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Review Article

Light-trap Catch of Harmful Microlepidoptera Species in Connection with Polarized Moonlight and Collecting Distance

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Abstract: The paper deals with light-trap catch of 25 Microlepidoptera species depending on the polarized moonlight and collecting distance. The catching data were chosen from the 27 stations of the Hungarian National Light-trap Network and from the years between 1959 and 1961. Relative catch values were calculated from the catching data per stations and swarming. They are ranged and averaged in the phase angle divisions. The catching peak of ten species is in First Quarter, another ten species have the peak in the First Quarter and Last one, and only in two cases, the peak is in Last Quarter. Then there is the maximum ratio of polarized moonlight. Catching peak of only three species is in connection with the collecting distance when is the greatest of collection distance.

Keywords: Microlepidoptera, Light-Trap, Moon Phases, Polarized Moonlight, Catching Distance.

1. Introduction

The Hungarian light trap network (Jermy, 1961), has been operating since the 1950s, in recent decades value of materials provided invaluable scientific entomological research base, prognostics of plant protection and environmental research (Nowinszky, 2003).

A number of environmental factors influence the collection results and the moonlight is one of the most important parts, because of inherently of the method.

The influence of the moonlight on the catches of light-traps has been examined for decades (Nowinszky, 2008). In one of the earliest light-trapping studies, Williams (1936) found that much fewer insects were collected at Full Moon compared to New Moon. Williams (1936) 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.

No scientist could give a provable answer to this question in recent decades. Some authors find an explanation by accepting the theory of the impact of a collecting distance, others refer to decreased activity.

1.1 Moonlight inhibits flight's activity

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. Similarly, but with greater precision, we have defined the concept of flight activity as follows. Flight activity is the ratio of the proportion of specimens actually flying inside 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 (Nowinszky and Puskás, 2010). However, it is clear that the proportion of the total population, which currently flying in the air, and they spent time not measured. Therefore, only results in the catching, in field observations and experiments logical conclusion will be confirmed or refuted in the moonlight possible inhibitory effect on flight activity (Nowinszky and Puskás, 2013).

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Because of their studies, Baker and Sadovy (1978); Baker (1979) and Sotthibandhu and Baker (1979) believe that moonlight cannot have an influence on the collecting distance. Thus, in their point of view, increased light intensity moderate flight's activity. McGeachie (1989) is of the view that the change of moonlight influences behavior rather than the efficiency of the trap. With his light trap equipped with two 5W fluorescent UV tubes, Brehm (2002) collected geometrid moths (Geometridae) in Ecuador. He is of the view that the catch represents activity rather than abundance. Maximum activity was recorded right after dusk, decreasing later on. The decrease was stronger at the canopy level than at lower levels, perhaps because the activity of the species drops with low temperature. 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 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. This observation is quite demonstrative, as the eyes of nocturnal insects adapt to darkness only 5-9 minutes after it sets in.

This topic is closely related to the effect of polarized moonlight on the success of light trapping. Danthanarayana and Dashper (1986) 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 Monchadskiy (1963) 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*., 1979), we detected in the combined light-trap catch data of seven 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.

For astronavigation, nocturnal insects can potentially use several celestial cues such as the direct light of the bright moon disc, the circular sky pattern of polarized moonlight around the Moon (atmospheric scattered light), or the constellation of stars (Wehner, 1984; Horváth and Varjú, 2004; Warrant and Dacke, 2011). Insect species may be able to use more than one of these nocturnal orientation cues for navigation. Of these orientation cues, insects can easily see the large and bright moon disc because its perception does not require a specialized visual system (Dacke *et al*., 2003 and 2011). 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 (Tóth *et al*., 1983). The relatively strong illumination by the Moon cannot be the reason for a catch minimum 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 illuminated by moonlight (Nowinszky *et al*., 2008).

According to our opinion, it is impossible that the polarized moonlight reduces the light-trap catch when the polarized moonlight helps the insect orientation (Nowinszky and Puskás, 2013).

1.2 Moonlight decreases the collecting distance

Before we start to discuss the different views in scientific literature regarding the role of the collecting distance as a modifying factor, 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).

1.3 The size of the theoretical collecting distance depends on

The luminous intensity of the artificial light source (Candela), which is theoretically constant, but the change of voltage may modify the parameters of light (lifespan, luminous flux, total power input, and luminous efficacy). 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.

Several authors, for different light-trap types and lunar phases, have calculated theoretical collecting distance. According to calculations by Dufay (1964), the collecting distance of a 125W HPL light source is 70m at a Full Moon and 830m at a New Moon. Bowden and Morris (1975) determined to collect distances for 125W mercury vapour lamp: 35m at a Full Moon, 518m at a New Moon. He described (Bowden, 1982) the collecting radius of three different lamps with the same illumination: a 125W mercury vapour lamp, in the UV range 57m at a Full Moon, 736m at a New Moon, 160W wolfram heater filament mercury vapour lamp 41m at a Full Moon, 531m at a New Moon, 200W wolfram heater filament lamp 30m at a Full Moon, 385m at a New Moon. He also recorded correction values for the codes of the 10 categories of cloud types in tables, according to which the catch rises under more clouded skies. Bowden and Morris (1975) corrected daily catch results by an index calculated from the collecting distance. They established the index in the following way: They determined the collecting distance for all hours of all the nights of the lunation. Taking the value at a New Moon as an index unit (10), they expressed all the index values belonging to the different phase angles as a percentage of this. After this correction, the catch of more taxa reached its maximum at the time of a Full Moon. Nag and Nath (1991) collected in India with a 160W mercury vapour lamp. The catch of the Greek Character (*Agrotis ipsilon* Hfn.) was smaller at a Full Moon. They explain the results by a shorter collecting distance. In the view of Bowden and Church (1973), Vaishampayan and Shrivastava (1978), Vaishampayan and Verma (1982) and Shrivastava *et al*., (1987) the smaller catches of light traps at a Full Moon is in connection with the stronger and brighter light of the Moon and smaller collecting area, and is therefore a clear physical phenomenon.

The authors cited above did not as yet have to consider light pollution.

1.4 The length of a real collecting distance is influenced by the following factors

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.

1.5 The clouds

According to Nowinszky *et al*., (2010b) the clouds determine the theoretical catching distances of both the Járfás-type light-trap 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 with 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 more clear than overcast in the event both the all and low clouds.

1.6 The light pollution

By light pollution, we mean a change in natural nocturnal light conditions caused by anthropogenic activity. Recently Cinzano and his colleagues discussed the nocturnal state of the sky in several studies. They even published a world atlas (2001) 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 *et al*., 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.

The Indian authors (Vaishampayan and Verma, 1982) 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 the difference between the catches of Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) at Full Moon and New Moon in Hungary between 1993 and 2006 (Nowinszky, 2008). 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 (Nowinszky and Puskás, 2011). We also found the highest catch at the same quarters monitoring consolidated light-trap catch results of seven species (Nowinszky *et al*., 1979).

1.7 Vagility of certain species

The vagility (mobility) of the adults of the different species varies, some only fly tens of meters from the population centres as other, migrant moths arrive from a distance of hundreds or thousands of kilometers (Mészáros, 1990).

1.8 The distance of the insects’ reaction to the light stimulus

Laboratory experiments and field observations lead us to believe that the moth attracting power of light is inversely proportionate to the distance. Apart from the quality of light, the distance varied also concerning different species but was generally between 10 and 250 meters (Graham *et al*., 1961; Stewart *et al*., 1969; de Jong *et al*., 1971; Agee, 1972). According to McGeachie (1988), the attracting distance of a 125W mercury vapour lamp is about 10m.

In the course of recapturing tethered and free flying marked specimen of the Large Yellow Underwing (*Noctua pronuba* L.) and *Agrotis exclamationis* L. Baker and his colleagues (Baker and Sadovy, 1978; Baker, 1979; Sotthibandhu and Baker, 1979) established that moths reacted to light from the surprisingly short distance of 3-17m, the difference varies according to the height of the light source. Bucher and Bracken (1979) are of the view that the efficiency of light traps depends on the zone of efficiency, to wit a distance from where it attracts moths, and on trapping efficiency, which is the proportion of trapped insects as compared to the total number arriving to the trap.

The purpose of our current work is to confirm or eke out the analysis of 25 species Microlepidoptera the results of previous research.

2. Material

2.1 Collecting sites and their geographical coordinates

The national light-trap network for all traps we used the data of selected species.

The list of light-traps, the years of their operation and their geographic coordinates of containing the Table 1.

Table 1. Light-traps of the plant protecting stations and research institutes between 1959 and 1961.

Towns and villages	County	Years	Geographical coordinates	
			Latitudes	Longitudes
Baj	Komárom	1959-1961	47°38'N	18°21'E
Budapest	Pest	1959-1961	47°28'N	19°09'E
Budatétény	Pest	1960-1961	47°24'N	19°00'E
Csopak	Veszprém	1959-1961	46°58'N	17°55'E
Fácánkert	Tolna	1959-1961	46°25'N	18°44'E
Gyöngyös	Heves	1959-1961	47°46'N	19°55'E
Győr-Kismegyer	Győr-Sopron-Moson	1959-1961	47°39'N	17°39'E
Hódmezővásárhely	Csongrád	1959-1961	46°25'N	20°19'E
Kecskemét	Bács-Kiskun	1959-1961	46°54'N	19°41'E
Kenderes	Jász-Nagykun-Szolnok	1980-1961	47°13'N	20°43'E
Keszthely	Zala	1959-1961	46°46'N	17°15'E
Kisvárda	Szabolcs-Szatmár-Bereg	1959-1961	48°13'N	22°04'E
Kompolt	Heves	1959-1961	47°44'N	20°14'E
Lengyeltóti	Somogy	1961	46°40'N	17°38'E
Martonvásár	Fejér	1961	47°19'N	18°47'E
Mikepércs	Hajdú-Bihar	1959-1961	47°26'N	21°38'E
Miskolc	Borsod-Abaúj-Zemplén	1959-1961	48°06'N	20°47'E
Mohora	Nógrád	1959-1961	47°59'N	19°20'E
Nagytétény	Pest	1959-1961	47°23'N	18°58'E
Pacsa	Zala	1959-1961	46°43'N	17°00'E
Sopronhorpács	Győr-Sopron-Moson	1959-1961	47°29'N	16°44'E
Szederkény	Baranya	1959-1961	45°59'N	18°27'E
Tanakajd	Vas	1959-1961	47°11'N	16°44'E
Tarhos	Békés	1959-1961	46°48'N	21°12'E
Tass	Pest	1959-1961	47°00'N	19°01'E
Toponár	Somogy	1959-1961	46°23'N	17°50'E
Velence	Fejér	1959-1961	47°14'N	18°39'E

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 holding the funnel and a made of zinc-plated tin join 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 with a colour temperature of 2900°K. The lamp is in middle of the trussing, 200cm aboveground. The upper diameter of the funnel is 32cm, the lower one is 5cm, and its height is 25cm. In each case, chloroform was used as a killing agent.

The traps were operated through every night during the season from April until October. Turning on the light trap was 18 o'clock every night and off at 4 am.

2.2 Species investigated and their catching data

25 harmful Microlepidoptera species were selected from the national light-trap network material date back to years between 1959 and 1961 for our study. For our analyses, the light-traps produced suitable data sets from 25 species of the sampled Microlepidoptera moths as it follows Table 2.

2.3 Data of the moon phases, polarization of moonlight and collecting distances

Data on the illumination of the environment were calculated using our own software. The late astronomer G. Tóth specifically for our joint work developed this software for TI 59 computers at that time (Nowinszky and Tóth, 1987). M. Kiss transcribed the software for modern computers. 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. 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 (Table 3).

Table 2. Scientific and common names of examining Microlepidoptera species and the number of caught specimens and observing data.

English name	Scientific name	Number of Moths	Number of Data
	Yponomeutidae Yponomeutinae		
Orchard Ermine	*Yponomeuta padella* Linnaeus, 1758	300	747
Apple Ermine	*Yponomeuta* malinellus Zeller, 1838	994	1591
	Yponomeutidae *Plutellinae*		
Diamond back Moth	*Plutella xylostella* Linnaeus, 1758	3905	2696
	Oecophoridae Depressariinae		
Long Flat-body	*Depressaria depressana* Fabricius, 1775	338	699
	Gelechiidae Pexicopiinae		
Angoumois Grain Moth	*Sitotroga cerealella* Olivier, 1789	647	968
	Gelechiidae Gelechiinae		
Lesser Bud Moth	*Recurvaria nanella* Denis et Schiffermüller, 1775	898	1178
Beet Moth	*Scrobipalpa ocellatella* Boyd, 1858	2118	1998
	Gelechiidae Chelariinae		
Peach Twig Borer	*Anarsia lineatella* Zeller, 1839	405	825
	Tortricidae Tortricinae		
Dark Fruit-tree Tortrix	*Pandemis heparana* Denis et Schiffermüller, 1775	796	1595
Thicked Twist	*Pandemis dumetana* Treitschke, 1835	3146	2730
Large Fruit-tree	*Archips podana* Scopoli, 1763	180	605
Summer Fruit Tortrix	*Adoxophyes orana* Fischer von Röslerstamm, 1834	860	807
Long-nosed Twist	Sparganothis pilleriana Denis et Schiffermüller, 1775	222	292
	Tortricidae Olethreutinae		
Marbled Orchard Tortrix	*Hedya nubiferana* Haworth, 1811		
Bramble Shoot Moth	*Epiblema uddmanniana* Linnaeus, 1758	120	494
Lettuce Tortrix	*Eucosma conterminana* Guenée, 1845	896	1835
Bud Moth	*Spilonota ocellana* Denis et Schiffermüller, 1775	331	1002
Red Piercer	*Lathronympha strigana* Fabricius, 1775	859	1530
Codling Moth	*Cydia pomonella* Linnaeus, 1758	1281	2702
	Crambidae Evergestinae		
Marbled Yellow Pearl	*Evergestis extimalis* Scopoli, 1763	727	2015
	Crambidae Pyraustinae		
Diamond-spot Sable	*Loxostege sticticalis* Linnaeus, 1761	32294	1915
	Pyralidae Pyralinae		
Meal Moth	*Pyralis farinalis* Linnaeus, 1758	191	633
	Pyralidae Phycitinae		
Rosy-striped Knot-hom	*Onocera semirubella* Scopoli, 1763	21811	4757
Lima-Bean Pod Borer	*Etiella zinckenella* Treitschke, 1832	8203	6129
Eurasian Sunflower Moth	*Homoeosoma nebulella* Denis et Schiffermüller, 1775	859	1656

3. Methods

3.1 Data processing and statistical analysis

We have calculated the relative catch values of the number of specimens trapped by species and broods. 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 a species, relative catching values were calculated from the number of individuals. For each examined species, 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).

The mean revolution time of the moon in its orbit around the Earth is 29.53 days. This time period is not divisible by entire days, therefore we rather used phase angle data. For every midnight of the flight periods (UT = 0 h), we have calculated phase angle data of the moon. The 360° phase angle of the complete lunation was divided into 30 phase angle groups. The phase angle group including the Full Moon (0º or 360º) and ±6º values around it was called 0. Beginning from this group through the First Quarter until a New Moon, groups were marked as -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The next division was ±15, including the New Moon. From the Full Moon through the Last Quarter to the New Moon the phase angle groups were marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each phase group consists of 12° (Nowinszky, 2003). These phase angle groups relate to the four quarters of the lunar cycle as it follows: Full Moon (-2 – +2), Last Quarter (3 – 9), New Moon (10 – -10) and First Quarter (-9 – -3). All nights of the periods investigated were classified into the corresponding phase angle group (Nowinszky, 2003 & 2008).

Table 3. Features of the moonlight and catching distance of the Jermy-type light-trap at midnight, without light pollution, case of clear sky, between 1960.07.23 and 1960.08.22.

Phase angle divisions	Illumination of environment (Lux)	Polarized Moonlight %	Catching distance (metres)
15	0.0012		258.2
-14	0.0013		248.1
-13	0.0016	3.563	223.6
-12	0.0024	4.422	182.6
-11	0.0043	5.365	136.4
-10	0.0061	6.000	114.5
-9	0.0095	6.324	91.8
-8	0.0213	6.576	61.3
-7	0.0314	6.285	50.5
-6	0.0492	5.788	40.3
-5	0.0669	4.950	34.6
-4	0.0952	3.687	29.0
-3	0.1258	2.412	25.2
-2	0.1656	–0.412	22.0
-1	0.1742	–0.115	21.4
0	0.1891	0	20.5
1	0.1532	–1.115	22.8
2	0.1078	–0.041	27.2
3	0.0753	2.511	32.6
4	0.0513	3.927	39.5
5	0.0356	5.412	47.4
6	0.0235	6.869	58.3
7	0.0144	7.941	74.5
8	0.0082	8.714	98.8
9	0.0062	8.765	113.6
10	0.0043	7.212	136.0
11	0.0039	6.083	143.2
12	0.0024	4.939	182.6
13	0.0019		205.2
14	0.0012		258.2

With the help of our own software, we have calculated environmental illumination every night for 11 p.m., which operated in the light traps. From the environmental illumination values, we have calculated theoretical collecting distances, assigning our catch data to these.

We calculated the collecting distance values for the all phase angle divisions. We have sorted relative catch values into the proper phase angle divisions. We have arranged data regarding phase angle divisions together with the relating relative catch values into classes.

The number of these classes was calculated with consideration to the method of Sturges (Odor and Iglói, 1987) by use of the following formula:

$$\mathbf{k = 1 + 3.3 * 1g\ n}$$

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

The data thus obtained are tabulated. We determined that the expected value (1) in which Moon Quarter is significantly higher or lower relative catch value. If in the First or Last Quarter was found high-value relative catch we were looking relationship with the polarized moonlight values, in case of New Moon, with the collection distance.

4. Results and Discussion

Relative catch data of 25 investigated species depending on the phase angle divisions can be seen in Table 4. This Table shows the significance levels of Moon Quarters and the light-trap catch of examining species.

Except for three species, the catching peaks of all the other species can be observed in the First and Last Quarter. The catching peak of ten species is in First Quarter, another ten species have the peak in the First Quarter and Last one, and only in two cases, the peak is in Last Quarter. 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; Nowinszky and Puskás, 2010; Nowinszky *et al*., 2012a) which have already established that the polarized moonlight helps the orientation of insects.

Experiencing a peak in the Last Quarter can be partially explained by the fact that a higher percentage of the polarized moonlight in Last Quarter than in the First Quarter. Another reason may be that in Hungary during the summer months a long time can be seen the Moon in the Last Quarter as the First Quarter. This feature will only cover those species that can fly also in the second half of the night (Nowinszky *et al*., 2007;

Nowinszky *et al*., 2008). The Moon is staying above the horizon in First Quarter in the evening and in the Last Quarter after midnight. In our recent study, the caddisflies (Trichoptera) species led to similar results (Nowinszky *et al*., 2010; Nowinszky *et al*., 2012b). Catching peak of only three species is in connection with the collecting distance.

These species are capable of "use" the large collection distance. This means that they can fly and respond to the light stimulus from this distance. Probably the polarized moonlight is likely to be less important for these species than for most species.

At Full Moon, all examined species' swarming touch bottom. It is certain that this is not because of the strong moonlight, because the twilight hours of environmental lighting is orders of magnitude higher than that moonlight in Full Moon. At dusk, the most species have been flying (Nowinszky *et al*., 2007; Nowinszky *et al*., 2008). It can not be a reason of the smallest collection distance neither because in our new study (Nowinszky and Puskás, 2012) we showed that the moths in the North Carolina and Nebraska (USA) in the recent past the First- and the Last Quarter fly to the greatest number of light-traps in turn in Full Moon the catch is very low. However, today in this area there is extremely high light pollution. Consequently, the collection distance has a little difference between each other.

We think that further studies are necessary to clarify the cause of the minimum catch during the Full Moon.

Table 4. The relative catches of examining species depending on the phase angle divisions of the Moon.

Species / Phase angle divisions of the Moon	Influencing factors (Regression equation — Significance level)
Yponomeutidae Yponomeutinae	
Yponomeuta padella Linnaeus, 1758 Orchard Ermine	Polarized moonlight — First Quarter (-8 — -3) $y = -0.0058x^3 + 0.0906x^2 - 0.312x + 0.9075$ $R^2 = 0.7678$ $P < 0.01$
Yponomeuta malinellus Zeller, 1838 Apple Ermine	Collecting distance — Total Lunar Month $y = 3E\text{-}07x^3 - 0.0001x^2 + 0.0199x + 0.2457$ $R^2 = 0.6998$ $P < 0.001$
Yponomeutidae Plutellinae	
Plutella xylostella Linnaeus, 1758 Diamondback Moth	Polarized moonlight — Last Quarter (2 — 7) $y = 0.0042x^2 + 0.0109x + 0.8542$ $R^2 = 0.9216$
Oecophoridae Depressariinae	
Depressaria depressana Fabricius, 1775 Long Flat-body	Polarized moonlight — Last Quarter (3 — 10) $y = 0.012x^3 - 0.087x^2 + 0.1998x + 0.6482$ $R^2 = 0.8248$
Gelechiidae Pexicopiinae	
Sitotroga cerealella Olivier, 1789 Angoumois Grain Moth	Collecting distance — First Quarter (-12 — 0) $y = 0.4291Ln(x) - 0.5035$ $R^2 = 0.8024$ $P < 0.001$
Gelechiidae Gelechiinae	
Recurvaria nanella Denis et Schiffermüller, 1775 Lesser Bud Moth	Polarized moonlight — First and Last Quarter (-6 — -1) and (2 — 7) $y = -0.0054x^3 + 0.0355x^2 + 0.0848x + 0.5248$ $R^2 = 0.8892$ $P < 0.01$ $y = 0.0941x + 0.5906$ $P < 0.01$
Scrobipalpa ocellatella Boyd, 1858 Beet Moth	Polarized moonlight — First and Last Quarter (-8 — -3) and (2 — 9) $y = 0.0001x^2 - 0.0073x + 1.1812$ $R^2 = 0.8154$ $P < 0.05$ $y = -0.0105x^2 + 0.1737x + 0.1596$ $R^2 = 0.9283$ $P < 0.001$
Gelechiidae Chelariinae	
Anarsia lineatella Zeller, 1839 Peach Twig Borer	Collecting distance — Total Lunar Month $y = -2E\text{-}07x^3 + 6E\text{-}05x^2 - 0.0024x + 0.8084$ $R^2 = 0.5993$ $P < 0.001$
Tortricidae Tortricinae	
Pandemis heparana Denis et Schiffermüller, 1775 Dark Fruit-tree Tortrix	Polarized moonlight — First Quarter (-8 — -4) $y = 0.1337x + 0.3224$ $R^2 = 0.9617$ $P < 0.01$
Pandemis dumetana Treitschke, 1835 Thicked Twist	Polarized moonlight — First Quarter (-8 — -3) $y = 0.0126x^2 - 0.0085x + 0.7731$ $R^2 = 0.885$ $P < 0.001$
Archips podana Scopoli 1763 Large Fruit-tree Tortrix	Polarized moonlight — First Quarter (-5 — -1) $y = 3.577Ln(x) - 0.0576$ $R^2 = 0.9977$ $P < 0.001$
Adoxophyes orana Fischer von Röslerstamm, 1834 Summer Fruit Tortrix	Polarized moonlight — First and Last Quarter (-9 — -1) and (2 — 9) $y = 0.0065x^2 + 0.104x + 0.2444$ $R^2 = 0.9017$ $P < 0.001$ $y = -0.0124x^2 + 0.2061x + 0.389$ $R^2 = 0.8941$ $P < 0.001$
Sparganothis pilleriana Denis et Schiffermüller, 1775 Long-nosed Twist	Polarized moonlight — First and Last Quarter (-9 – -1) and (1– 9) $y = -0.0013x^3 - 0.004x^2 + 0.2489x - 0.0678$ $R^2 = 0.9204$ $P < 0.001$ $y = 0.0027x^3 - 0.05x^2 + 0.3559x - 0.1132$ $R^2 = 0.7777$ $P < 0.01$

Table 5. The relative catches of examining species depending on the phase angle divisions of the Moon (continuation).

Species / Phase angle divisions of the Moon	Influencing factors (Regression equation — Significance level)
Tortricidae Olethreutinae	
Hedya nubiferana Haworth 1811 Marbled Orchard Tortrix	Polarized moonlight — First Quarter (-7 — -2) $y = -0.024x^3 + 0.2471x^2 - 0.5556x + 1.1025$ $R^2 = 0.9742$ $P < 0.001$
Epiblema uddmanniana Linnaeus, 1758 Bramble Shoot Moth	Polarized moonlight — First and Last Quarter (-7 — -2) and (2 — 7) $y = 0.0177x^3 - 0.1307x^2 + 0.2275x + 0.743$ $^R2 = 0.9038$ $y = -0.0048x^3 + 0.052x^2 - 0.0405x + 0.7323$ $R^2 = 0.8741$ $P < 0.001$
Eucosma conterminana Guénée, 1845 Lettuce Tortrix	Polarized moonlight — First and Last Quarter (-9 — -2) and (3 — 8) $y = -0.0016x^3 + 0.0094x^2 + 0.1228x + 0.6778$ $R^2 = 0.8959$ $P < 0.001$ $y = -0.003x^3 + 0.0586x^2 - 0.3175x + 1.3058$ $R^2 = 0.9118$ $P < 0.001$
Spilonota ocellana Denis et Schiffermüller, 1775 Bud Moth	Polarized moonlight — First Quarter (-5 — -2) $y = 0.1513x + 0.6449$ $R^2 = 0.9666$ $P < 0.05$
Lathronympha strigana Denis et Schiffermüller, 1775 Red Piercer	Polarized moonlight — First Quarter (-9 — -2) $y = -0.0247x^3 + 0.3045x^2 - 1.048x + 1.8038$ $R^2 = 0.8259$ $P < 0.01$
Cydia pomonella Linnaeus, 1758 Codling Moth	Polarized moonlight — First and Last Quarter (-9 — -3) and (3 — 9) $y = 0.008x^2 + 0.0222x + 0.6951$ $R^2 = 0.8582$ $P < 0.01$ $y = 0.0082x^3 - 0.1275x^2 + 0.6647x - 0.4636$ $R^2 = 0.9532$ $P < 0.001$
Crambidae Evergestinae	
Evergestis extimalis Scopoli, 1763 Marbled Yellow Pearl	Polarized moonlight — First Quarter (-9 — -2) $y = -0.0054x^2 + 0.1227x + 0.6133$ $R^2 = 0.94$ $P < 0.001$
Crambidae Pyraustinae	
Loxostege sticticalis Linnaeus, 1761 Diamond-spot Sable	Polarized moonlight — First and Last Quarter (-9 — -2) and (3 — 9) $y = 0.2307Ln(x) + 0.8702$ $R^2 = 0.8876$ $P < 0.01$
Pyralidae Pyralinae	
Pyralis farinalis Linnaeus, 1758 Meal Moth	Polarized moonlight — First Quarter (-7 — -1) $y = 0.0217x^3 - 0.235x^2 + 0.7626x + 0.3572$ $R^2 = 0.773$ $P < 0.01$
Pyralidae Phycitinae	
Onocera semirubella Scopoli, 1763 Rosy-stripet Knot-hom	Polarized moonlight — First and Last Quarter (-9 — -2) and (2 — 9) $y = 0.2077Ln(x) + 0.7924$ $R^2 = 0.9856$ $P < 0.001$ $y = 0.044x + 0.7416$ $R^2 = 0.9337$ $P < 0.001$
Etiella zinckenella Treitschke, 1832 Lima-Bean Pod Borer	Polarized moonlight — First and Last Quarter (-9 — -2) and (3 — 9) $y = -0.0038x^2 + 0.1207x + 0.4719$ $R^2 = 0.9523$ $P < 0.001$ $y = -0.0136x^2 + 0.1749x + 0.6066$ $R^2 = 0.9775$ $P < 0.01$
Homoeosoma nebulella Denis et Schiffermüller, 1775 Eurasian Sunflower Moth	Polarized moonlight — First and Last Quarter (-9 — -1) and (1 — 9) $y = 0.0015x^3 - 0.04x^2 + 0.3343x + 0.3034$ $R^2 = 0.7721$ $P < 0.001$ $y = 0.0026x^3 - 0.0435x^2 + 0.2549x + 0.3349$ $R^2 = 0.8532$ $P < 0.001$

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