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RESEARCH ARTICLE

Possible Reasons for Reduced Light Trap Catches at a Full Moon: Shorter Collecting Distance or Reduced Flight Activity?

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ABSTRACT

The study details the connection between the moon phases, the catching distance and the polarized moonlight and the efficiency of the light trapping. We used the catching data from the light-traps of the Hungarian National Light-trap Network, the fractionating light-trap of Kecskemét, the light-traps working in different states in the USA and data of an Indian study that made their light-trap in India. The catches of the examined species were lowest at the time of a Full Moon in the earlier years and the catch of the European Corn Borer (Ostrinia nubilalis Hbn.) in the latest years, too. This decrease is independent of the geographical locality, the type of the light-traps, too. The catches increase around the first- and last quarters. However in the present light polluted environment the catch of the Fall Webworm Moth (Hyphantria cunea Drury) and the Scarce Bordered Straw (Helicoverpa armigera Hbn.) at the time of a full moon neither low. The increase of the catching distance until some 90 metres increases the light trap catch an exception the catch of the European Corn Borer (Ostrinia nubilalis Hbn.) which growing to the border of the theoretical catching distance. Our findings show a growth of light trap catch when the polarized part of moonlight is higher. The catch of the species trapped at Kecskemét reaches a maximum when polarization is much higher (6.6 and 8.4 %). We can generally declare that the moonlight reduces neither the number of caught individuals by the reduced catching distance neither the reduced flight activity at the Full Moon.

KEYWORDS: *Light-trap, Moon, collecting distance, flying activity*

INTRODUCTION

Most of the authors experienced a drop in the efficiency of light trapping as a result of moonlight. Williams [1] have published fundamental studies in this field. According to Williams [1], the reasons for a smaller catch at a Full Moon might be as follows:

- The light of the lamp collects moths from a smaller area in moonlit environment,
- Moonlight reduces the activity of insects and so the active population accessible for the light trap is smaller,

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.

Our present study examines these two possibilities.

If we presume that strong moonlight at a Full Moon induces unsuccessful light trapping by reducing the collecting distance or inhibiting flight activity, it seems to be advisable to examine if insects start to fly already during twilights - when illumination by the Sun is much stronger than moonlight - and if the number of specimens caught is also low in this period.

Appeared in our study in the recent past Nowinszky et al. [2] we assessed the species caught by the fractionating light-trap start flying to light at night under the most different illumination conditions. These do not suggest a regularity that might be linked to any taxonomical classification.

The beginning of flight to light at night happens at distinct lighting conditions in the case of certain species. These do not indicate a regularity that should be linked to taxonomical rating. The flight of 50 species to light happens when the entire given hour is in the duration of navigation twilight, of 26 species in the duration of astronomical twilight and of seven species in the duration of night light. There were two species where the first imago was already captured during daylight.

The time of sunset and sunrise and the time and duration of civil, nautical and astronomical twilights change from day to day.

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.

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. [3].

―The theoretical collecting distance

The size of the theoretical collecting distance depends on:

- 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).
- The continuously changing illumination of the environment (time and span of twilights, the periodical changes of the Moon, cloudiness, light pollution, that may be different depending on geographical pition, the season of the year or during one night).

The illumination of the clear night sky is 0.0009 lux [4]. he joint effect of clouds and moonlight had been a subject of study by Williams [1]. In the case of noctuids (*octuidae*, he observed tendency of a lower catch by clear that by cloudy skies. Robertson [5] reports on similar results.

n the other hand, several scientists observed that cloudiness –although it lengthens the collecting distance - does not increase, but in fact reduces the efficiency of collecting [6 7,8].

y light pollution, we mean a change in natural nocturnal light conditions caused by anthropogenic activity. Recently Cinzano t al.9]and his colleagues discussed the nocturnal state of the sky in several stues. They even published a world atlas listing the most important data by countries. In this work, the ahors consider artificial illumination above 10% of the natural background illumination as light pollution.

he theoretical collecting distance can be calculated with the help of the following formula:

$$r_0 = \sqrt{\frac{I}{E_S + E_M + E_{NS} + E_{LP}}}$$

Where: r_0 = collecting distance, I = illumination from the lamp [candela], E = the illumination coming from the environment [lux] the latter consisting of the light of the setting or rising Sun (E_S), the Moon (E_M), the starry sky (E_{NS}) and light pollution (E_{LP}).

Theoretical collecting distance has been calculated by several authors, for different light trap types and lunar phases. According to calculations by Dufay [10], the collecting distance of a 125 W HPL light source is 70 m at a Full Moon and 830 m at a New Moon.

Studies by Bowden [11], Bowden [12], Bowden and Church [13] discuss in detail the decline of luminous intensity between civil and astronomical twilight as a function of the lunar phases. He summarized in tables the illumination from the Moon in all lunar phases also considering atmospheric absorption, classified by zones in the vicinity of the equator. They determined collecting distances for 125W mercury vapour lamp: 35m at a Full Moon, 518 m at a New Moon [14]. Bowden [15] described the collecting radius of three different lamps with the same illumination: a 125 W mercury vapour lamp, in the UV range 57 m at a Full Moon, 736 m at a New Moon, 160 wolfram heater filament mercury vapour lamp 41 m at a Full Moon, 531 m at a New Moon, 200 W wolfram heater filament lamp 30 m at a Full Moon, 385 m 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 [14] corrected daily catch results by an index calculated from the collecting distance. After this correction, the catch of more taxa *Bostrychidae* (*Isoptera* and *Spodoptera triturata* Wlk.) reached its maximum at the time of a Full Moon.

In the view of Mukhopadhyay [16], the collecting distance of a 100 W wolfram heater filament light trap is 245.2 m at a New Moon and 16.7 m at a Full Moon.

In the view of Bowden and Curch [13], Vaishampayan and Shrivastava [17], Vaishampayan and Verma [18] and Shrivastava et al. [19] 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 clearly physical phenomenon.

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

In our earlier works (Nowinszky et al. [3], Nowinszky and Tóth [20], we determined these distances as 18m and 298 m for the Jermy-type trap working with a 100W normal bulb. Based on the collecting distances we also calculated the corrections for the Turnip Moth (*Agrotis segetum* Den. et Schiff.) and the Greek Character (*Agrotis ipsilon* Hfn.). The results showed the catch maximums at a Full Moon [21]. However, today we think that the correction based on collecting distances is only acceptable, if the reason for the detected low catch at a Full Moon was – in the case of all species – the minimal collecting distance at that time. In addition, the collecting distance calculated for a New Moon and a Full Moon has shown little difference at the heavily light-polluted areas since the time these papers were written [22]. The theoretical collecting distances of the Jermy-type light-trap in connection with the moon phases for Full Moon suitable light pollution and cloud cover are as follows: Clear sky at Full Moon 14 metres at New Moon 19 metres. The collection distance in case of cloudy sky all at the time of a Full Moon, all at the time of New Moon 20 metres [22].

The real collecting distance

We have defined the concept of a *real collecting distance* by saying that it is a section of the theoretical collecting distance along which an increase of the catch is observable. The length of a real collecting distance is influenced by the following factors

Abiotic factors:

The abiotic factors the successors: the topographic features which can be found inside the all-time theoretical collection distance, the covering of landmarks, buildings, vegetation and the presence of disturbing lights.

Biotic factors:

- Sensitivity to light

It would be practical to define sensitivity to light as the tendency of insects to prefer light stimuli against other kinds of information (the polarization pattern of the sky, lines of geomagnetic forces, and outline of the objects of the terrain) for their spatial orientation in certain cases.

- 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 kilometres [23].

- 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 [24]. However, moths reacting to light do not necessary fly into the trap [25]. Other authors are of the view that the chance of recapturing insects from different distances decreases with the growth of the distance [26].

Moonlight inhibits flight activity

According to Edwards [27], 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 specimen.

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. By available specimens we mean the ones inside the real collecting distance in those hours of trapping, when the given species is flying. If we accept this definition, then the degree of flight activity could be expressed numerically, namely, as the percentage of available specimens actually flying multiplied by the percentage of the length of time spent flying. However, the total number of the specimens of the population available for the trap is never known. The length of time insects spend flying is also impossible to measure.

Győrfi [28] attributes the much smaller amount of insects flying to light at a Full Moon to decreased activity. Nemec [29] is on the view that moths are having an inactive period at a Full Moon. Persson [30] found that moonlight had an effect of decreasing flight activity more in the case of female than male specimen. The study of Bowden and Morris [14] confirms the hypothesis, that insects are more active at a Full Moon, because the catch is higher then what could be expected due to the decreased efficiency of the trap. By reason of their studies, Baker and Sadovy [31], Baker [32] and Sotthibandhu and Baker [33] believe that moonlight cannot have an influence on the collecting distance. Thus, in their point of view, increased light intensity moderates flight activity.

The following observations by Dufay [10] 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.

Experiments by Dacke et al. [34] proved the African scarabid beetle *Scarabeus zambesianus* Péringuey as capable of using polarized moonlight one million times paler than sunlight for orientation. They found that on moonlit nights after astronomic twilight, when the Sun was more than 18 under the horizon and patterns of polarized light from the Sun could not play a role in orientation, the beetles were rolling their pellet of dung radiantly along a straight line. On the other hand, on nights without moonlight this straight line of movement was discontinued. With the help of polarization filters, they managed to change the direction of the beetles' movement.

Hungarian authors Schwind and Horváth [35] (1993), Horváth [36], Horváth [37] Horváth and Gál [38], Horváth and Varjú [39] (1997), Csabai et al. [40] studied the role of polarized light reflected from water surfaces in the orientation of aquatic insects. Horváth and Varjú [41] discovered that some insects are able to use the polarization pattern of the sky in daytime and at dusk. Several aquatic insects find their habitats with the help of polarized light reflected from the water surface. Numerous insects take tar lakes and black nylon foils for water surfaces [42], [43] as they may be much more polar than a water pool. Gál et al. [44] found the polarization pattern of the nocturnal sky - including the position of the Arago- and Babinet-points at a Full Moon - practically identical to that of the diurnal sky, provided that the zenith distance of the Sun and the Moon was the same.

Kovrov and Monchadskiy [45] were the first to examine the use of polarized light for light trapping. They collected with a 1000 W mercury-quartz lamp. Specimens of Diptera species flew to polarized light in greater amount (77 %). Lepidoptera specimens also preferred polarized light. Using polarized light they collected more than twice the amount of the catch of the unpolarized light trap of all insect orders (except Trichoptera). Szentkirályi et al. [46] used horizontally polarized and unpolarized light traps for collecting ground beetles (Carabidae). 8 of the 115 species caught occurred more frequently in the traps emitting polarized light.

The studies discussed above show that despite several decades of research into the influence of the Moon and moonlight on light trap catch, our knowledge in this field remains quite insufficient. Relying on a large amount of light trap catch data from Hungary and abroad, we performed further studies to learn more about lunar influence.

MATERIALS

The Full Moon time data we needed to create our lunar phase classes were downloaded from the Astronomical Applications Department of US Naval Observatory: . Further data required for our studies were found at the following sites: Phase of the Moon: http://aa.usno.navy.mil/cgi-bin/aa pap.pl, and , We have arranged data by Pellicori [47] and Horváth and Varjú [41] on the relative polarization of moonlight into classes of phase angle divisions. Data on the illumination of the environment were calculated with our own software [48]. The software calculates the illumination of the Sun at dusk, the light of the Moon and the illumination of the starry sky – all in lux – for any given geographical place, day and time, separately or summarized. It also calculates with cloudiness.

All our data on clouds were taken from the Annales of the Hungarian Meteorological Service. Data in these books are recorded for every 3rd hour in okta (eighth part). We have used the value given for a given hour also for the following two hours.

Besides all the above, we also considered light pollution data in calculating theoretical collecting distances. Our estimation was based on a study be Cinzano et al. [9], according to lunar illumination data. In our work, we were calculating with average illumination by a Full Moon.

Our light trap catch data come, in part, from the five-decade material of the National Agricultural and Forestry Light

Trap Network of Hungary. We have processed the 3-year data of the fractionating light trap of Kecskemét for 4 species. This trap was operated and the specimens caught were identified by J. Járfás. We have downloaded 12 years of data on the European Corn-Borer (*Ostrinia nubilalis* Hbn.) from the light traps working in the different states of the USA. We have compared our own results to the ones published by Vaishampayan and Verma [18]. Domestic and foreign data employed in our works is listed in Table 1.

METHODS

For every midnight of the flight periods (UT = 0 h), and – in the case of fractionating light- trap – for the 30th minute of every hour we have calculated phase angle data of the Moon. Of the 360 phase angle degrees of the full lunation we established 30 phase angle divisions. The phase angle division including a Full Moon (0^o or 360^o) and values 0 ± 6^o was named 0. Beginning from this group through the First Quarter until a New Moon, divisions were marked as -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The next division is ±15, including the New Moon. From the Full Moon through the Last Quarter in the direction of the New Moon divisions, were marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each division consists of 12 degrees [49]. These phase angle divisions can be related to the four quarters of lunation as follows: Full Moon (-2 – +2), Last Quarter (3 – 9), New Moon (10 – -10) and First Quarter (-9 – -3). The nights and hours of the periods under examination were all classed into these phase angle divisions.

We have calculated the relative catch values of the number of specimens trapped by species and broods. Relative catch (RC) is the ratio of the number of specimen caught in a given sample unit of time (1 hour or 1 night) and the average number of specimen caught in the same time unit calculated for the whole brood. If the number of the specimen trapped equals the average, the value of relative catch is: 1. Only nights and hours with some catch were included in the calculations, as our earlier works [49], had convinced us that although the Moon has an influence on the efficiency of trapping, it never makes collecting impossible.

Further, on, we studied the catch of European Corn Borer (*Ostrinia nubilalis* Hbn.) and the Fall Webworm Moth (*Hyphantria cunea* Drury) as a function of lunar phases based on the data of the National Light Trap Network in the different years. While comparing the catch results of earlier decades with those of recent years, we tried to detect differences that might indicate the possible impact of light pollution. We have examined in relation with the lunar phases data available on the Internet on the European Corn-Borer (*Ostrinia nubilalis* Hbn.) from North-Carolina, Nebraska and Illinois between 1994 and 2005.

The fact that the same subspecies of the Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) is flying in India and Hungary [50] gave us a possibility for and interesting comparison. Using the results of Vaishampayan and Verma [18] collecting in the Jabalpur region of India between 1975 and 1979, we could calculate specimen numbers for the different days of the lunar month. We have processed these with our own method and compared the outcome with the results gained by processing data from Hungary for the period 1994-2006.

We have sorted relative catch values into the proper phase angle divisions. We have arranged data regarding theoretical collecting distance and the relative polarization of moonlight together with the relating relative catch values into classes.

In our examination of the catch and the lunar phases, we plotted relative catch values against phase angle divisions. We have analyzed the difference between the catch results of the 4 quarters with a t-test. For these curves, we have calculated regression equations, the strength of correlation and significance level. These can be seen in our figures.

For calculating real collecting distances, we used, in the first place, data from the fractionating light trap of Kecskemét. For the 30th minute of every hour, we calculated environmental illumination values (lux), considering light coming from the setting or rising Sun, the Moon and the nocturnal sky, including cloudiness. We did not count with light pollution that was probably negligible in those years. From the environmental illumination values we have calculated theoretical collecting distances, assigning our catch data to these.

We have arranged data regarding theoretical collecting distance and the relative polarization of moonlight together with the relating relative catch values into classes.

Using data from Kecskemét, we have examined the connection between the efficiency of trapping and the ratio of polarized moonlight. We have also tested if the efficiency of trapping changes when moonlight oscillates vertically or horizontally. We have arranged data regarding theoretical collecting distance and the relative polarization of moonlight together with the relating relative catch values into classes. We have also plotted relative catch results against collecting distance and polarized moonlight.

RESULTS

Results are shown in Fig. 1 –12 and Table 2.

We compared the catch results of the European Corn-Borer (*Ostrinia nubilalis* Hbn.) in the periods 1959-1963 and 2000-2006. The catch results were very similar. In both periods, catch maxima fell to the vicinity of the First and the Last Quarter and minima to a Full Moon. Light pollution has evidently been on the increase in recent years, so the difference between the collecting distance at a New and a Full Moon decreased. Still, the catch minimum observed at a Full Moon is similar in dimension. Despite a compensation of the difference between collecting distances, low catches at a Full Moon are still observable. Consequently, in this period the catch of this species decreases also due to other reasons (Fig. 1). The comparison of the catch of the Fall Webworm Moth (*Hyphantria cunea* Drury) in the periods of 1953-1963 and 2000-2006 yielded a very important result. The catch minimum at a Full Moon experienced in earlier years has recently disappeared. From this we may conclude that the catch at a Full Moon was primarily influenced by the collecting area (Fig. 2).

The USA is one of the most light polluted territories in the world. Thus, it was expectable, that – as the difference between the collecting distance at a New and a Full Moon is nearly the same – there is no significant change in the catch results at a Full Moon. In spite of all this, a strong decrease is observable in the catch at a Full Moon. However, the reason for this has nothing to do with the collecting distance (Fig. 3).

Data provided by Vaishampayan and Verma [18] make it clear that there was a catch maximum at a New Moon and a minimum at a Full Moon. In Hungary, however, one can observe no maximum at a New Moon or minimum at a Full Moon, only smaller, still significant maxima in the First and the Last Quarter. 30 years ago, India was much likely less light polluted than Hungary has been in recent years. Consequently, there is no difference between the catch in this two quarters, but there is a maximum in the First and the Last Quarter (Fig. 4).

Table1:- Light-trap data from Hungary India and USA

Hungarian light-trap network	**Years**	**Individuals**	**Data**	**Nights**
Ostrinia nubilalis Hbn.	1959–1963	16315	4190	501
Ostrinia nubilalis Hbn.	2001–2006	93509	11264	937
Hyphantria cunea Drury	1953–1963	4895	1428	551
Hyphantria cunea Drury	2000–2006	2659	1225	547
Helicoverpa armigera Hbn.	1993–2006	21578	5467	1186
USA (Nebraska, North Carolina)	Years	Individuals	Data	Nights
Ostrinia nubilalis Hbn.	1994–2005	81103	3677	1091
India (Jabalpur) *	Years	Individuals	Data	Nights
Helicoverpa armigera Hbn.	1975–1979	18732	?	?
Kecskemét	Years	Individuals	Data	Nights
Ostrinia nubilalis Hbn.	1967–1969	1408	707	190
Hyphantria cunea Drury	1967–1969	3141	854	211
Agrotis segetum Den. et Schiff.	1967–1969	5735	952	187
Agrotis exclamationis L.	1967–1969	2449	785	198

* = from data of Vaishampayan and Verma (1982)

Table 2: Light-trap catch depending on the positive and negative polarized moonlight around the Full Moon (Kecskemét, 1967-1969)

Species	Negative	RC	Data	Positive	RC	Data	P
Ostrinia nubilalis Hbn.	– 0.52	1.037	63	0.64	0.796	10	—
	– 1.06	0.786	7	1.52	0.927	19	—
Hyphantria cunea Drury	– 0.52	1.034	100	0.51	0.946	33	—
	– 1.10	0.938	22	1.52	0.967	15	—
Agrotis segetum Den. et Schiff.	– 0.53	0.943	100	0.59	0.425	13	—
	– 1.09	0.739	39	1.52	0.969	46	—
Agrotis exclamationis L.	– 0.53	0.817	71	0.62	0.968	11	—
	– 1.10	0.744	20	1.52	1.238	27	0.05

Notes: RC = average of relative catches, N = Number of data, P = significance

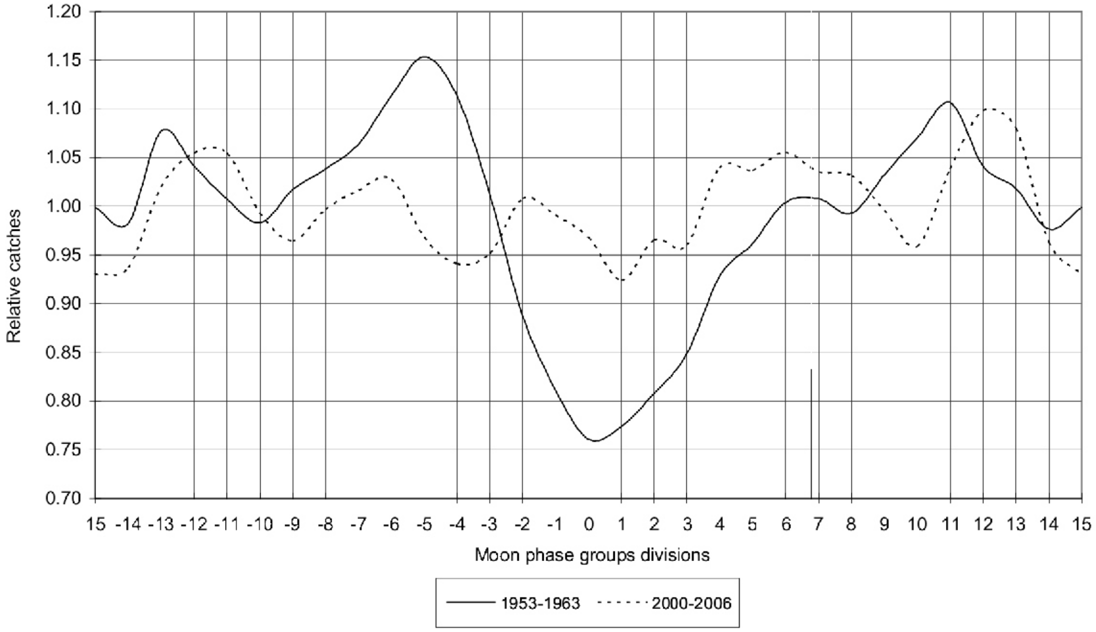
Fig. 1

Light-trap catch of the European Corn Borer (Ostrinia nubilalis Hbn.) as a function Hbn. of moon phases, from the data of Hungarian national light-trap network for the periods 1953-1963 and 2001-2006

Significance levels between a Full Moon and the other moon phases 1953-1963 $P < 0.001$; 2001-2006 $P < 0.05$

Fig. 2

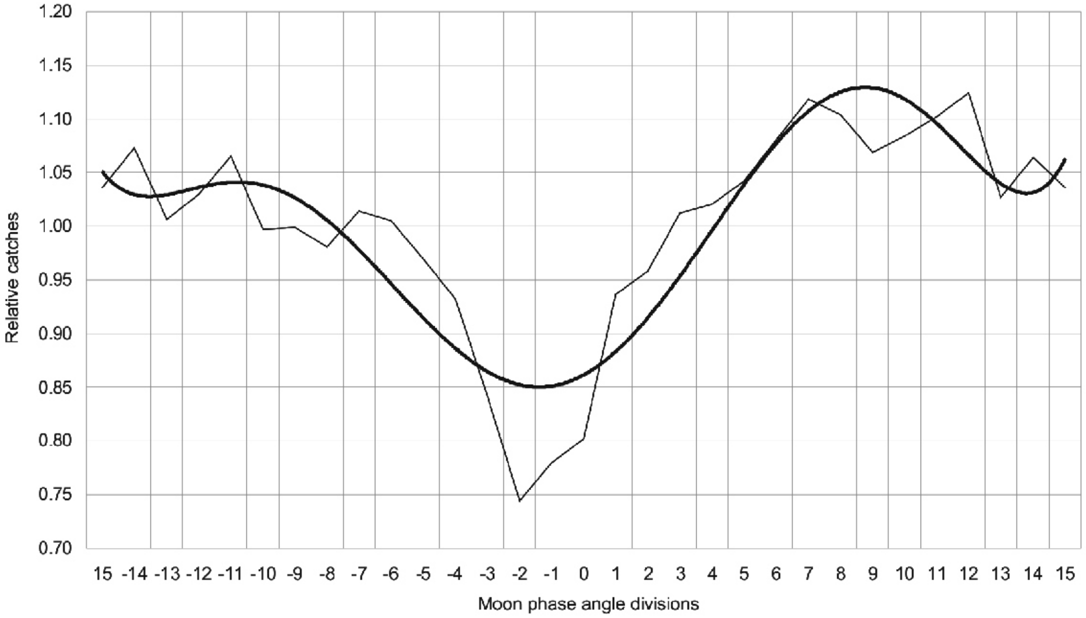
Light -trap catches of Fall Webworm Moth (*Hyphantria cunea* Drury) as a function of moon phases from the data of the national light-trap network between 1953-1963 and 2000-2006



Significance levels between 1959 and 1963: First Quarter and a Full Moon $P < 0.01$, First Quarter and Last Quarter $P < 0.05$, a Full Moon and Last Quarter $P < 0.05$, a Full Moon and New Moon $P < 0.01$. At the time of a Full Moon between 1959-1963 and 2000-2006 $P < 0.001$. The differences of light-trap catches at moon quarters are not significant in years 2000-2006.

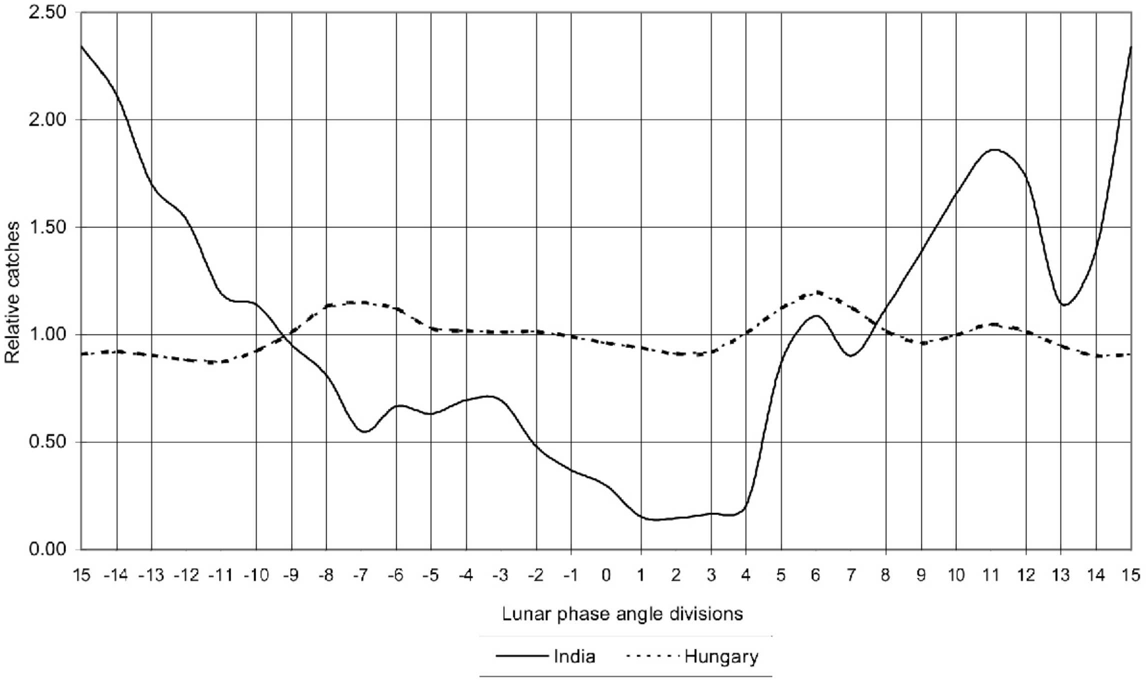
Fig. 3

Light trap catch of the European Corn Borer (*Ostrinia nubilalis* Hbn.) as a function of moon phases, based on data from USA (North Carolina, Nebraska and Illinois) (1994-2006)



The regression equation: $y = 1E\text{-}07x^6 – 1E\text{-}0.5x^5 + 0.0003x^4 – 0.0052x^3 + 0.034x^2 - 0.0921x + 1.1138$ $R^2 = 0.797$ $P < 0.001$. Significance level of the difference between the catch of the Full Moon and all the other moon phases $P < 0.05$

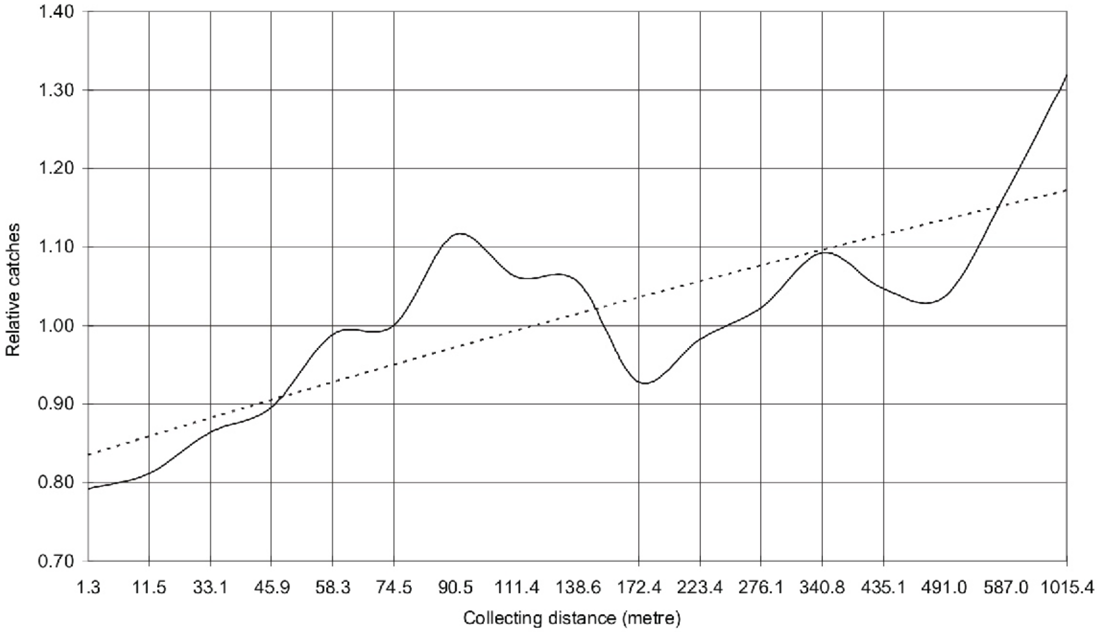
Fig. 4
Light-trap catches of Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) as a function of moon phases in India (1975-1979) from the data of Vaishampayan and Verma (1982) and the Hungarian light-trap network1993-2006



The regression equation for the Indian data: $y = 0.008x^2 – 0.2531x + 2,4113$ $R^2 = 0.822$ $P < 0.001$. Significance levels: First Quarter-Full Moon $P < 0.001$, Full Moon –Last Quarter $P < 0.05$, Full Moon-New Moon $P < 0.001$, Last quarter-New Moon $P < 0.01$. The regression equation for the Hungarian data:

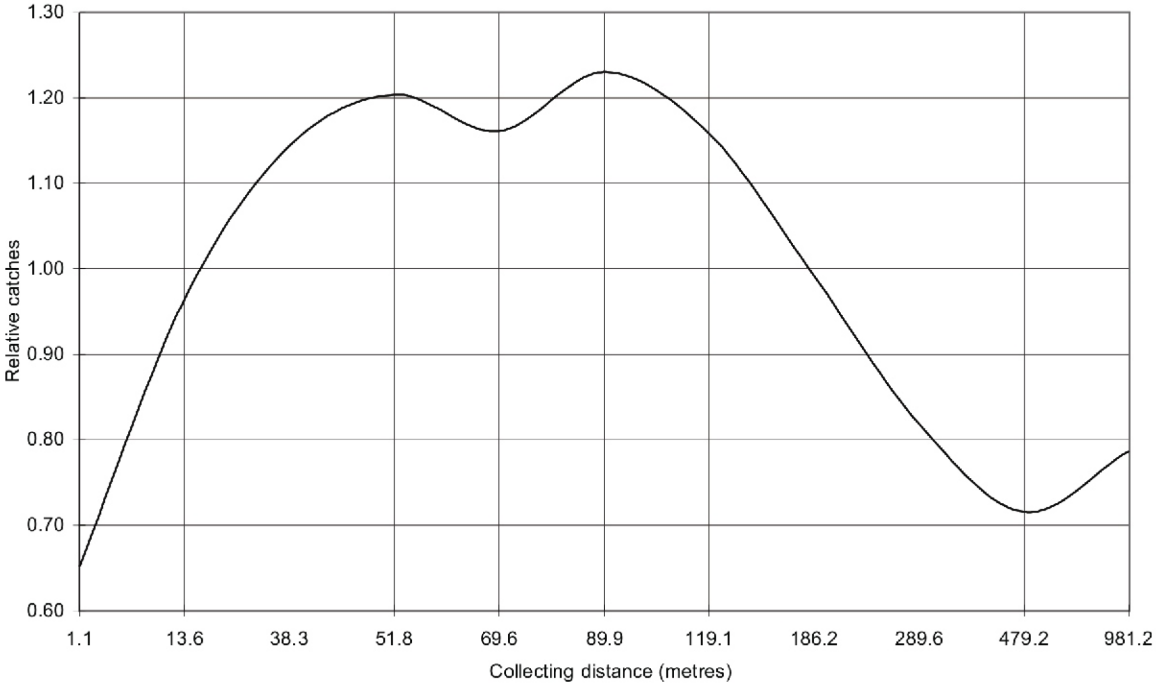
$y = 2E\text{-}07x^6 - 2E\text{-}05x^5 + 0.0006x^4 - 0.011x^3 + 0.0914x^2 - 0.2955x + 1.1671$ $R^2 = 0.5989$ $P < 0.001$

Fig. 5
Light trap catch of the European Corn Borer *(Ostrinia nubilalis* Hbn.) as a function of catching distance (Kecskemét, 1967-1969)



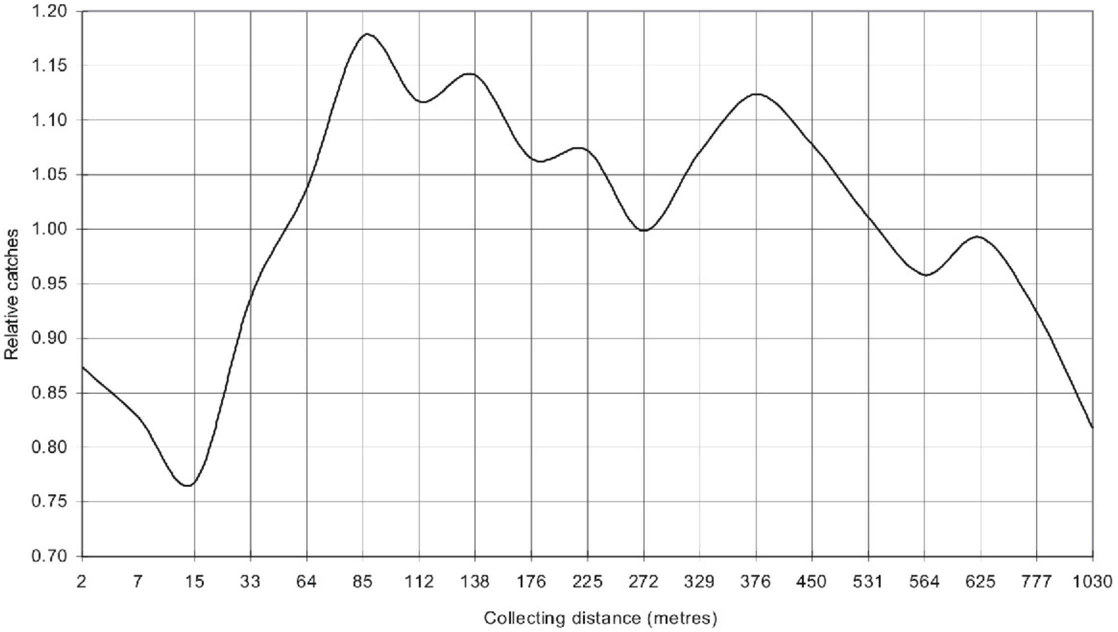
The regression equations between 1.3 and 90.5 metres: $y = 0.0047x^2 + 0.0148x + 0.7701$ $R^2 = 0.978$ $P < 0.001$
Between 1.3 and 1015.4 metres: $y = -0.0002x^2 + 0.8112$ $R^2 = 0.6588$ $P < 0.001$

Fig. 6
Light trap catch of the Fall Webworm Moth (*Hyphantria cunea* Drury) as a function of catching distance (Kecskemét, 1967-1969)



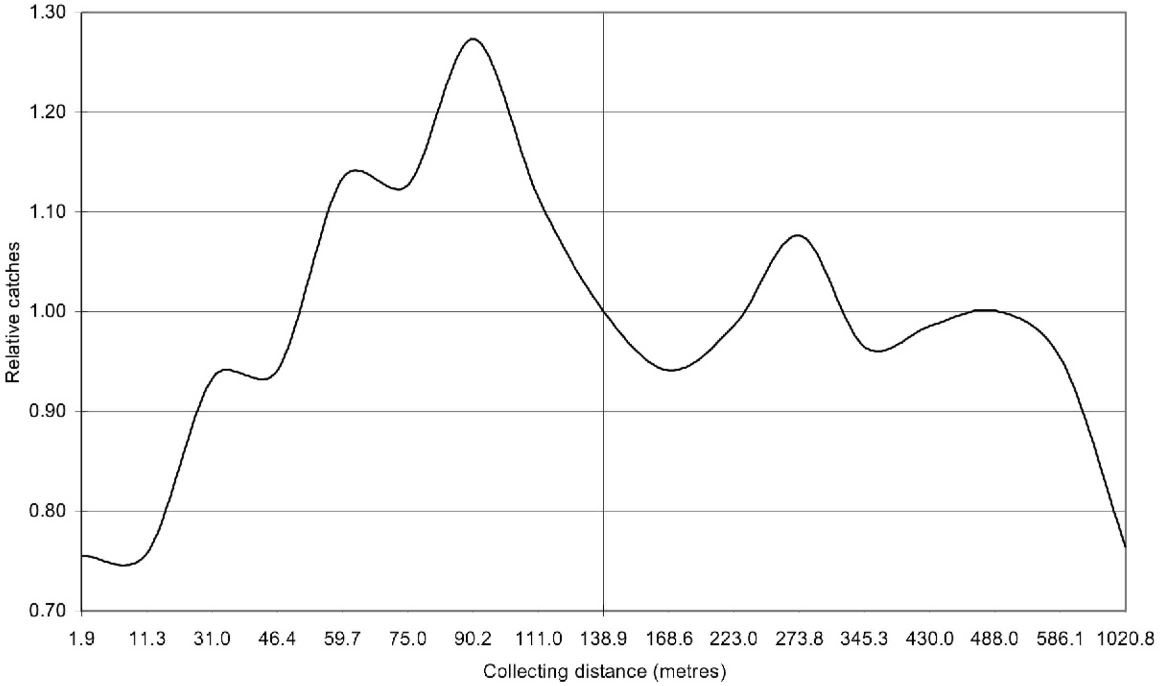
The regression equations between 1.1 and 89.9 metres: $y = 0.0376x^2 + 0.3647x + 0.3531$ $R^2 = 0.956$ $P < 0.001$
Between 89.9 and 981.2 metres: $y = 0.0174x^2 - 0.228x + 04843$ $R^2 = 0.9379$ $P < 0.001$

Fig. 7
Light trap catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) as a function of catching distance (Kecskemét, 1967-1969)



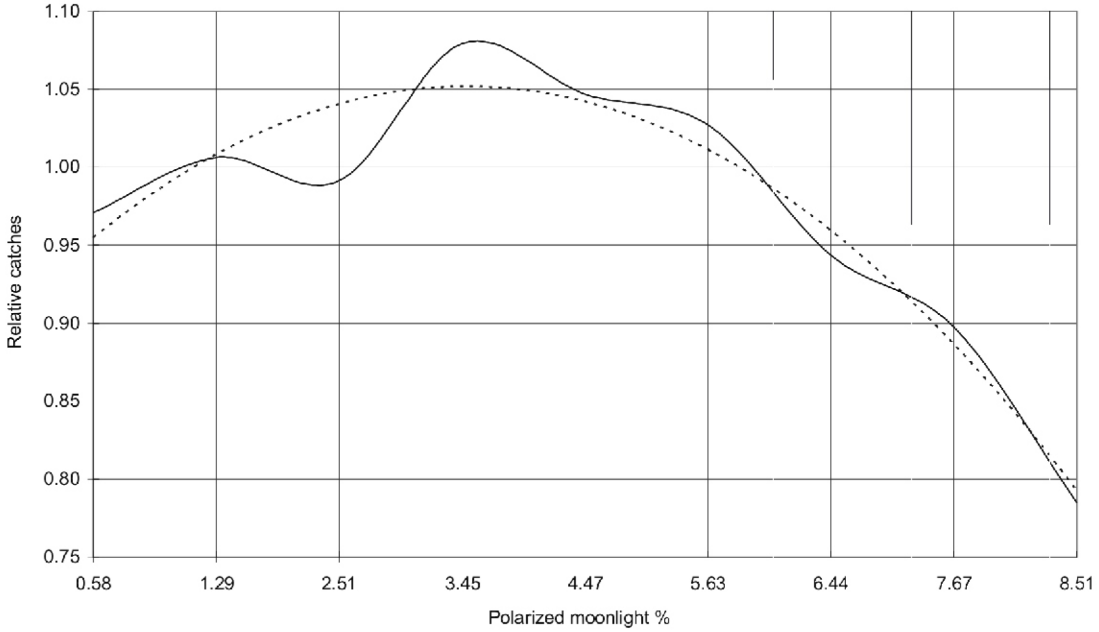
The regression equations between 2 and 85 metres: $y = 0.028x^2 - 0.1301x + 0.9667$ $R^2 = 0.9435$ $P < 0.001$
Between 85 and 1030 metres: $y = -0.014x^2 + 0.0018x + 1.288$ $R^2 = 0.7711$ $P < 0.001$

Fig. 8
Light trap catch of the Heart and Dart Moth (*Agrotis exclamationis* L.) as a function of catching distance (Kecskemét, 1967-1969)



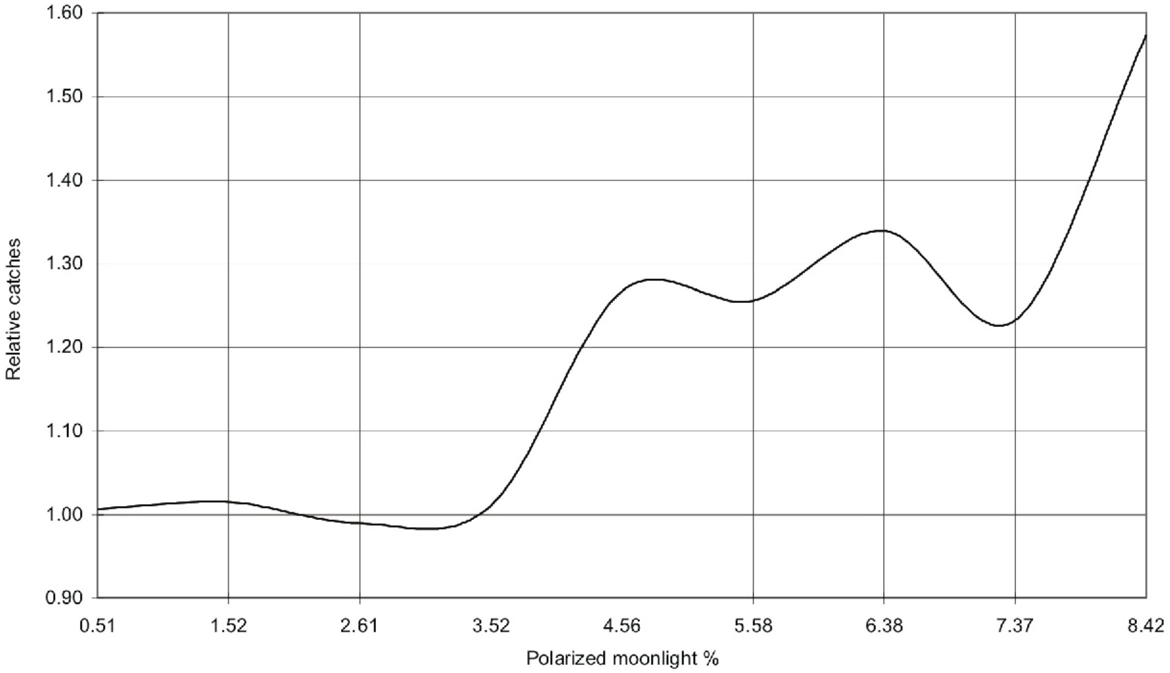
The regression equations between 1.9 and 90.2 metres: $y = 0.0021x^2 - 0.0724x + 0.6576$ $R^2 = 0.9491$ $P < 0.001$
Between 90.2 and 1010.8 metres: $y = -0.012x^2 - 0.0434x + 1.2081$ $R^2 = 0.5747$ $P < 0.01$

Fig. 9
Light trap catch of the European Corn Borer (*Ostrinia nubilalis* Hbn.) as a function of polarized moonlight (Kecskemét, 1967-1969)



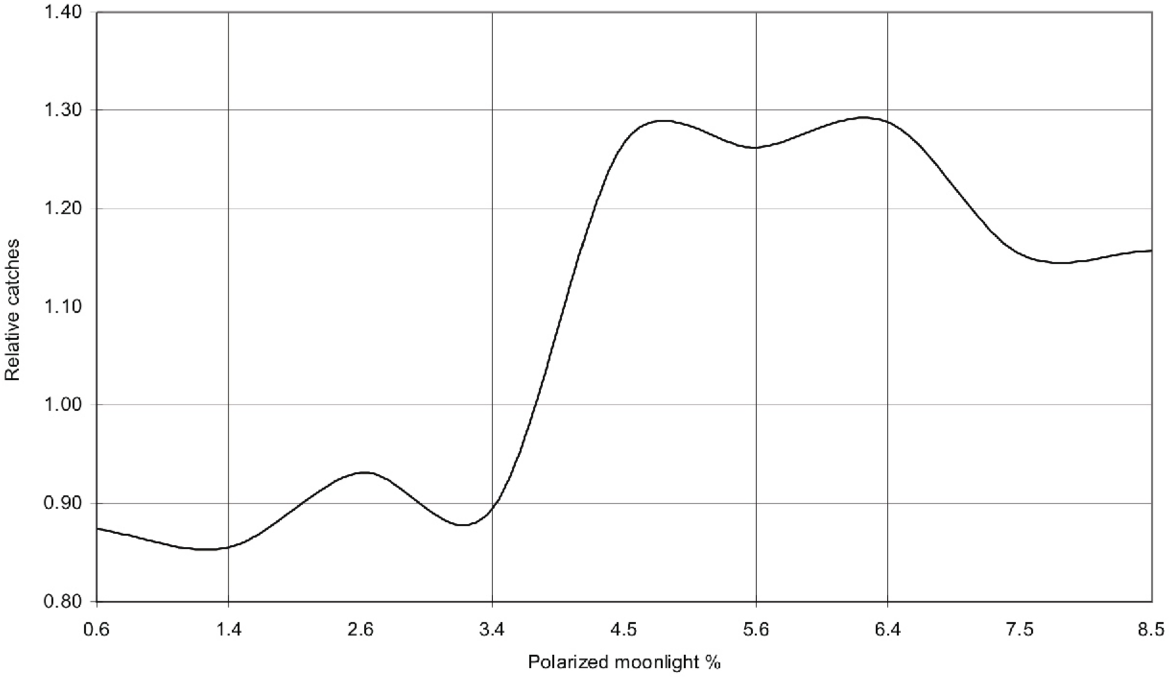
The regression equation: $y = -0.0105x^2 + 0.085x + 0.8804$ $R^2 = 0.9343$ $P < 0.001$

Fig. 10
Light trap catch of the Fall Webworm Moth (*Hyphantria cunea* Drury) as a function of polarized moonlight (Kecskemét, 1967-1969)



The regression equation 3.5 and 8.4 %: $y = 0.081x + 0.9144$ $R^2 = 0.7733$ $P < 0.01$

Fig. 11
Light trap catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) as a function of polarized moonlight (Kecskemét, 1967-1969)



The regression equation 3.4 and 8.5 %: $y = -0.0422x^2 + 0.3241x + 06763$ $R^2 = 0.7463$ $P < 0.05$

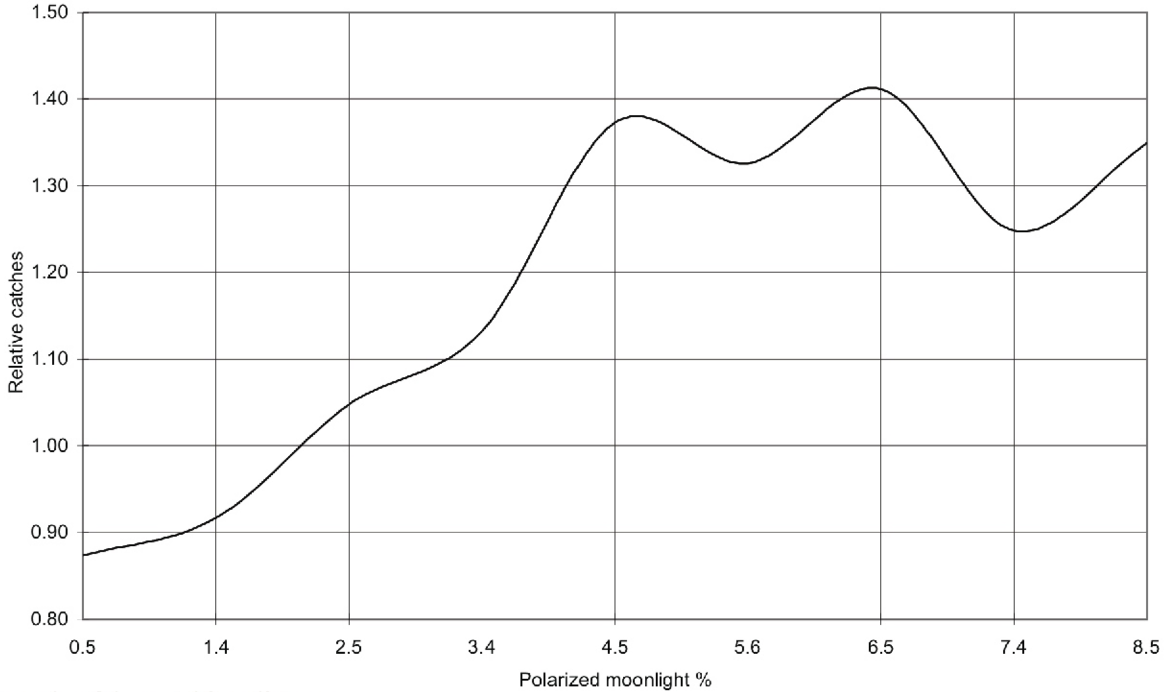


Fig. 12
Light trap catch of the Heart and Dart Moth (*Agrotis exclamationis* L.) as a function of polarized moonlight (Kecskemét, 1967-1969)

- The role of the catching distance
- We have to draw a line of distinction between the concept of a theoretical and that of an actual collecting distance.
- 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,
- 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,
- A change in the collecting distance can have a significant influence only on species that can fly to light from at least the boundaries of the theoretical collecting distance, if no significant amount of vegetation or field objects are present within this distance to overshadow the light source and if the extent of light pollution is negligible. It is also to be considered that in the temperate zone, where dusk lasts relatively long, illumination may change drastically even in a short time. Nevertheless, during the night, clouds and moonlight are the primary causes of the continuous change of illumination both in temperate and tropical areas.
- Light traps don't catch more of such insects arriving from long distance, which can be caught to the light trap at new moon than at full moon.
- Missing that fact we will underestimate the amount of damage.
- The long term changes of light trap catch results can also make a false impression on the changes of masses of well flying species.
- In the case of short distance flying species these distortions are weaker or absent.
- The connection between the light pollution and light trap catch should be investigated separately for every species.
- The role of the flying activity
- Generally, illumination by the Moon does not hamper the flight activity of insects. Besides the points made by Dufay [10], 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,

- The relatively strong illumination by the Moon can not be the reason for a catch minimums 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,
- The experiments by Dacke et al. [34] 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.
- Many insects fly onto the light traps on strongly light polluted areas. In the states of USA (for example North Carolina and Nebraska) the daily catch of a lot of species, for example: Corn Earworm *(Heliothis zea* Boddie), European Corn Borer *(Ostrinia nubilalis* Hbn.), Woolly Bear *(Pyrrharctia Isabella* Smith), and Western Bean Cutworm *(Richia albicosta* Smith) is multitudinous.
- Nevertheless, it is also possible, that in the period of a Full Moon when moonlight is weakly polarized, there is reduced flight activity compared to the period of the First and the Last Quarter, but not to the vicinity of a New Moon.
- Few insects do not fly because of the strong moonlight onto the light trap at the time of a full moon, but because of the deficiency of the polarized moonlight.

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