnetic field intensity plays a bigger part in the orientation in contradiction to light stimulus, which increases the safety of orientation [15, 31, 57].

6.2.3. The moon phases and the polarized moonlight

Based on our knowledge acquired from the research studies of other scientists and our own findings described above, we summarize the effect of the Moon and moonlight on light trap collection in the following way [8]:

6.3. Lunar phases and the efficiency of light trapping

Lunar phases affect catch result on the different days of lunation considering all light trap types and all species under examination.

Deviations may vary between species; the behaviour of different species may be similar or different,

The catch of certain species may be different or similar when the volume of catch at two distant periods of time is compared.

The catch of the same species might be different in the same period of time and geographical locality, when different types of light traps are used. However, the collecting efficiency of some light traps is almost the same.

In the case of light trap types and all the species under examination a minimum catch is recorded in the presence of a Full Moon.

Maximum catches rarely occur exactly on a New Moon, rather in the First and/or the Last Quarter, or in the phase angle divisions between a New Moon and the Quarters. This might be explained by the joint effect of an already relatively large collecting distance and the high ratio of polarized moonlight characteristic for this period. Consequently, the effect of high polarization that intensifies activity is added to the effect of the collecting distance in increasing the catch.

The influence of the lunar phases in modifying the catch may be detected not only during moonlit hours, but also in those without moonlight. This seems to prove a statement by Danthanarayana [30] claiming that lunar influence is independent of the visibility of the Moon.

Thus, we have to distinguish lunar influence and the influence of moonlight.

6.4. Collecting distance and the efficiency of light trapping

We have to draw a line of distinction between the concept of theoretical and actual collecting distance. The actual collecting distance is, in most cases, much shorter than the theoretical one calculated on the basis of the level of illumination in the environment,

The constant change of the theoretical and actual collecting distance used to play an important, but not exclusive role in the efficiency of collecting. 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, but in the case of 100 W normal bulb traps it was approx. 90 m for many species.

If a catch minimum can be detected at a Full Moon also in the catch data of recent years, the reason for this should be found in other lunar influences.

We find the correction of catch results—applied earlier by more authors— acceptable, even in case of data dating back several decades, only if it happens based on an actual collecting distance. We find a similar correction of recent data perilous.

6.5. Illumination from the Moon and the activity of insects

Generally, illumination by the Moon does not hamper the flight activity of insects. Besides the points made by Dufay [5], 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. Based on data on the rising and setting of the Moon in the period close to the Last Quarter, Reddy et al. [58] determined whether each flight occurred only if the Moon was above the horizon before midnight, the period when this species is active.

The relatively strong illumination by the Moon cannot be the reason for a minimum catch recorded at a Full Moon. Most insects start to fly in some kind of twilight. And illumination at twilight is stronger by orders of magnitude than illumination by moonlight.

Suction trap studies by Danthanarayana [30] have not justified the decrease observable with light traps at a Full Moon.

Observation claiming that insects spend less time in flight during a Full Moon should be compared 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.

6.6. The certainty of the orientation of insects

Moderate catch results recorded at a Full Moon may be explained by the better orientation of insects. This hypothesis attributes low catch results to negative polarization typical for the period immediately before and after a Full Moon, possibly enabling insects to distinguish the light of the lamp from moonlight and thus avoid the trap. Our findings force us to reconsider this hypothesis, as we could not detect any difference between the catch during positive and negative polarization. Still, Jermy's [2] assumption might be true. The experiments by Dacke et al. [59] allow us to presume that the high ratio of polarized moonlight provides more information for insect orientation, than the smaller ratio of positive or negative polarized moonlight in the vicinity of a Full Moon. This might be the reason for high catches recorded in the First and the Last Quarter, and the low ones at a Full Moon. It is derived from the observation that insects use sources of information other than moonlight for their orientation in the vicinity of a Full Moon. Such sources may be the polarization pattern of the sky, lines of geomagnetic force or certain objects in the field. However, in this case orientation relies on light stimuli to a much smaller extent, thus the certainty of orientation might increase. For the nocturnal species, the sensitivity of the optical polarization compass can be greatly increased without any loss of precision [60].

In the last few years, we proved that the polarized moonlight plays a deciding role in the effect of the Moon [16, 61–65].

Comparing the catch results of the different migrant types with those of full lunation (lunar month), the following can be established:

The higher trap catches a smaller number of specimens of the non-migrant species in the First Quarter and at a Full Moon, but there is no observable difference between the different quarters in the catch of the lower trap,

In the case of migrant species, significant differences can be observed in the catch of the lower trap. Collecting is least successful at a New Moon and in the Last Quarter, when the catch is minimum even in the higher trap.

Vertical migrants can be caught with little success in the higher trap in the First Quarter and at a Full Moon, while in the catch of the lower trap no difference can be detected.

There is no significant difference in the catch results of the proposed migrant species, either in the higher or in the lower trap. The development of the number of species and the number of specimen caught of the different migrant types and lunar phases is practically the same [35].

The catching peak of ten harmful Microlepidoptera species is in First Quarter, another ten species have the peak in the First Quarter and Last one, and only in two cases, the catching peak is in Last Quarter [57, 58]. This fact in these Moon Quarters attributes to the high-polarized moonlight. This confirms the results of previous studies given in references [9, 30, 62, 66, 67], which have already established that the polarized moonlight helps the orientation of insects.

6.7. The Weather

6.7.1. Macrosynoptic weather situations

The flying activity of Turnip Moth (*Agrotis segetum* Den. et Schiff.) during the change of macrosynoptic situations classified due to Péczeý is investigated by the numbers of captures of this kind of moths by light traps. It can be shown that the flying activity is high during periods of fundamental changes in the weather situation and the activity resumes low if there is no change in the atmospheric circulation regime. At times of changes and/or existences of these types, the light-trap catches of two insect pests have been investigated [68], Fall Webworm (*Hyphantria cunea* Drury) and the Gipsy Moth (*Lymantria dispar* L.). We publish in this paper the favourable and unfavourable meteorological situations to trap the two given species.

The authors have established that from the various 29 types of Hess-Brezowsky's macrosynoptic weather situations, if they are continuous, which one 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 [36].

6.7.2. Weather fronts and air masses

A few number of individuals were caught by the light-trap if the cold air mass was near the surface. The collecting is successful if there is warm air mass above the surface.

We found the effectiveness of subtropical air masses in increasing flight activity and of course, light-trap catching. We found high catch in that cases, when the arriving cold front brings temperate maritime air in place of Saharan air coming from the Mediterranean Sea which has the strong activity of spherics (electromagnetic radiation) [69].

6.7.3. *Weather events*

The instability line decreases alone the number of caught specimen only at that case, when it repeats during some days. If other meteorological events are involved, the influence is disadvantageous or inefficient for the catching result. The next day the amount of the collection increases only if a subtropical air mass also arrives. The convergence zone is inefficient on its own, but in case of cyclogenesis, the number of collected moth decreases compared with the results of the day before. There is a disadvantageous influence if a moderate maritime air mass is involved from the previous day to the next. The collecting results are small in number on the previous day if cyclogenesis is the only influencing factor. On the day of arrival, it is also low when it is combined with any other meteorological events. In case of country-wide rain, the catching is low even on the next day. It is noticeable that country-wide rain on its own is favourable before and after the event for the success of the catching, but if it comes with any other meteorological events, it is unfavourable for the catching. For a cold weather front arriving on its own on, the previous day of its arrival is advantageous for collecting, but it is unfavourable on the day of arrival and the following one. It is also disadvantageous if it is combined with a moderate air mass, and the collecting results are higher in number in case of an arctic air mass, but they decrease on the next day. A warm weather front arriving combined with a subtropical air mass is favourable for the catching on the day of arrival and the previous one, but it is unfavourable if the warm front combines with moderate maritime air mass. The number of moths caught is low on the day of arrival and the following one if there is a moderate maritime air mass and it is independent from whether it is combined with any other meteorological events or not. The number of the catching is not very high—except if it is combined with other meteorological events—on the previous day of the arrival of a moderate continental air mass, but it is high on the following days. If the instability line on the previous day is followed by a moderate continental air mass with a cold front on the day of arrival, the catching of the previous night is high in number, but it is low on the following one. If the instability line on the previous day is followed by a moderate maritime air mass with a cold front on the day of arrival, a low number of the collection can be detected on that day, but it is increasing on the following one. Subtropical maritime air masses—arriving on their own, with the instability line and a cold front—are disadvantageous, but they are favourable on the previous and following days. If these sorts of air masses combine with a convergence zone and cyclogenesis, the number of the collection is less on the previous night.

Subtropical maritime air masses—arriving with a warm weather front—are advantageous for the success of collecting on the previous day and also on the day of arrival. The number of moths caught showed a decrease on the day of the arrival of a subtropical continental air mass and the trend was the same on the next day. The number of moths collected is lower on the day of the arriving of subtropical continental air masses and the following days. The catching

is high in number on the previous day and the day of the arriving of an arctic air mass combined with a cold weather front, but there is a decrease on the following day [70].

6.8. Weather elements

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 brings on the ratio between the mass and surface of the body of the insect [71]. 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 [72]. Southwood [73] on the other hand, is of the view that the flight of insects has a minimum and maximum temperature threshold typical for each species. The insect flies if the temperature is above the minimum and below the maximum threshold and becomes inactive when the value is below the minimum or above the maximum threshold. According to him, there are other reasons for 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 [47, 74, 75].

The high values of air temperature vapour pressure, saturation deficit and the height of cloud base increase the catch of *Rivula sericealis* Scopoli, and on the contrary, the wind velocity, relative humidity and amount of cloud decrease it.

The decreasing clouds, and thunder and lightning preceding thunderstorms also increase the flight activity. Modifying effect of precipitation has become more accurate as well. The effect of rain in hindering the catch is well known, but the fact that the hindering effect remains after the rain has stopped is a new finding.

Our results demonstrate that low temperature minima depress both the number of species and individuals in all aspects. In contrast, higher than the minimum value can rise in number of caught species and individuals. The daily temperature ranges—the 24-hour period noted between the highest and lowest temperature difference—in the temperate zone are more important than in the tropics, as activity of insects is strongly dependent on the daily temperature range in the temperates than in the tropics [76].

We found that the light trap catch of both Caddisfly (Trichoptera) species increased when the daily maximum temperature, minimum and average values of temperature were 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 [47].

The study of Nowinszky and Puskás [77] examines the efficiency of light-trap catching of Turnip Moth (*Agrotis segetum* Den. et. Schiff.) and various values of atmospheric electricity. The number of specimens trapped is the largest near the region close to 0 V/m. The rising positive values have a slight effect on the catch, while negative values of the atmospheric electricity are extremely disadvantageous for trapping.

6.9. The air pollutants

We established that the light trapping of European Cockchafer (*Melolontha melolontha* L.) is most effective if the ozone concentration is high. As opposed to this, low ozone concentration reduces the success of the catch [78]. We established that the light trapping of this Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) is most fruitful when the ozone content of the air exceeds the 80 $\mu\text{g}/\text{m}^3$ value. As opposed to this, the low ozone values reduce the success of the catching to a moderate level. Our results suggest that the flying activity of the European Cornborer (*Ostrinia nubilalis* Hbn.) increase when the ozone content is high. The light-trap catches verify this fact [79]. In a recent study, the light-trap catch of three beetle species (Coleoptera) in connection with the everyday function of the chemical air pollutants (SO_2 , NO, NO_2 , NO_x , CO, PM10, O_3) has been examined.

We found that the behaviour of the studied beetle species can be divided only into two types: as the air pollution increases the catch either increase or decrease [80].

7. Discussion

Based on our studies, the examined species are of three types: ascending, descending, ascending then descending. The increase or decrease in the catch can be explained by our previous hypotheses. There is always a correlation between low relative catch values and environmental factors in which the flight of insects is reduced. However, high values cannot be interpreted easily. Major environmental changes lead to physiological transformations of insect organisms. The imago is short-lived; therefore adverse conditions endanger the survival of the given specimen and the species as a whole. According to our hypothesis, the individual may adopt two different strategies to evade the impacts hindering its normal functioning. It may either display more activity by increasing flying intensity, copulation and egg-laying activities or take sanctuary against environmental factors of an unfavourable situation. In accordance with what we have found, we might say that both high and low catch can occur in case of unfavourable environmental factors [16]. It can be explained on the basis of our hypothesis of the first rising and then falling catch results. However, the answer is in the passivity for the additional increase of the radiation.

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