NOCTURNAL ILLUMINATION AND NIGHT FLYING INSECTS

L. NOWINSZKY

Berzsenyi Dániel College,
H-9700 Szombathely, Károlyi Gáspár square 4.
e-mail: nlaszlo@deimos.bdtf.hu
(phone: +36-94-504-357)

(Received 12th March 2004; accepted 10th May 2004)

Abstract. The present study discusses the light trapping of insects depending on the environmental illumination, twilight polarization phenomena and the moon phases. The trapping data were taken of Hungarian national light-trap network. The important results are the followings: The Babinet-point, a polarization free spot of the sky at twilight, can be a role of orientation of insects. The height of the Moon above the horizon is in negative correlation with the number of the caught insects. The maximum individual number of species was collected at various moon phases.
Keywords: *light-trap, collecting distance, Babinet-point, moon phases*

Introduction

Great many studies in professional literature are devoted to the role of the Moon in modifying light trapping catch. The conclusions are contradictory and up to this day a good many questions have remained unclarified. True, the authors usually collected differing species at the most different geographical locations and have not even registered the Moon phase in every case.

Review of Literature

In astronomical terms, twilight means that the Sun is set just below the horizon. At the time of sunset and sunrise, the zenith distance (ZSun) is equally 90.5°. In the period of civil twilight (ZSun = 90.5°-96°), provided the sky is clear, the visible outlines of objects in the environment make appropriate orientation possible. The brightest celestial bodies which help orientation appear at the time of navigational twilight (Z Sun = 96°-102°). Complete darkness sets in at the end of astronomical twilight (ZSun = 102°-108°). From then on, provided the Moon or zodiacal light observable near the Equator does not enhance the illumination of the environment, only the brightness of the night sky is perceivable. Its mean value is $9*10^{-4}$ lux (Nielsen [116], Roach and Gordon [151]). Naturally, at dawn, the same events follow one another in reverse order.

The light of the sky at sunset and daybreak is strongly polarized. In some places, however, neutral spots can be observed in areas of a few arc-square grades where polarization is practically zero (Rozenberg [156], McCartney [101]). Babinet's point follows the Sun on its virtual trajectory by 15-25° in the evening and precedes it by the same value at daybreak, so it is observable at twilight. More recently, Hungarian researchers have also been devoting attention to the unpolarized points of the sky (Gál et al. [62], Horváth és Varjú [79]). The neutral points are presumably perceived by insects as discontinuities in a sky emitting a continuity of polarized light. Therefore we assume that these points

http://www.ecology.kee.hu • ISSN 1589 1623

might have a role to play in their orientation. From this point of view, Babinet's point especially may be of significance in the periods of evening and dawn twilight.

The question of the distribution of the catch by light-trap in the course of a night has been a subject of research for several decades. Williams [199] used a fractionating light-trap in four years of examining flight activity as it was changing over the night.

Tshernishev [187] claims that the flight activity of each species follows a special daily rhythm that usually corresponds to the time of flying to light. From this point of view he establishes four basic types of insects:

- Flight of short duration tied exclusively to twilight, can never be observed by night (most Ephemeroptera, Corixida, Coleoptera, Diptera and Hepialida species).
- Species of a flight of longer duration. They start their flight later, reaching the peak early in the evening. Some species fly all night (Trichoptera, Chironomida and a few east-African Ephemeroptera species).
- Intensive flight from sunset to close on sunrise, not letting up during the night (Tripuloidea and some Ephemeroptera species).
- Typical night flight with a well discernible nocturnal peak (Ophionina, Lepidoptera, especially the species of Noctuidae and *Serica brunnea* L.).

In the same work, the author lays down for a number of insect orders and for some significant species the values of illumination expressed in lux characterizing the beginning and the peak of the activity. The activity of most Lepidoptera species increases from 0.01 lux to 0.001 lux but decreases by illumination below that value.

The intensity of illumination is of outstanding importance from the point of view of the collecting area as well as regarding flight activity. For by a lower level of illumination in the environment, the light-source of the trap will be discernible from a greater distance. However, this possibility has been studied so far only in the context of the light of the Moon (Bowden and Church [23], Bowden and Morris [26]).

The fact that the polarized light of the sky has a role to play in the orientation of some insects has been known for about fifty years. Dantharanayana and Dashper [43] examined insect behaviour in response to polarized light by using three Pennsylvania type light-traps. It is quite remarkable that the result pertaining to moths contradicts an earlier finding by Kovarov and Montchadski [92] who claim that species of that order fly in masses to polarized light. We have not come across with any publication in professional literature discussing light trapping efficiency in an interrelationship with the position of neutral points.

Several researchers include moonlight in their list of factors that modify collecting, but owe us a detailed analysis of the workings of that influence (Ármai [4], Malicky [99], Harling [73], Hardwick and Lefkovich [72], Jermy [89], Lödl [96], Pedgley et al. [137]). Leinonen et al. [94] tested four different types of light-traps and bulbs in northern Finland. The 4 traps changed places every night, but on every fifth night were put back to their original places, in order to evade the influence of the Moon. Ito et al. [83] applied auto-correlation calculation to establish that collecting by light-trap has a 29-30 day periodicity. In actograph examinations, Danthanarayana and Gu [44] experienced a 27 day periodicity in the flight activity of *Epiphyas postvittana*, a period remarkably close to the length of the sideric lunar month (27.7 days). Ho and Reddy [76] have found that moonlight exerted a stronger influence on light trapping catch than on the catch by pheromon traps.

Findings by other researchers have been contradictory. Corbet [38], Hanna [70], Day

http://www.ecology.kee.hu • ISSN 1589 1623

and Reid [46], Chaston [34], Bidlingmayer [15], Hardwick [71], Mikkola [104], Bowden and Church [23], Bowden and Gibbs [24], Szabó and Járfás [176], Robertson [155], Pedgley [136], Holck and Meek [78] and Brinson et al. [30] either did not find adequate proof to confirm differences in insect activity during lunation, or just stated that the different species reacted to moonlight in different ways. Nabili et al. [112] hold that the lunar phase has no significant bearing on the effectiveness of light trapping useful insects, such as Coccinellidae (Coleoptera), Ophion sp. (Hymenoptera: Ichneumonidae), Chrysopa spp. (Neuroptera: Chrysopidae), Hemiptera: (Nabidae), Hemerobius spp. (Neuroptera: Hemerobiidae). A comprehensive study by Tshernishev [188] refers to several publications that contradict one another. Gregg et al. [65] did not find any difference accompanying the changing phases of the Moon when light trapping migrating noctuids (Noctuidae) and hawk-moths (Sphingidae). However, that may also be explained by the method they used. They arranged the 30 days of lunation into 6 groups, of 5 days each, and subjected them to a contingency test. However, the transformation of the optical parameters of the Moon during the lunar month is not an even process and similar optical conditions are not of identical duration, therefore the method applied does not seem to be satisfactory. Light trapping a mosquito species, *Anopheles aquasalis* Curry in Brazil, Flores-Mendoza and Lourenço-de-Oliveira [60], too, experienced no difference in the number of individuals caught in the presence or in the absence of moonlight.

Most authors, however, observed a decline in the catch under the influence of the Moon. The most fundamental studies are associated with the name of Williams [198] that devised for his specific, entomological purposes equipment to register moonlight (Williams and Emery [201]). He found that on a bright night by new moon, three times as many insects flew to light than at full moon. Under a cloudy sky, the ratio went down to 2:1, while the proportion of insects caught by new moon and full moon, respectively, was 2.7:1, cloud conditions ignored. Subsequently Williams [200] extended research to cover several orders of insects. He collected the highest number of individuals on the 20th day of the lunar month and the lowest on the first day, by full moon, that is. Williams et al. [203] offers two possible explanations:

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

The past few decades did not come up with a satisfactory answer to that dilemma.

Moonlight reduces the quantity of insects trapped. This view is shared by Győrfi [67], Cleve [35], Mazochin-Pornsjakov [100], Hosny [80], Wéber [196], Barr et al. [11], Dzhafarov [55], Bréniére et al. [29], Balogh [9], Mirzayeva [105], Theowald [181], Voigt [195], Brown et al. [31], Agee et al. [1] Bowden [20], Tshernishev and Bogus [189], Schaefer [162], Persson [141], Robertson [152], [153], [154], Southwood [172], Oloy [133], Douthwaite [51], Vaishampayan and Shrivastava [192], Járfás [85], Skuhray and Zumr [170], Morton et al. [109], Herczeg and Vojnits [75], Banerjee et al. [10], Vaishampayan and Verma [193], Tucker [191], Taylor [180], Shrivastava et al. [167], Pedgley et al. [138], Dent and Pawar [47], Mészáros [103], Nag and Nath [113], Muirhead-Thomson [110], Rubio-Palis [157], Syed Nurul Alam [175], Finnamore [58], Dillon and MacKinnon [49], Steinbauer [173], Oxley [134].

Collecting in person in Madagascar, Howell [81] found that on moonless nights, the collecting sheet was covered by an uncountable multitude of insects. Various saturnid (Saturnidae) moths were light trapped by Wenzel in Venezuela (Maag [97]). He had modest catch on moonlit nights. The most favourable preconditions to successful trapping included cloudiness, warm sultriness and thunderstorm by new moon. Light trapping near full moon in Ecuador yielded very low numbers of specimens. The background illumination of the full moon makes artificial light sources practically invisible for insects. This effect is particularly strong in the tropics when the Moon is at its zenith (Brehm [28]).

According to Reinert [146], moonlight influences both light-trap effectiveness and the behaviour of mosquitoes. By full moon the light-trap will collect a smaller number of mosquitoes than by new moon. Garcia [63] collected Sphingidae species with mercury vapour light source in Venezuela. He trapped the highest number of individuals by waning Moon and the smallest number by full moon. In Burkina Faso, Constantini et al. [36] did not experience any influence of the lunar phases on the number of mosquitoes light-trapped indoors, however, out-of-doors, a smaller number of specimens were captivated at full than at new moon. According to a report by the Hock Company [77], in the light trapping of mosquitoes, there is a four-week periodicity accompanying the phases of the Moon. Collecting is successful on clouded and moonless nights. However, when 1-2 pounds of dry ice was hung up in an isolated container over the trap, there was a rise in the number of individuals caught and the influence of the Moon also diminished. In the light trapping of *Sopdoptera exampta* Walker (Lepidoptera: Noctuidae), big catches occurred much more often in the neighbourhood of a new moon than at the time of a full moon (Tucker [191]). The difference between nights with and without rain was insignificant. This refers to the fact that the relationship between rain and collecting has nothing to do with the Moon being covered by clouds. Light trapping the malaria mosquito species, *Anopheles culicifacies* Giles (Diptera: Culicidae) in India, Singh et al. [169] had a bigger catch on moonless than on moonlit nights. The difference was prevalent until midnight. Light trapping *Culicoides brevitarsis* Kieffer (Diptera: Ceratopogonidae), Bishop et al. [17] encountered a minimum by full moon. Whereas changing moonlight in the course of a night at the time of a full moon had no clear influence on the light-trap catch. Yela and Holyoak [204] examined with light-trap and bait trap the night-time activity of Noctuidae. The examination was going on for 2 years, encompassing 170 nights. The number of moths light-trapped diminished in the proximity of a full moon. The catch by the bait trap was not modified by full moon. The light-trap catch was, the bait trap catch was not increasing by growing cloudiness. According to Gustafson [66], the light-trap is not effective on cold nights, in rain, or when the Moon or other bright lights are visible in the area. The period from the last quarter to the new moon is the best time for light trapping. In that period, the Moon is visible little, if at all, in early evening. Butler et al. [33] found that moonlight restricted light trapping on cloudless nights. Moving from effective to less effective, he light-trap catch of *Chilo partellus* Swinhoe had the following order of success in India: new moon, first quarter, last quarter and full moon (Mahadevan and Chelliah [98]). Also in India, Rajaram et al. [145] light-trapped a higher number of specimens of 4 cotton pest species by new moon than by full moon, with differences in ratio though. Moonlight, in the first place by full moon, also slows down the activity of bats. According to Negraeff and Brigham [114], this has an explanation in the higher risk of catching a prey or the diminished number of insects.

The role of moonlight in reducing the catch is taken for granted by many researchers, so much so that they stop operating their light-traps at full moon, using it for collecting

http://www.ecology.kee.hu • ISSN 1589 1623

only at the time of the new moon and /or last quarter, perhaps in the period between the final and first quarter. They (Bragança et al. [27], Hall [69], Andreazze [3], Sant'Ana and Lozovei [159], Summerville and Crist [174], Toda and Kitching [183]) attempt to avoid the adverse impact of the Moon in this way. Tigar and Osborne [182], too, operated light-traps in 5 desert areas of Abu Dhabi by new moon every year. In an experiment, Csóka [40] claimed it was superfluous to operate a light-trap after moonrise, because he was convinced of the chances of a catch greatly reduced by moonlight.

Some researchers explain reduced catch by a slackening of flight activity and by a diminishing collecting area by others. The collecting area changes in line with the twilight or early morning illumination coming from the Sun, the light of the night sky and the light generated in its prevailing phase by the Moon. The light source of the trap is visible from a greater distance in weaker environmental illumination. The views found in professional writing are rather contradictory regarding the question of whether the changing light of the Moon influences the catch by modifying the collecting distance.

The collecting distance as a function of changing moonlight has been calculated by a number of researchers. Using a 125 W HPL light source, Dufay [53] determined the collecting distance as 70 meters at full moon and 830 meters at new moon. Studies by Bowden [19, 20], Bowden and Church [23] discussing in detail the fallback of light intensity from civil twilight to astronomical twilight as a function of the phase of the Moon are of fundamental importance. In these, Bowden examined with graphoanalytical method and arranged in charts the illumination generated by the Moon in its different phases in zones in the vicinity of the Equator, atmospheric light absorption also taken into account. He determined the collecting distances for his 125 W mercury vapour light source as 35 meters at full moon and 519 meters at new moon (Bowden and Morris [26]). Bowden [22] determined, by identical illumination, the collecting radius of three different lamps: 125W mercury vapour in the UV range: 57m at full moon and 736m at new moon, 160 W mercury vapour lamp with wolfram filament: 41m by full moon, 531m by new moon, 200 W wolfram lamp: 30m by full moon, 385m by new moon. Preuss and Preuss [142] established the height, direction and vertical distribution of the flight of nocturnal insects with the help of a telescope set up in the direction of the Moon. They compared their findings to their own light-trap catch data. They determined the collecting distance of the light-trap as 7m. Regarding the distance, Farrow [58] came to an identical conclusion. Observation by Rezbanyai-Reser (verbal message) confirms that light has an area of attraction of not more, perhaps less than 10-20 metres. Only those insects are flying to light that would probably have flied through the area anyway, in the absence of a lamp, too. In the case of a 100 W regular bulb, we determined these distances as 18m and 298m (Nowinszky et al. [122], Nowinszky and Tóth [124]). We also established, however, that the collecting distance had a provable impact on the quantity of the catch only in periods without moonlight when illumination was generated by the setting or rising Sun. The influence of the Moon on the catch exerts itself not only through the modification of the collecting area (Nowinszky et al. [131]).

Some important experiments have shown that insects fly into the trap only from the direct vicinity of the light source, a few meters at most. Recapturing tethered and free-flying marked imagoes of *Noctua pronuba* L. and *Agrotis (Scotia) exclamationis* L., Baker and his fellow researchers (Baker and Sadovy [7], Baker [6], Sotthibandhu and Baker [171]) found that the insects reacted to artificial light from the amazingly short distance of 3-17m, depending on the height of the light source. These authors rule out the possibility of moonlight exerting any influence on the collecting distance. They hold that the growing intensity of light slackens flight activity. The chance of recapturing insects released at different distances from the light-trap decreases in proportion to the growth of the distance (Szeőke [179], Morrison et al. [108]), while the proportion of the individuals trapped of the ones in the direct vicinity of the trap is identical (Bucher and Bracken [32]).

Other researchers are of the view that moonlight slackens the flight activity of insects. Over a period of three years, Nemec [115] collected the smallest number of *Heliothis zea* Boddie specimens at full moon, and the highest number at new moon. To find out about the reasons, he brought up the moths in total darkness in a laboratory. They became inactive as soon as illumination rose to over 0.1 lux. That observation, combined with his light-trap results, lead him to the conclusion that moonlight hindered flying activity. McGeachie [102] reached the same conclusion.

On the other hand, observations by Dufay [53] contradict the theory on the hindering impact of moonlight:

- Even in moonlight, nocturnal moths are there to be seen in the beam of car head-lights.
- The catch diminishes but does not stop altogether at a full moon.
- At the time of a lunar eclipse when the Moon is hiding, the catch is high, despite being low directly before and after the eclipse. This is a rather telling observation, as the eyes of nocturnal insect's adept to darkness with a delay of 5-9 minutes.

Personally engaged in collecting at the time of a lunar eclipse, Rezbanyai-Reser [147] once observed stepped up insect flight activity as soon as the Moon disappeared, and again, its gradual dying away after the Moon appeared in the sky.

Bowden and Morris [26] always calculated for an identical area the volume of their catch made in the course of the lunar month in areas reduced by the effect of moonlight. The highs of the standardized data occurring in the proximity of the full moon also contradict the theory on the hindering effect of moonlight. Our own experiments (Nowinszky and Tóth [126]) have also shown, after the corrections required by the change in the area of collecting were made, a maximum catch of two pestilent species (*Scotia segetum* Schiff. and *Scotia ipsilon* Hfn.) at full moon. In a subsequent work, Bowden [22] criticizes the remark by Baker and Sadovy [7] who had claimed that the large yellow underwing (*Noctua pronuba* L.) and the heart-and-dart moth (*Scotia exclamationis* L.) fly to light only from a distance inside 3m. Were that the case, Bowden holds, a large volume of light-trap catch over a single night would entail the existence of a population too large to be true. He believes the findings of Baker and Sadovy [7] might be valid for certain forms of behaviour in the direct vicinity of a strong light source, yet argues that their method of experimentation may be subject to criticism.

Jermy's assumption [88] that the presence of moonlight reduces the catch because it helps insects by enhancing their security of orientation is remarkable, although unchecked by concrete experiments. Wehner [197] claims that nocturnal insects, guided by the light of the Moon, are capable of orientation in space, despite the fact of this being a much more complicated task than orientation by the Sun at daytime. For the Moon is not above the horizon every night, the time of its rise and set changes from night to night, and its position alters much more drastically in the course of a night than that of the Sun in the course of a day.

A number of researchers have found that intensive moonlight does not reduce, in fact, in some cases, increases the catch by light-trap (Bogus [18], Pristavko [143], Cullen [39], Johnson [90], Duviard [54], Papp and Vojnits [135], Doiron and De Oliveira [50], Bowden and Jones [25], Járfás and Viola [86], Jeffrey and Dyor [87], Cook and Perfect [37], Shrivastava et al. [166], Saroja et al. [161], Linhares and Anderson [95], Ito et al. [83], Janousek and Olson [84]). Collecting two rice pests (*Scotinophora coarctata* F. and *Scotinophora lurida* Burmeister) with a 125 W mercury vapour lamp, Balasubramani et al. [8] observed a higher catch by the full, then by the new moon. The Malayan Black Bug (*Scotinophora coarctata* Fabricius) flies to light in large quantities. It can be light-trapped in the largest masses during the five days before and after the full moon (http://pne.gsnu.ac.kr/riceipm/ scotinop.htm.) Sharma and Badan [165] observed a catch maximum both at the time of the new and the full moon and a minimum in the vicinity of the first and last quarters. Sekhar et al. [164] claims, that the catch is higher in the period from the full to the new moon than from the new to the full moon. Collecting mosquito species, Dickson and Hatch [48] encountered a catch maximum in the first or last quarter.

According to some observations, flying activity is lengthened by the stay of the Moon above the horizon (Heikkinheimo [74]) and that leads to a richer catch (Nowinszky and Tóth [124], Tóth et al. [186], Nowinszky et al. [131]). On the other hand, Siddon and Brown [168] in a suction trap experiment encountered a catch maximum 11 hours after sunset in the 7 day period preceding the full moon and 2 hours after sunset, in other words, in the moonless periods of the night in the 7 day period following the full moon.

From the point of view of clarifying the relationship between the light of the Moon and light-trap effectiveness, studies examining the moonlight-related activity of insects by use of other methods are of great significance. For these may exclude the disturbing differences in the reaction of insects to the trap stimulus. Saha and Mukhopadhyaya [158] observed a difference in the copulation activity of the species *Orthomorpha coarctata* Saussure (Polydesmida, Paradoxosomatidae) in the first quarter of lunation. In their experience, the height of activity occurred half an hour before sunset, 3-5 days before the full moon and the new moon. Kerfoot [91] reports, those nocturnal bees carried on with their collecting activity as long as the Moon stayed above the horizon. Some water insect larvae display increased liveliness of activity in the presence of moonlight (Ribbands [148]), an experience not shared by some other authors (Andersen [2], Chaston [34]). Some mosquitoes, gnats and tsetse flies become more aggressive when the Moon is visible (Vanderplank [194], Ribbands [148], Monchdadskiy [107], Muradov [111]). On the other hand, observation to the opposite effect is reported by Bhatt et al. [13]. Desert ants carry on with their daytime feeding activity on moonlit nights (Hunt [82]). Riley et al. [150] have observed in radar experiments that the presence of moonlight protracts the activity of insects flying at twilight. Sáringer [160], too, believes in the possibility of moonlight making the day longer for insects with a perception threshold of luminous intensity below that of the Moon. Therefore in the case of some species, moonlight should also be considered in any study of the photoperiodic reactions. According to Schaefer [162], the flight maximum observed by radar was not reflected in the light-trap catch in strong moonlight. Using a radar device, Drake [52] and Riley et al. [149] who also used radar as well as infrared optics found no relationship between the direction of the orientation of migratory insects and the position of the Moon, therefore they do no see the theory of orientation by the Moon confirmed. From the catch of a Jermy-type light-trap and bait trap of the same construction, Gyulai and Nádler [68] have come to the conclusion that a light-trap will catch a higher number of insect species and individuals in most parts of the year. However, at spring, in the autumn and by strong moonlight, catch results are balanced out over the year. Suction traps often demonstrate an activity peak, not indicated by light-traps, in the period of the full moon (El-Ziady [57], Bidlingmayer [14], Perfect and Cook [140]). In a subsequent suction trap examination, Bidlingmayer [15] found no difference between the collecting results in the period of the full moon on the one hand and the new moon on the other. Bidlingmayer [16] also established that the number of mosquitoes collected in the suction and bait traps from the time of the new moon to that of the full moon grew by 2-3% every day. Bowden's [21] corrected light-trap data were basically the same as those of the suction trap. Using a suction trap, Davies [45] demonstrated an activity peak in the evening and in early morning at the time of the new moon, on other nights this was modified in line with the phase of the Moon and at the time of the full moon shifted in time to coincide with the time of the rise of the Moon and the middle of the night. The light-trap catch did not confirm evening and early morning activity. In pheromone trap experiments, Sekhar et al. [163] found no difference in the number of *Helicoverpa armigera* Hbn. moths collected at the time of the full moon on the one hand and that of the new moon on the other. Mean catches of the African sweet potato weevils, *Cylas brunneus* and *Cylas puncticollis*, did not differ significantly between new and full moon caught by pheromone trap (Laboke and al. [93]). Tshernishev and Dantanarayana [190]) established in laboratory experiments that the activity of the three noctuid species (*Helicoverpa armigera* Hbn., *Helicoverpa punctigera* Wallengren and *Heliothis rubescens* Walker) studied with the help of an infrared actograph reached its peak by full moon and by new moon, and its low from the second day following the new moon to the two days preceding the full moon. Williams and Singh [202] have reported on the following suction trap catch results in the + 3 day proximity of the various Moon phases: full moon: 204, last quarter: 589, new moon: 1 259, first quarter: 562 specimens. El-Ziady [57] modifies the original question by Williams [198] on the modest catch at the time of the full moon in the following way:

- Moonlight has a direct influence on activity and reduces the number of flying insects.
- It is possible that insects stay at the shaded, darker places at the time of the full moon.
- It is equally perceivable that insects fly in the higher layers of the atmosphere in that period.

On the other hand, Danthanarayana [41] in his suction trap experiments detected a major peak in the catch at the time of the new moon and a smaller one at the time of the full moon. According to Danthanarayana [42], the flight activity of insects has a three peak lunar periodicity: in the first and last quarters and directly after the period of the full moon. The latter peak however, remains obscured in light-trap collecting as it occurs in the period characterized by the smallest collecting area. The lunar period of flight activity gets superimposed on the circadian rhythm. In his view, the three peak lunar periodicity might be related to migration. In these periods, insects fly in the higher layers of the atmosphere, thus reaching heights where they get transported by horizontally moving masses of air. In our earlier work (Nowinszky et al. [130]) we demonstrated that only in traps operated at 2 m and 10 m is the difference in the specimen number of migratory species insignificant at the time of the full moon, in the period of other lunar phases, the light-trap lying lower collects a much smaller number of individuals. This fact might support the assumption of Danthanarayana, although in the absence of a satisfactory amount of investigation in Hungary, we cannot come out with a well-founded argument on this question. And in the absence of high traps, the possibility of further research is ruled out. However, the outcome of an experiment by El-Ziady [57] might be an important contribution: using a suction trap placed at a height of about 9m (30 feet), he collected the highest number of flies (Diptera) at the time of the full moon.

Danthanarayana and Dashper [43] observed a peak in the activity of nocturnal insects at the time of the full moon and in the proximity of the first and the last quarters. The latter two maximums are related to polarized moonlight, which is of the highest intensity in the same two lunar quarters. Kovarov and Montchadski [92] found that a light-trap using polarized light was twice as effective as the one using regular light. In an earlier study (Nowinszky et al. [122]), we detected in the combined light-trap catch data of 7 species three catch maximums in the course of the lunar cycle. However, in the place of the first maximum at the time of the full moon, we found a smaller local catch maximum in the period of the new moon. The abundance of catch in the first and last quarters can be explained with the high ratio of polarized moonlight, while the catch high in the vicinity of the new moon, when there is no moonlight, might follow from the fact that this is the phase characterized by the largest collecting area. Mizutani [106] could not confirm the influence of polarized moonlight on the catch, but then he had a mere 17 nights at his disposal and there was a strong wind at the time of collecting. An experiment by Sotthibandhu and Baker [171] shows that the large yellow underwing (*Noctua pronuba* L.) finds its bearings on moonless, bright nights by the stars positioned some 95° from the North Star.

All in all, not to this day have researchers arrived at a common platform regarding the influence of the Moon on the flight activity of insects and on the light-trap catch. Therefore, making use of the enormous mass of collecting data supplied by the Hungarian national light-trap network and the hourly catch of Járfás' fractionating light-trap in Kecskemét, we examined this question in several studies (Nowinszky [119]).

Material and Methods

In our work, we used data of national light-trap network pertaining to the species listed in *Table 1*. The material of the Kecskemét fractionating light-trap, we processed data on turnip moths (*Scotia segetum* Schiff.) and heart-and-dart moths (*Scotia exclamationis* L.).

http://www.ecology.kee.hu • ISSN 1589 1623

Table1. *Data of the species examined from the material of the national light-trap network.*

Species	**Number of** Light-traps	**Years**	**Individuals**	**Data**
Coleoptera: Alleculidae				
Hymenalia rufipes F.	3	5	604	3602
Lepidoptera: Cossidae				
Dyspessa ulula Brkh.	33	14	2893	1351
Lepidoptera: Plutellidae				
Plutella maculipennis Curt.	26	3	3953	4821
Lepidoptera: Hhyponomeutidae				
Hyponomeuta malinellus L.	24	3	1591	994
Lepidoptera: Notodontidae				
Clostera pigra L.	2	10	1238	963
Lepidoptera: Lasiocampidae				
Odonestis pruni L.	25	17	2363	947
Lepidoptera: Lymantriidae				
Lymantria dispar L.	55	20	4721	3326
Porthesia similis Fuess	12	14	1195	786
Lepidoptera: Noctuidae				
Scotia vestigialis Schiff.	15	19	1109	3396
Amathes c-nigrum L.	7	12	4108	12401
Mamestra suasa Schiff.	28	10	6502	5447
Brachyonicha sphinx Hfn.	17	10	2142	3623
Lepidoptera: Geometridae				
Abraxas grossulariata L.	12	11	889	1105
Erannis marginaria Brkh.	10	9	1671	2077

We used our own software devised for the purpose to calculate the times of sunset and sunrise and the start of civil, navigational and astronomic twilight as well as the values of illumination in the environment expressed in log lux (Tóth et al. [185], Tóth and Nowinszky [184], Nowinszky and Tóth [125]). The same software made it possible for us to define for any given point of time the light of the twilight sky from the setting or rising Sun, illumination generated by the Moon always in correlation with the given lunar phase and the light of the starry sky which is constant (0.0009 lux). The software also considers the extent of cloudiness. Our own software also helped us to calculate the position of Babinet's point above the horizon. In the current study we have no scope to outline the theoretical bases and actual succession of calculations. However, let me refer to our earlier work (Tóth et al. [185], Nowinszky et al. [122]), where all these were described in detail, with the software in question and our results included (Nowinszky and Tóth [125], Nowinszky and Tóth [129]).

From the material of the Kecskemét fractionating light-trap we have used collecting data pertaining to the fall webworm moth (*Hyphantria cunea Drury*) and the turnip moth (*Scotia segetum* Schiff.). In the context of the position of Babinet's point, we examined light trapping efficiency concerning the catch of turnip moths (Scotia segetum Schiff.) and heart-and-dart moths (*Scotia exclamationis* L.). And with regard to the collecting distance, we processed the catch data pertaining to all three species. We computed the collecting distance of the Kecskemét fractionating light-trap for different values of environmental illumination and the ensuing probabilities of approach in a way described in

http://www.ecology.kee.hu • ISSN 1589 1623

an earlier study (Nowinszky et al. [122]). In what follows we give you the result without repeating the process of calculation. With the exact time of the catch within each hour unknown, the data were always calculated for the 30th minute following every full hour. By the distance of collecting we mean the radius of a circle with a circumference made up of points that receive an equal amount of illumination from the light-source and the environment. This is the formula to determine the radius:

$$r_o = \sqrt{I/E} \qquad \text{(Eq. 1)}$$

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

If the illumination in the environment comes exclusively from the starry sky, the maximum collecting distance with a Jermy-type light-trap is this:

$$r_o = \sqrt{80/0.0009} = 298\text{m} \qquad \text{(Eq. 2)}$$

And with the Kecskemét fractionating light-trap using F-33 light-tubes:

$$r_o = \sqrt{255/0.0009} = 532\text{m} \qquad \text{(Eq. 3)}$$

At full moon, when the environmental illumination comes partially from the Moon, the collected distance with a Jermy-type light-trap is the following:

$$r_o = \sqrt{80/0.25+0.0009} \approx 18\text{m} \qquad \text{(Eq. 4)}$$

And with the Kecskemét fractionating light-trap using F-33 light-tubes:

$$r_o = \sqrt{255/0.25+0.0009} \approx 32\text{m} \qquad \text{(Eq. 5)}$$

We are to assume that the flight of an insect at distance r from the light-trap is equally probable in every direction. In that case, the probability (probability of approach) of the insect flying in the direction of the two-dimensional plane determined by the tangents to a circle with radius r_o is the following:

$$P(A) = (1/p) \arcsin (r_o/r) \qquad \text{(Eq. 6)}$$

From the catch data we calculated relative catch (RC) values by species, generations and hours. In the swarming periods of the different generations, we calculated for each night the times of sunset and sunrise as well as the start of civil, navigational and astronomic twilight in both the evening and early morning hours and the onset of night time illumination, the accompanying values of environmental illumination expressed in lux and the period in which the Moon stayed above the horizon. We arranged collecting hours into the range of illumination to which they belonged over a longer period of time, separating moonlit hours and those without moonlight. Within each range of illumination, we averaged the accompanying relative catch values. The level of significance of the difference between the catch by the same illumination before and after midnight as well as the catch belonging to consecutive ranges was checked by a t-test (Nowinszky et al. [120]).

We computed the whole collecting area for the twilight and night hours both with and without moonlight. Without considering the hour of collecting, yet making a distinction between the hours of twilight and night with and without moonlight, we arranged these areas into classes, and then drew averages (Nowinszky et al. [131]). By use of our own method, we calculated three point moving averages of the accompanying relative catch data. Then we attempted to reveal the possible connection by correlation calculations by species.

The assumed effect of Babinet's point on the orientation of insects considering both

http://www.ecology.kee.hu • ISSN 1589 1623

evening and daybreak collection data in a contracted form, we studied then compared with each other the modifying effect on the catch of the Moon on the one hand and Babinet's point on the other. We arranged in three classes the values of environmental illumination below -1 log lux, -2 log lux and -3 log lux. In each class, we separated two groups depending on the position of the Moon and Babinet's point above the horizon:

- The Moon and Babient's point were both above the horizon (M+Bp+).
- The Moon was not, Babinet's point was above the horizon (M-Bp+).

In all illumination classes and groups, we summed up then averaged the relative catch values of the relevant hours. Then we examined the differences, if any, between the catch data pertaining to the different species and classes of illumination. We checked the significance levels of the differences with a t-test.

Then, disregarding environmental illumination, we went on analysing those cases in which both the Moon and Babinet's point were above the horizon. Here we wanted to find out whether there is any difference in the light trapping efficiency of the different species depending on whether the Moon or Babinet's point was higher on the horizon. Since Babinet's point was always positioned below 45° above the horizon, we examined cases when the Moon, too, did not rise higher than 45°. We separated our data depending on whether the Moon or Babinet's point was positioned lower above the horizon. All in all, also distinguishing between evening and early morning hours, we studied the differences in the catch results of four different eventualities. Both in the evening and early morning hours, we compared the catch results in the following situations:

- The Moon and Babinet's point are both below 45° above the horizon, but the Moon is positioned lower.
- The Moon and Babinet's point are both below 45° above the horizon, but Babinet's point is positioned lower.

Just like before, we summed up, then averaged the relative catch values by species and checked the significance level of the differences with a t-test.

Based on a study by Austin et al. [5], Pellicori [139] and our own earlier work (Ekk et al. [56], Szabó et al. [177], Nowinszky and Tóth [123], [124], [126], Nowinszky et al. [122]), we have sketched the relative luminousness of the Moon and the ratio of its polarized light as a function of the phase angle. Based on our earlier work (Tóth and Nowinszky [184]) were calculated with the help of software of our own development (Nowinszky and Tóth [125]).

Looking at the Kecskemét collection data of the turnip moth (*Scotia segetum* Schiff.) and the heart-and-dart moth (*Scotia exclamationis* L.), we were first trying to find an answer to the question of whether the differing heights of the Moon above the horizon influenced the effectiveness of light trapping? The catch data from the fractionating light-trap provide us with the specimens caught in each full hour, within that, however, we have no knowledge of the exact time of trapping, therefore the data related to the height of the Moon above the horizon were calculated electronically, with our own software, always pertaining to the 30th minute of each hour (Nowinszky and Tóth [125]). We processed the catch of only those nights when the Moon was observable both below and above 45° on the horizon.

We arranged in classes, and then averaged the values of the height of the Moon above the horizon following Sturges' method (Odor and Iglói [132]). One by one, the relative catch values of the species examined were correlated to the values of the height of the

Moon above the horizon determined for each given hour of the catch. These were then averaged in each class. We checked with a t-test the differences between the average relative catch values in the successive classes. We made correlation calculations for both species between the height of the Moon above the horizon and the accompanying 3 point moving average of the relative catch.

We calculated the phase angle value of the Moon for the 24[th] hour (UT) of each night in the swarming periods of the various species. Then we formed 30 phase angle groups of the 360 degrees of the complete lunar cycle. The group of the phase values in the ± 6o vicinity of the full moon (0° or 360°) was marked 0. Starting from this, the groups through the first quarter in the direction of the new moon were marked -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. And the groups from the full moon via the last quarter in the direction of the new moon are marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The phase angle group containing the new moon was ±15. Each group contains 12 phase angle values. The following phase angle groups fall in the four typical lunar quarters: full moon (-2 - +2), last quarter (3 - 9), new moon (10 - -10) and first quarter (-9 - -3). We arranged all the nights of the swarming periods of the species examined in one of the above phase angle groups, and then averaged the accompanying relative catch data of the various species. To reduce the misleading effect of other, simultaneously existing environmental factors, we performed a 10 point digital filtering of the average values (Nowinszky et al. [131], Nowinszky and Tóth [127, 128]) by use of the Hanning filter formula (Gold and Rader [64]) which contains the following filter parameters:

$$F(1) = \frac{2}{P1} - \frac{2}{P2} \quad \text{and} \quad F(k) = \sum_{k=2}^{T}\left(\sin\frac{2\pi k}{P1} - \sin\frac{2\pi k}{P2}\right)\frac{\cos\left(\frac{\pi k}{T}\right)}{2\pi k} \qquad \text{(Eq. 7 and 8)}$$

Where P1 = the lower limit of the filter, P2 = the top limit of the filter, T = P1 - P2, k = 2,... T. The filtered values and the basic data are obtained by a convolution of the above filter parameters.

On the swarming curves received after the Hanning filtering had been performed, maximum and minimum catches are found in the same groups of phase angles as on the curves drawn on the basis of the original catch data, but the maximum values lay higher and minimum values lower. So filtering had reduced the disturbing effect of other, simultaneously existing environmental factors made the curves more typical and highlighted the catch maximums and minimums. We did not perform any filtering of the Kecskemét data, as we needed the original catch values for subsequent calculation.

http://www.ecology.kee.hu • ISSN 1589 1623

Results

The catch results in the context of environmental illumination of the turnip moth (*Scotia segetum* Schiff.) and the fall webworm moth (*Hyphantria cunea* Drury) are shown in *Table 2.*

Table 2. *Light-trap catches of the Scotia segetum Schiff. and the Hyphantria cunea Drury in connection with the environmental illumination, in periods with and without moonlight.*

Twilight and illumination	**Zenith distance of the Sun**	**Moonlit and without moonlight periods**	**Scotia segetum Schiff.**		**Hyphantria cunea Drury**	
			RC	**N**	**RC**	**N**
Sunset 188 lux	90.5°	Without moonlight	0.612	38	0.612	94
Civil twilight	90.5°-96°	Without moonlight	1.897	102	0.766	177
188-3.3 lux		Moonlit	0.421	37	0.905	59
Navigation twilight	96°-102°	Without moonlight	2.284	86	0.683	152
3.3-0.01 lux		Moonlit	1.074	54	1.647	103
Astronomical twilight	102°-108°	Without moonlight	1.861	87	1.001	154
0.01-0.001 lux		Moonlit	1.071	53	1.055	122
Nocturnal illumination	108°alatt	Without moonlight	1.289	292	*0.915*	553
0.0009 lux		Moonlit	1.316	221	*1.267*	479
Astronomical twilight	102°-108°	Without moonlight	0.804	78	1.050	154
0.01-0.001 lux		Moonlit	1.131	62	1.952	100
Navigation twilight	96°-102°	Without moonlight	0.516	88	1.000	171
3.3-0.01 lux		Moonlit	0.920	52	1.633	82
Civil twilight	90.5°-96°	Without moonlight	0.256	126	0.578	220
188-3.3 lux		Moonlit				
Sunrise188 lux	90.5°	Without moonlight	0.052	24	0.122	90

RC = relative catches, N = Number of observing data. Underlined and italic numbers indicate the twilight periods in which the relative catch is significantly (at least at a 99% and 95% level) higher than that of the night.

Table 3 contains the catch results by light-trap of the species examined as a function of the collecting distance, in hours without moonlight. As we could establish no relationship between the collecting distance and the catch in moonlit hours, we omit publication of the relevant results. With regard to the position of Babinet's point over the horizon, the catch results pertaining to turnip moths (*Scotia segetum* Schiff.) are seen in *Table 4* and those concerning heart-and-dart moths (*Scotia exclamationis* L.) are seen in *Table 5 Table 6* shows the results of light trapping depending on the height of the Moon above the horizon based on the material of the Kecskemét light-trap.

http://www.ecology.kee.hu • ISSN 1589 1623

Table 3. *Light-trap catch of the species examined at times of civil, navigational and astronomic twilight, in hours without moonlight in the function of the collecting distance (in metres).*

Scotia segetum Schiff.			**Scotia exclamationis L.**			**Hyphantria cunea Drury**		
Distance	**RC**	**N**	**Distance**	**RC**	**N**	**Distance**	**RC**	**N**
8.9	0.856	362	1.9	0.380	319	1.5	0.974	353
33.7	0.912	54	4.3	0.371	71	34.1	1.233	56
76.5	1.036	51	11.6	0.431	59	77.3	1.566	70
126.3	1.293	33	37.7	0.736	61	129.3	1.188	31
184.3	1.306	17	72.9	0.997	59	185.4	1.402	27
228.9	1.093	22	137.0	1.180	61	241.0	1.740	30
276.7	1.033	26	242.3	1.134	60	300.8	1.341	43
334.9	1.065	66	314.4	1.134	61	359.2	1.285	13
373.0	1.124	48	348.4	1.260	59	434.1	1.610	22
416.2	1.203	27	365.1	1.174	57	492.2	2.037	13
469.5	1.404	20	425.1	0.997	67			
r = 0.631 (significance = 95%)			r = 0.783 (significance = 99%)			r = 0.688 (significance = 95%)		

Table 4. *Light-trap catch of the turnip moth (Scotia segetum Schiff.) in connection with the position of the Moon and the Babinet- point over the horizon.*

Position of the Moon and Babinet-point above the horizon	**log lux - 1..... RC**	**N**	**log lux - 2..... RC**	**N**	**log lux - 3..... RC**	**N**
Both the Moon and the Babinet-point are above horizon	*1.033*	104	*0.686*	89	0.246	5
The Moon is below the horizon, the Babinet-point is above the horizon	*1.219*	91	*1.253*	168	0.608	30

Both the Moon and the Babinet-point are lower than 45°,	*Evening* RC	N	*At dusk* RC	N
but the Babinet-point is higher,	1.008	84	*0.614*	49
but the Moon is higher	1.040	41	*1.123*	63

RC = relative catches, N = number of observing data. Italic numbers indicate if the differences of relative catch values one after the other are those significantly higher than 95%.

Table 5. *Light-trap catch of the turnip moth (Scotia exclamationis L.) in connection with the position of the Moon and the Babinet- point over the horizon.*

Position of the Moon and Babinet-point above the horizon	**log lux - 1..... RC**	**N**	**log lux - 2..... RC**	**N**	**log lux - 3..... RC**	**N**
Both the Moon and the Babinet-point are above horizon	*0.773*	117	1.015	85	0.777	10
The Moon is below the horizon, the Babinet-point is above the horizon	*0.954*	118	1.034	214	0.858	14

Both the Moon and the Babinet-point are lower than 45°,	*Evening* RC	N	*At dusk* RC	N
but the Babinet-point is higher,	*0.745*	77	*0.811*	78
but the Moon is higher	*1.394*	48	*2.141*	54

RC = relative catches, N = number of observing data. Italic numbers indicate if the differences of relative catch values one after the other are those significantly higher than 95%.

Scotia segetum Schiff.			Scotia exclamationis L.		
Height of the Moon above horizon (°)	Relative catches	Number of data	Height of the Moon above horizon (°)	Relative catches	Number of data
7.5	1.82	14	7.4	2.11	13
11.9	1.47	15	12.1	2.11	13
17.1	1.31	15	16.9	2.06	13
21.7	1.21	15	21.9	1.83	13
26.8	1.28	15	26.6	1.68	13
31.9	1.20	16	32.0	1.55	15
37.3	0.99	16	36.9	1.41	12
41.9	1.07	15	41.5	1.45	14
47.0	0.97	24	46.9	1.29	21
51.8	0.69	14	51.9	0.86	15
58.7	0.26	14	56.8	0.11	11
r = - 0.933 (Significance level is higher than 99 %)			r = - 0.867 (Significance level is higher than 99 %)		

Table 6. *Light-trap catch of the turnip moth (Scotia segetum Schiff.) and the heart-and-dart moth (Sctoia exclamationis L.) related to the height of the Moon over the horizon (in degrees) (Kecskemét, 1967-1969).*

Of the material of the national light-trap network, guided in our selection by an effort to give as wide a representation as possible to the reflection of taxonomic categories, we put forth some of our new findings concerning characteristic types of behaviour re-flect-ing the influence of the Moon in *Figures 1-7.*

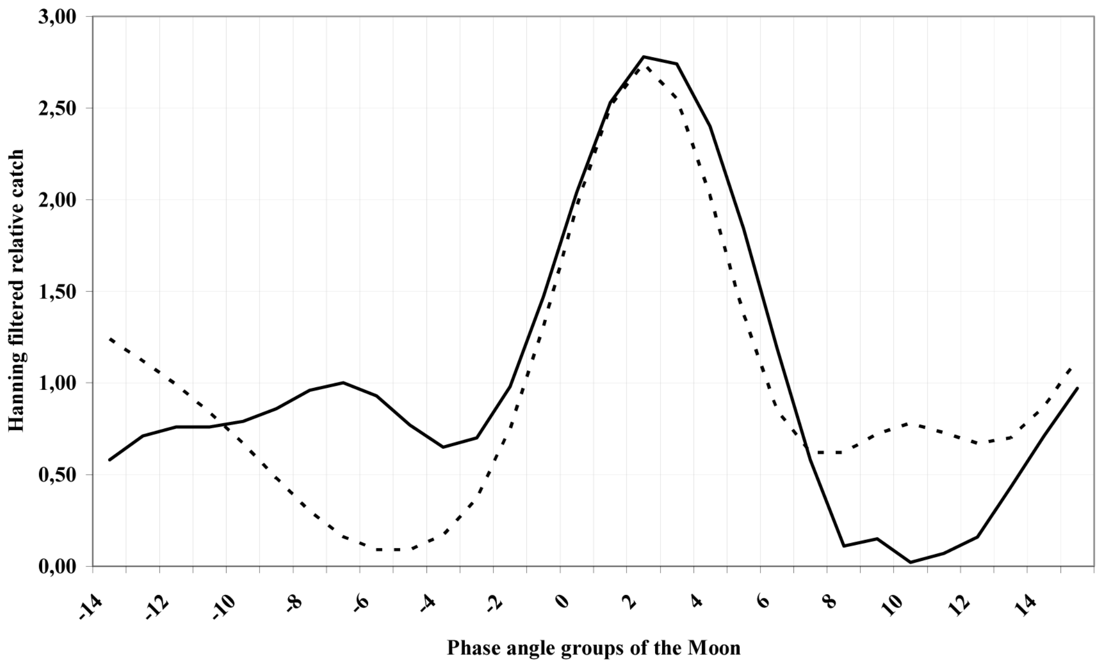
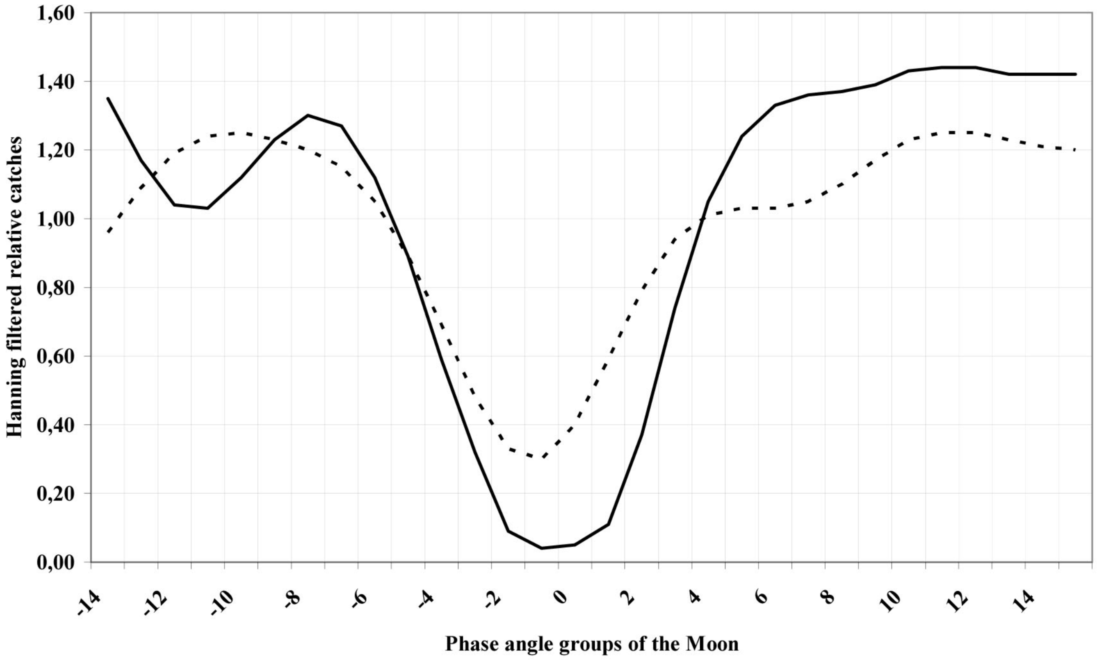


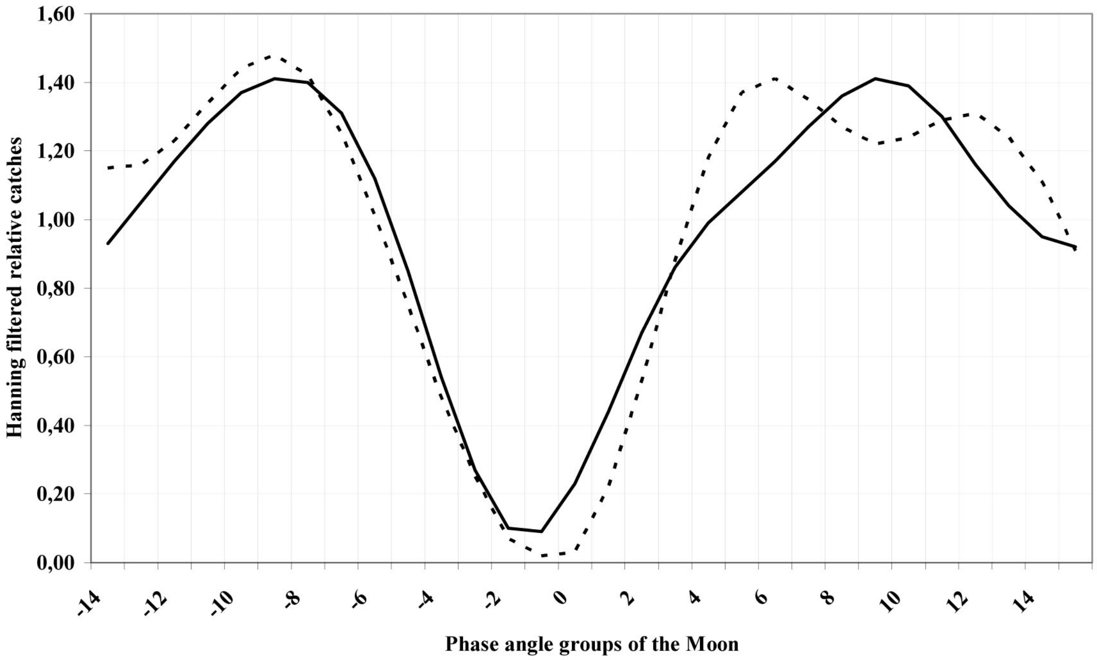
Figure 1. *Hanning filtered relative catches of the Erannis marginaria Brkh. (continuous line) and the Hymenalia rufipes F. (dotted line) depending on the phase angle groups of the Moon. (A single explicit catch maximum at full moon or directly after.)*

Figure 2. *Hanning filtered relative catches of the Hyponomeuta malinellus L.. (continuous line)*

http://www.ecology.kee.hu • ISSN 1589 1623



and the Mamestra suasa Schiff. (dotted line) depending on the phase angle groups of the Moon.
(High catches from the last quarter to first one, not falling back at the new moon.)
Figure 3. *Hanning filtered relative catches of the Amathes c-nigrum L.. (continuous line) and the*



Lymantria dispar L. (dotted line) depending on the phase angle groups of the Moon.
(Two nearly identical catch maximums in the first and last quarters.)

http://www.ecology.kee.hu • ISSN 1589 1623

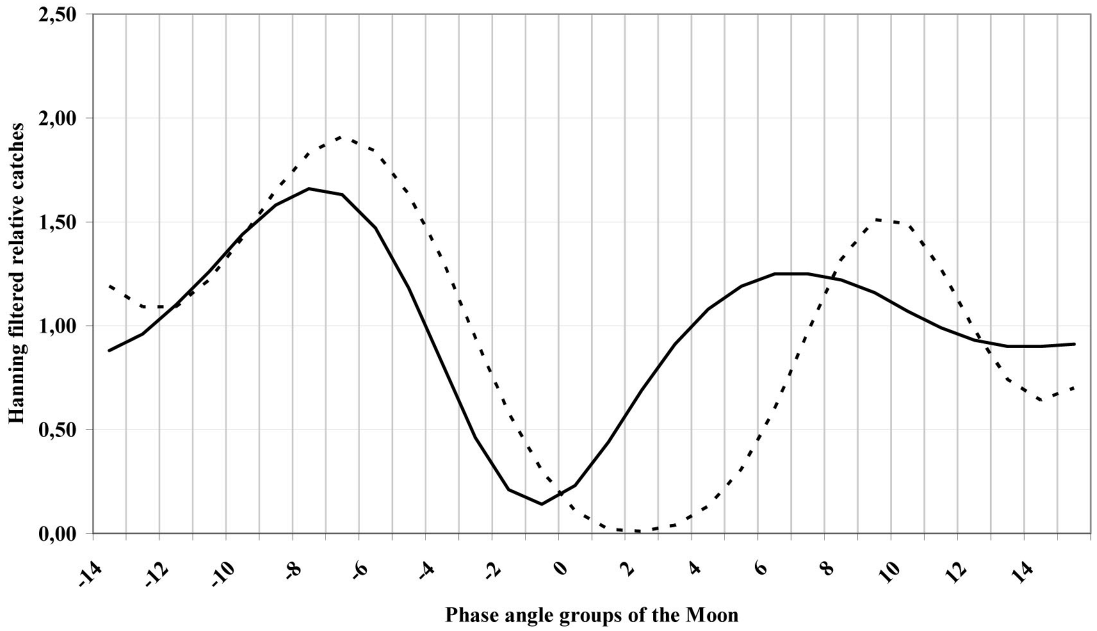


Figure 4. Hanning filtered relative catches of the Pygaera pigra L. (continuous line) and the Brachyonica sphinx Hfn. (dotted line) depending on the phase angle groups of the Moon. (Two catch maximums, the stronger in vicinity of the first quarter.)

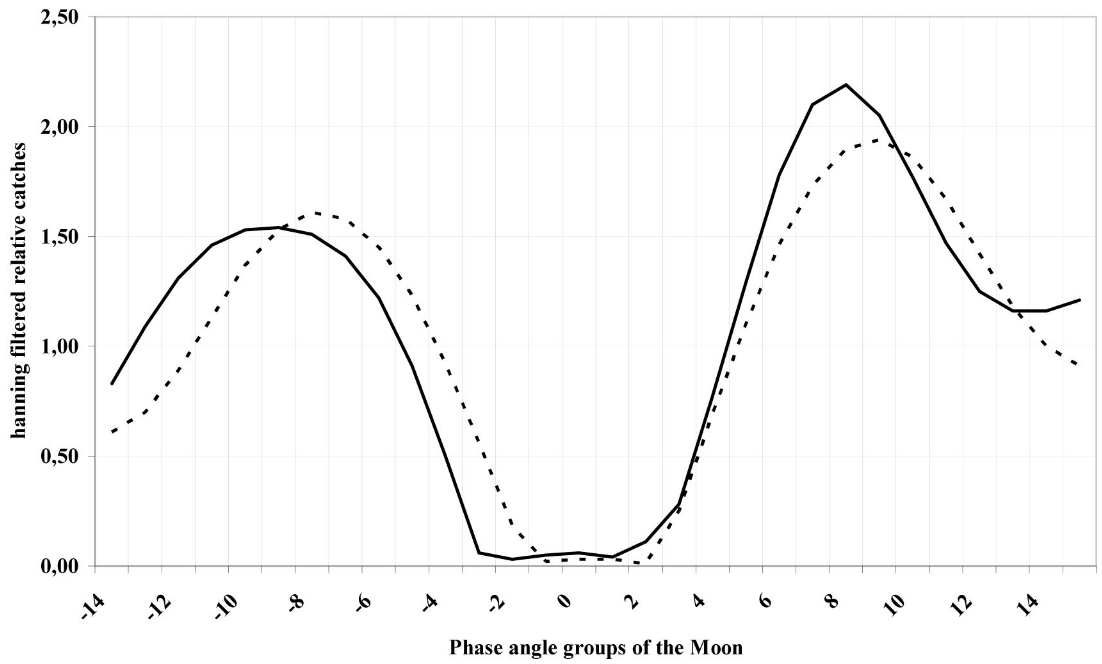


Figure 5. Hanning filtered relative catches of the Odonestis pruni L. (continuous line) and the Porthesia similis Fuess. (dotted line) depending on the phase angle groups of the Moon. (Two catch maximums, the stronger in vicinity of the last quarter.)

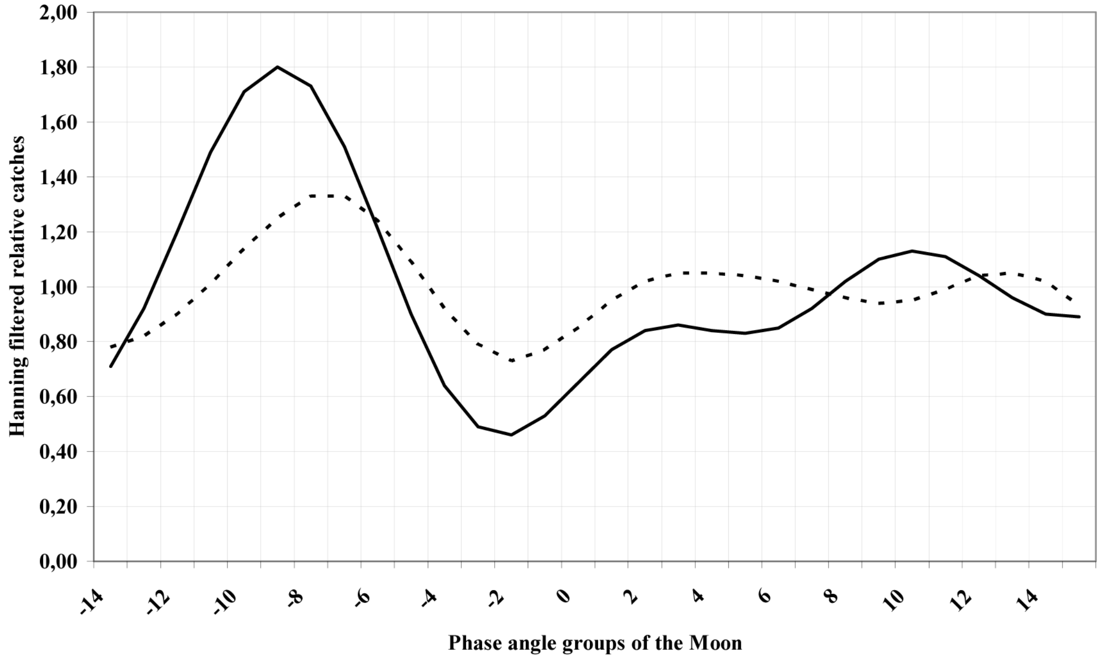
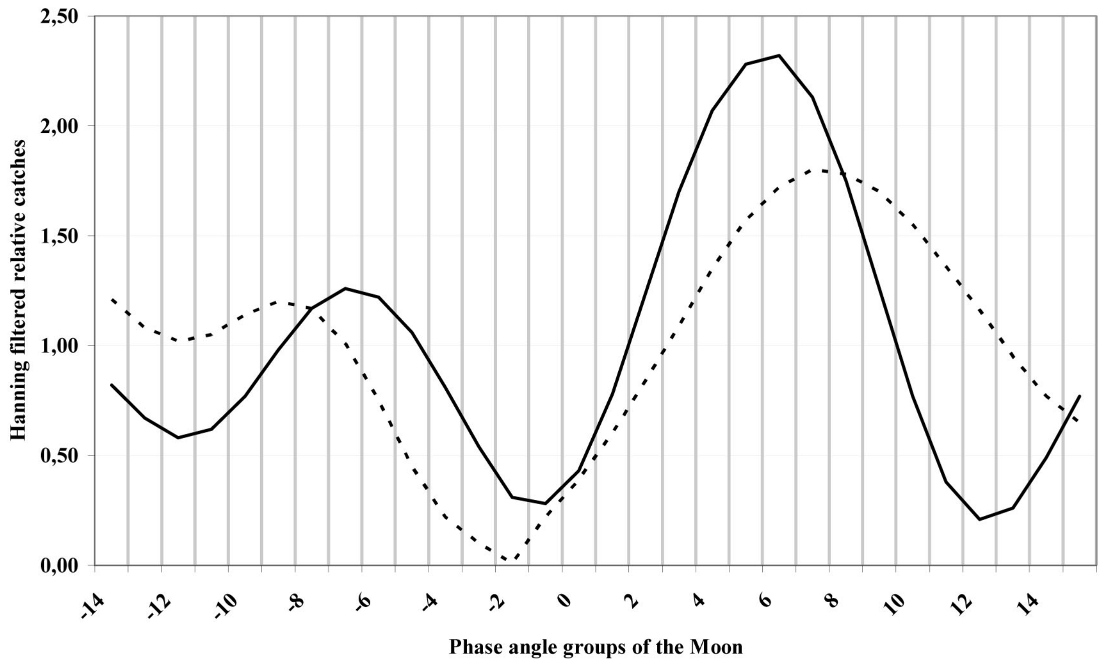


Figure 6. *Hanning filtered relative catches of the Scotia vestigialis Schiff. (continuous line) and the Plutella maculipennis Curt. (dotted line) depending on the phase angle groups of the Moon. (Single explicit catch maximum at first quarter.)*

Figure 7. *Hanning filtered relative catches of Abraxas grossulariata L. (continuous line) and*



Dyspessa ulula Brkh. (dotted line) depending on the phase angle groups of the Moon. (Single explicit catch maximum at last quarter.)

Discussion

Illumination generated by the Sun and the Moon changes not only on the different days of the swarming period, but also in the course of each night, therefore it is an extremely important factor modifying collecting.

In the case of the turnip moth (*Scotia segetum* Schiff.) we find that in the periods without moonlight, every range of illumination, with the expectation of the middle hours of the night, is accompanied by significantly higher catch results before than after midnight.

In the middle of the night when the light of the nocturnal sky is the only natural source of light to ensure the illumination of the environment, the catch before and after midnight is the same, presumable because of the small time difference. Whichever of the three forms of twilight illumination may prevail, the catch after sunset is significantly higher than at the time of sunset or in the hours of illumination by night. However, the relative catch values accompanying civil, navigational and astronomic twilight show no variation. It is extremely remarkable that the number of moths caught during the successive twilight's after midnight goes on decreasing significantly (*Table 2*).

Our earlier results (Nowinszky et al. [121]), however, have also made it clear that this phenomenon is explained neither by temperature regularly dropping by dawn, nor by increasing relative humidity. Our examinations have proved that in all comparable cases by identical illumination and temperature as well as by identical illumination accompanied by relative humidity, the catch was always significantly higher before than after midnight. It is remarkable, however, that the above circadian rhythm is modified by the presence of the Moon above the horizon: the activity of flying to light does not lose from its liveliness until the navigational twilight of the early morning hours, in fact significantly more moths fly to light at dawn than under the same illumination conditions in the periods without moonlight. However, during the total solar eclipse of August 11th, 1999, the light-traps in Vas county did not catch a single insect (Puskás et al. [144]). Sudden short darkness at daytime does not disturb the circadian rhythm.

Our examination related to the fall webworm moth (*Hyphantria cunea* Drury) has produced an opposite result. In the hours of civil, navigational and astronomic twilight and by identical temperature and humidity, the imagoes of this species show greater activity in flying to light after midnight. It is remarkable, however, that in every sphere of illumination, the number of moths caught is higher in the moonlit periods.

In the hours without moonlight, the catch relevant to all three species increases as the distance of collecting grows (*Table 3*). However, this relationship cannot be proved when illumination is generated partly by the Moon. Although moonlight reduces the distance of collecting, the catch results do not go down accordingly. So the Moon exerts is influence not only through the area of collecting.

In all three spheres of illumination and regardless of the Moon being positioned above or below the horizon, the light trapping of both species will be more successful when Babinet's point is below the horizon (*Table 4* and *Table 5*). When the Moon and Babinet's point are both below 45° over the horizon, the catch will be more successful if the Moon is positioned higher. We presume that the Moon and Babinet’s point both play a role in the orientation of insects, but of the two the one seen higher will be of greater importance. If Babinet's point is positioned higher, the insect may escape the light-trap, perceiving the former as a discontinuity in a sky emitting a continuity of polarized light,

http://www.ecology.kee.hu • ISSN 1589 1623

and it can hardly mistake that discontinuity for an artificial source of light as it is perceivably does in the case of the Moon. So, unlike the Moon, Babinet's point bolsters the security of orientation.

Gál et al. [61] observed patterns including the positions of the Arago and Babinet neutral points of the moonlit night sky and sunlit day sky are practically identical if the zenith angle of the Moon is the same as that of the Sun. The biological relevance of the polarization pattern of the moonlit night sky in the polarization vision and orientation of night-active insects is possible.

In our assumption, the Moon, when staying above the horizon, provides insects with guidance of orientation, therefore they avail of light stimuli in the first place to find their bearings in space. In that situation, light trapping is more efficient, as, provided certain conditions are given, the insect might mistake the light of the artificial sources that have been around for only a few millennia for the light of the Moon and therefore will be trapped. As shown in *Table 6*, the height of the Moon above the horizon is in negative correlation with the 3 point moving average of the relative catch. A remarkably strong and significant fallback occurs in the catch of both species when the Moon is 45° above the horizon. If the Moon is observable higher than that, the light-trap will collect few insects. We might try to interpret this observation on the basis of experiments by Baker and Sadovy [7] and Baker [6]. Insects flying on the surface of the ground will see the top of a 360-cm column of light at an angle of 45° from a distance of 3.6m. That distance fits the 3-17m determined by Baker et al. as the distance from which insects react to artificial light. If the insects fly higher than the surface of the ground, they will always see the top of the source of light from an angle less than 45°. So, provided Baker is right, we have an explanation for why the catch is high in the moonlit hours of the night only when the Moon is on the horizon at an angle smaller then 45°, as only then will insects see the top of the trap and the Moon at the same height and only when that happens can they mistake the artificial light for the light of the Moon. So, the critical point in the position of the Moon above the horizon below which we have a high catch and over which we have a low catch is 45°. It remains a problem though that the Kecskemét light-trap was equipped with fluorescent tubes instead of a point like source of light. Because if the height of the Moon above the horizon and its vertical diameter are indeed the most important factors causing confusion, it is not clear how the insect might mistake the column of light for the Moon? Another possible explanation might be this: if the Moon stays low above the horizon, moonlight will penetrate through a thicker layer of air and so its spectral composition shifts to the domain of longer wavelengths. In this case, the light source of the trap may substitute the light waves of shorter wavelengths, to which the insect eye is extremely sensitive, and the catch grows. However, this hypothesis is in sharp contradiction with all the findings we have had so far which appear to confirm that collecting is efficient when the risk of making the mistake runs high. Following from the Mie effect, moonlight gets scattered and consequently polarized much more when penetrating through a thicker layer of air than in the case of arriving in the vicinity of a right angle. This fact, well compatible with our results, may increase the effectiveness of collecting. An analysis of the catch data presented in a study by Szabóky [178] is an interesting contribution to the subject, although it cannot be regarded as decisive evidence in support of our results. The author referred to registers the exact time, with accuracy to the minute, of the landing of 57 specimens of *Anarta myrtilli* L. on the sheet as he was collecting with a 125 W mercury vapour lamp. In 43 cases of the points of time listed, the Moon was not above the horizon and 14 cases were positioned lower than 45°.

Our research into the relationship between the lunar phases and collecting by light-trap have given an answer to the question of what phase angle domains are favourable or unfavourable from the point of view of light trapping the different species. As confirmed in *Figures 1-7*, this has not been observed with any of the species. The Moon has been proved to modify collecting, while it was also established that the various spe-cies display different behaviour in the face of moonlight. Based on more recent research we have been engaged in, we have set up 7 basic types of behaviour:

1. A single explicit catch maximum at full moon or directly after.
2. High catch from the first to the last quarter, not falling back at the time of the new moon.
3. Two nearly identical catch maximums in the first and last quarters.
4. Two catch maximums, the stronger of the two observed in the vicinity of the first quarter.
5. Two catch maximums, the stronger of the two observed in the vicinity of the last quarter.
6. A single catch maximum in the first quarter.
7. A single catch maximum in the last quarter.

The influence of the Moon on light trapping varies by species, a fact that cannot be explained by either the degree of taxonomic relationship, or by the difference in the swarming periods. It is quite likely that the various species respond in different ways to the optical characteristics of the Moon, which have their maximums always in different phase angle groups. For instance, in Hungary, in the hours of light trapping (6 p. m. – 4 a. m. UT), light intensity and the duration of the stay of the Moon above the horizon is the longer in the 2nd phase angle group following the full moon, while the extent of polarization is the highest in the first and last quarters. On the other hand, the colour temperature of a regular light-trap (2900 °K) comes closest to the colour temperature of the Moon (4100 °K at full moon according to Bernolák [12]) between the first and last quarters and the new moon (-10 and 11 phase angle group) (Nowinszky et al. [131]). Although the optical characteristics presumably exert their influence in their complexity on the insects collected, individuals of the various species might react to the various features in different ways.

The sensitivity to light of the species in first type is the highest at the time of the full moon, or directly after in the +1, or +2 phase angle group. Danthanarayana [42] also reported on the catch maximums observed on such occasions. However, this group contains only a small proportion of the species studied so far. Most species examined display strongly slackening activity at the time of the full moon. Moonlight is unpolarized at the full moon, while negative polarization can be observed directly before and after, the period in which the colour temperature of the Jermy-type light-traps comes closest to that of the Moon. It is in this latter fact that can be a probable reason for the maximum observed at this time.

In the type two, catching maximum can be seen at the time of last quarter, new moon and first quarter, and deep minimum at full moon.

It is a common feature of the last five types that one or two distinct catch maximums are observed in the vicinity of the first and/or last quarters. The two maximums might be

http://www.ecology.kee.hu • ISSN 1589 1623

of the same size, but one might be significantly higher than the other. With these types positively polarized moonlight probably has a positive influence on activity. However, it happens in several cases that the maximum is not exactly in the phase group containing the first and the last quarters, instead, gets somewhat shifted in the direction of the new moon, non the less, in this case, too, there is a remarkable fall-back in the volume of catch at the time of the new moon.

Based on the findings of other scholars as well as our own investigation we take it as confirmed that neither the smaller size of a collecting area nor reduced flying activity are reasons of general validity in way of explaining the influence of the Moon on light-trap effectiveness.

Changes of the area of collecting cannot explain with general validity the differences in the catch results related to the lunar phases. Although, beyond doubt, the illumination generated by the Moon reduces the area of collecting, yet, this fact can have significance only exceptionally from the point of view of light-trap effectiveness. Because in this case should be observe a single catch maximum, and that at the time of the new moon. But as demonstrated the catch data, this is typical of but a few species. A catch maximum is observed with most species in the first and/or last quarter. Hourly collecting data, too, did not make any decline of the catch in relationship with the size of the collecting area apparent in moonlit hours. Therefore a smaller collecting area cannot be regarded as a general reason for the more moderate catch experiences in the vicinity of the full moon. So, regarding the majority of species, the influence of the Moon manifests itself not only through modifications of the area of collecting.

Moonlight does not reduce the flight activity of the insects either. For the catch maximum in the case of most species occurs in the vicinity of the first or the last quarter, or most often, in the neighbourhood of both. So moonlight increases instead of decreasing activity and the catch. It is quite remarkable; on the other hand, that in the vicinity of the full moon, i.e. at the time of negative polarization, there is a clearly distinguishable catch minimum with most species. The negative polarization reduces the quantity of insects collected by light-trap. Had moonlight, regardless of its phase at the time, reduced the activity of insects, there would be no catch maximum in the first and last quarters either. Collecting with other methods by the researchers quoted above do not confirm either the slackening of flight activity at the time of a full moon.

In the absence of traps in high positions, there has been no Hungarian research to confirm or refute the theory expounded by El-Ziady [57] who claims that insects fly in higher layers of the atmosphere at the time of the full moon, although this phenomenon could be detected in the case of some migratory species. Admittedly, the corrected catch results of the silver Y moth (*Autographa gamma* L.) were good also at full moon in the Jermy type traps operating at a height of 2m.

At the time of the full moon – both when there is negative polarization and when there is no polarization – the Moon steps up flight activity. The low catch results observed with most species at this time are related to the insects' security of orientation. Our own findings appear to confirm the theory of Jermy [88] who has been assuming that moonlight might increase the security of orientation, at the same time revealing the difference following from the positive and negative polarization of moonlight. We presume that at the time of positive and negative moonlight polarization, insects rely for orientation primarily on light stimuli, while in the vicinity of the full moon, probably owing to the pres-

http://www.ecology.kee.hu • ISSN 1589 1623

ence of negative polarization, the difference some species perceive between moonlight and artificial light is bigger than in other lunar phases. Therefore while the Moon continues to supply them with information helping their orientation, the risk of a mix-up diminishes, in other words, the security of orientation increases and the catch falls back. This theory is confirmed by an observation made by Cleve [35] who found that insects fly from one light-trap to the other, but very rarely fall into the trap at the time of the full moon. Other species, on the other hand, can be effectively collected also at times of negative polarization. For some, so far unknown, reason the security of orientation does not increase for them (Nowinszky [118]).

Light trapping has been taking place at the most different geographical locations, under changing weather and light conditions and in different seasons. Also, researchers have been collecting different species, flying at varying hours of the night with light-traps of different types. It is possible therefore that the contradictions manifest in the findings are only apparent and further research on the most important questions may lead to new results to be used with benefit in prognostics in the foreseeable future.

At the same time, our latest findings have also supplied us with fresh evidence to prove that despite several decades of research, the influence of the Moon on light trapping has to this day remained one of the most complex and least known problems.

REFERENCES

[1] Agee, H. R., Webb, J. C., Taft, H. M. (1972): Activity of bollworm moths influenced by full moon. – Environmental Ecology. 1. 3: 384-385.

[2] Anderson, N. H. (1966): Depressant effect of moonlight on activity of aquatic insects. – Nature. 209. 5020: 319-320.

[3] Andreazze, R. (2001): Dynastinae beetles (Coleoptera, Scarabaeidae, Dynastinae) of Parque Nacional do Jau, state of Amazonas, Brazil (in Portuguese). – Acta Amazonica Abstract 31. 3: 431-435.

[4] Ármai, I. (1960): The role of light-traps of insects in plant protecting (in Hungarian). – A Növényvédelem Időszerű Kérdései. 2: 68-75.

[5] Austin, R. H., Philips, B. F., Webb, D. J. (1976): A method for calculating moonlight illuminance at the Earth's surface. – J. Appl. Ecol. 13. 3: 741-748.

[6] Baker, R. R. (1979): Celestial and light-trap orientation of moths. – Antenna. 3: 44-45.

[7] Baker, R. R., Sadovy, Y. (1978): The distance and nature of the light-trap response of moths. – Nature. 276: 818-821.

[8] Balasubramani, V., Chandrasekaran, J., Subramanian, M. (1998): Bug burn in paddy. http://www.webpage.com/hindu/daily/981203/08/08030006.htm

[9] Balogh, I. (1962): Ecological and faunistical investigation of the material of moths caught at Pécs (in Hungarian). – Pécsi Pedagógiai Főiskola Évkönyve. 1961-1962: 397-415.

[10] Banerjee, T. C., Nayek, T. K., Mondal, A. S. (1981): The influence of moonlight on the catches of Clivina helferi Putzeys (Coleoptera: Carabidae). – Rev. Écol. Biol. Sol. 18. 3: 403-412.

[11] Barr, A. R., Smith, T. A., Boreham, M. M. (1960): Light intensity and the attraction of mosquitoes to light traps. – J. Econ. Ent. 53. 5: 876-880.

[12] Bernolák, K. (1981): The light (in Hungarian). – Műszaki Kiadó. Budapest. 304.

[13] Bhatt, R. M., Sharma, R. C., Kohli, V. K., Gautam, A. S., Gupta, D. K. (1991): Biting rhythms of malaria vector Anopheles culicifacies in Kheda district, Gujarat. – Indian Journal of Malariology. 28: 91-97.
[14] Bidlingmayer, W. L. (1964): The effect of moonlight on the flight activity of mosquitoes. – Ecology. 45. 1: 87-94.
[15] Bidlingmayer, W. L. (1971): Mosquito flight paths in relation to environment. I. Illumination levels, orientation and resting areas. – Ann. Ent. Soc. Amer. 64: 1121-1131.
[16] Bidlingmayer, W. L. (1985): The measurement of adult mosquito population changes some considerations. – J. Am. Mosq. Control Assoc. 1. 3: 328-348.
[17] Bishop, A. L. McKenzie, H. J., Barchia, I. M., Spohr, L. J. (2000): Moon phase and other factors affecting light-trap catches of Culicoides brevitarsis Kieffer (Diptera: Ceratopogonidae). – Australian Journal of Entomology 39. 1: 29-32.
[18] Bogush, P. P. (1951): Application of light-traps to the dynamical investigation of insects' population (In Russian). – Entomol. Obozr. 31. 3-4: 609-628.
[19] Bowden, J. (1973a): The influence of moonlight on catches of insects in light-traps in Africa. Part I. – Bull. Ent. Res. 63: 115-128.
[20] Bowden, J. (1973b): The significance of moonlight in photoperiodic responses of insects. – Bull. Ent. Res. 63: 605-612.
[21] Bowden, J. (1981): The relationship between light- and suction-trap catches of Chrysoperla carnea (Stephens) (Neuroptera: Chrysopidae), and the adjustment of light-trap catches to allow for variation in moonlight. – Bull. Ent. Res. 71: 621-629.
[22] Bowden, J. (1982): An analysis of factors affecting catches of insects in light-traps. – Bull. Ent. Res. 72: 535-556.
[23] Bowden, J., Church, B. M. (1973): The influence of moonlight on catches of insects in light-traps in Africa. Part II. – Bull. Ent. Res. 63: 129-142.
[24] Bowden, J., Gibbs, D. S. (1973): Light-trap and suction trap catches of insects in the northern Gezira, Sudan in the season of south ward movement of the intertropical front. – Bull. Ent. Res. 62: 571-596.
[25] Bowden, J., Jones, M. G. (1979): Monitoring wheat bulb fly, Delia coarctata (Fallén) (Diptera: Anthomyiidae), with light-traps. – Bull. Ent. Res. 69: 129-139.
[26] Bowden, J., Morris, G. M. (1975): The influence of moonlight on catches of insects in light-trap in Africa. Part III. The effective radius of a mercury-vapour light-trap and analysis of catches using effective radius. – Bull. Ent. Res. 65: 303-348.
[27] Bragança, M., DeSousa, Og., Zanuncio, J. C. (1998): Environmental heterogeneity as a strategy for pest management in Eucalyptus plantations. – Forest Ecology and Management. 102: 9-12.
[28] Brehm, G. (2002): Diversity of geometrid moths in a mountain rainforest in Ecuador. Dissertation zur Erlangung des Doktorgrades an der Fakultät Biologie (Chemie) Geowissenschaften der Universität Bayreuth. 203.
[29] Brénière, J., Rodriguez, H., Ranaivosoa, H. (1962): A pest of rice in Madagascar. Maliarpha separatella Rag. or the white borer. (Translation from the French). – Agron. trop. Ser. 3. 17: 223-302.
[30] Brinson, F. J., Hagan, D.V., Comer, J. A., Strohlein, D. A. (1992): Seasonal abun-

dance of Lutzomyia shannoni (Diptera: Psychodidae) on Ossabaw Island, Georgia. – J. Med. Entomol. 29. 2: 178-182.
[31] Brown, E. S., Betts, E., Rainey, R. C. (1969): Seasonal changes in distribution of the African armyworm, Spodoptera exempta Walk. (Lepid. Noctuidae), with special reference to Eastern Africa. – Bull. Ent. Res. 58: 661-728.
[32] Bucher, G. E., Bracken, G. K. (1979): The bertha armyworm, Mamestra configurata (Lepidoptera: Noctuidae). An estimate of light and pheromone trap efficiency based on captures of newly emerged moths. – Canad. Ent. 111. 9: 977-984.
[33] Butler, L., Kondo, C., Barrows, E. M., Townsend, E. C. (1999): Effects of weather conditions and trap types on sampling for richness and abundance of forest Macrolepidoptera. – Environmental Entomology. 28. 5: 795-811.
[34] Chaston, J. (1969): The light threshold controlling the periodicity of invertebrate drift. – J. Anim. Ecol. 38. 1: 171-180.
[35] Cleve, K. (1954): Einfluss der Wellenglänge des Lichtes auf den Lichtfang der Schmetter-linge. – Deutsch. Entomologtag in Hamburg.
[36] Constantini, C., Sagnon, N. F., Sanoga, E., Merzagora, L., Coluzzi, M. (1998): Relationship to human biting collections and influence of light and bednet in CDC light-trap catches of West African malaria vectors. – Bull. Ent. Res. 88: 503-511.
[37] Cook, A. G., Perfect, T. J. (1985): Seasonal abundance of macropterous Nilaparvata lugens and Sogatella furcifera based on presumptive macroptery in fifth-instar nymphs. – Ecological Entomology. 10: 249-258.
[38] Corbet, Ph. S. (1958): Lunar periodicity of aquatic insects in Lake Victoria. – Nature. 182: 330-331.
[39] Cullen, M. J. (1969): The biology of giant water bugs (Hemiptera: Belostomatidae) in Trinidad. – Proc. Roy. Ent. Soc. London. A. 44: 123-136.
[40] Csóka, Gy. (1984): Role of the lackey moth (Malacosoma neustria L.) on destruction of pedunculated oak (in Hungarian). – Tudományos Diákköri Dolgozat. Sopron.
[41] Danthanarayana, W. (1976): Environmentally cued size variation in the light-brown apple moth, Epiphyas postvittana (Walk.), (Tortricidae), and its adaptive value in dispersal. – Ocologia (Berl.) 26: 121-132.
[42] Danthanarayana, W. (1986): Lunar periodicity of insect flight and migration. In: Danthanarayana, W. (1986): Insect flight: Dispersal and migration. – Springer-Verlag. Berlin-Heidelberg. 88-119.
[43] Danthanarayana, W., Dashper, S. (1986): Response of some night-flying insects to polarized light. In: Danthanarayana: Insect flight: Dispersal and migration. 120-127. – Springer-Verlag. Berlin-Heidelberg.
[44] Danthanarayana, W., Gu, H. (2000): Flight periodicities in migrant moths. – Insect migration and related topics at ICE 2000. Abstracts. http://www.ph.adfa.oz.au/a-drake/ice/ ic00imab.htm
[45] Davies, J. B. (1975): Moonlight and the biting activity of Culex (Melanoconion) portesi Senevet and Abonnenc and C. (M.) taeniopus D. and K. (Diptera: Culicidae) in Trinidad forests. – Bull. Ent. Res. 65: 81-96.
[46] Day, A., Reid, W. J. Jr. (1969): Response of adult southern potato worms to light-traps. – Journ. Ecol. Entomol. 62: 314-318.
[47] Dent, D. R., Pawar, C. S. (1988): The influence of moonlight and weather on

catches of Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) in light and pheromone traps. – Bull. Ent. Res. 78: 365-377.
[48] Dickson, S. L., Hatch, G. L. (1999): The effects of lunar phases on mosquito light trap collections. http://www.umaa.org/luarpha.htm
[49] Dillon, M., MacKinnon, L. (2002): Using light traps to suppress Helicoverpa. – The Australian cottongrower. 23. 2: 32.
[50] Doiron, N., De Oliveira, D. (1978): Activité saisonniêre insectes dans une chęnaire bleue au Haut-Richelieu, Québec. – Phytoprotection 59. 1: 3-11.
[51] Douthwaite, R. J. (1978): Some effects of weather and moonlight on light-trap catches of the armyworm, Spodoptera exempta (Walker) (Lepidoptera: Noctuidae), at Muguga, Kenya. – Bull. Ent. Res. 68: 533-542.
[52] Drake, V. A. (1983): Collective orientation by nocturnally migrating Australian plague locusts, Chortoicetes terminifera (Walker) (Orthoptera: Acrididae): a radar study. – Bull. Ent. Res. 73: 679-692.
[53] Dufay, C. (1964): Contribution a l'Étude du phototropisme des Lépidopteres noctuides. Annales des Sciences Naturelles, Zoologie, Paris. 12. 6: 281-406.
[54] Duviard, D. (1974): Flight activity of Belastomatidae in central Ivory Coast. – Oecologia (Berlin). 15: 321-328.
[55] Dzhafarov, S. M. (1961): Trapping method of mosquitoes (Diptera: Heleidae) (in Russian). – Zool. Zhurn. 40: 393-396.
[56] Ekk, I., Kiss, M., Nowinszky, L., Szabó, S., Tóth, Gy. (1977): Environmental factors modifying the light-trap catch. Part I. Illumination changes and polarized light of the Moon (in Hungarian). – The work won the first prize of the Academy Board Veszprém.
[57] El-Ziady, S. (1957): A probable effect of the moonlight on the vertical distribution of Diptera. – Bull. Soc. Ent. Egypte. 41: 655-662.
[58] Farrow, R. A. (1977): Origin and decline of the 1973 plague locust outbreak in Central Western New South Wales. – Aust. J. Zool. 25: 455-489.
[59] Finnamore, A. T. (1999): Adjunct sampling protocols and public partnerships. http://www. cciw.ca/emantemp/reports/publications/sage/sage18.htm
[60] Flores-Mendoza, C., Lourenco De Oliveira, R. (1996): Bionomics of Anopheles aquasalis Curry 1932 in Guarai, state of Rio Janeiro Southeastern Brasil. – Memorias do Instituto Oswaldo Cruz. 91. 3: 265-270.
[61] Gál, J., Horváth, G., Barta, A., Wehner, R. (2001): Polarization of the moonlit clear night sky measured by full-sky imaging polarimetry at full moon: Comparison of the polarization of moonlit and sunlit skies. – Journal of Geophysical Research. 106. D19: 22647-22653.
[62] Gál, J., Horváth, G., Pomozi, I., Wehner, R. (1998): Polarization free points of the sky. Part I. (in Hungarian). – Természet Világa Természettudományi Közlöny. 129. 4: 151-154.
[63] Garcia, J. L. (1977): Influencia de los factores ambientales sobre la captura nocturna de Sphingidae (Lepidoptera) en Rancho Grande, Estado Aragua, Venezuela. – Rev. Fac. Agron. (Maracay). 9. 4: 63-107.
[64] Gold, B., Rader, Ch. M. (1969): Digital processing of signals. Mc Graw-Hill Co., New York.
[65] Gregg, P. C., Fitt, G. P., Coombs, M., Henderson, G. S. (1994): Migrating moths

collected in tower-mounted light traps in northern South Wales, Australia: Influence of local and synoptic weather. – Bull. Ent. Res. 84. 1: 17-30.

[66] Gustafson, D. L. (1996): Black light traps. http://www.esg.montana.edu/dlg/aim/methods/ blt.html

[67] Győrfi, J. (1948): The influence of illumination and light on insects (in Hungarian). – Erdészeti Kísérletek. 48. 3-4: 108-111.

[68] Gyulai, P., Nádler, M. (1977): Catching of harmful insects by poisoned ingredients (in Hungarian). – Növényvédelem. 13. 9: 418-420.

[69] Hall, S. P. (1999): Inventory of Lepidoptera of the Albemarle-Pamlico Peninsular Region of North Carolina, including Pettigrew, Goose Creek, and Jockey's Ridge State Parks and Nag's Head Woods Ecological Preserve. http://ils.unc.edu/parkproject/nhp/LepsALPA.html

[70] Hanna, H. M. (1964): Flight activity of Coleoptera as indicated by a light trap. – Bull. Soc. Ent. Egyipte 67. 47: 133-140.

[71] Hardwick, D. F. (1972): The influence of temperature and Moon phase on the activity of noctuid moths. – Can. Entomol. 104. 11: 17767-1770.

[72] Hardwick, D. F., Lefkovich, L. P. (1971): Physical and biotic factors affecting Euxoa species abundance in western North America: A regression analysis. – Can. Ent. 103. 9: 1217- 1235.

[73] Harling, J. (1968): Meteorological factors affecting the activity of night flying Macrolepidoptera in Robinson type mercury vapour lamp light trap. - Entomologist. 101. 1259: 83-90.

[74] Heikinheimo, O. (1971): On the phenology and light trapping of the codling moth (Laspeyresia pomonella L.). – Acta Ent. Fennica. 28: 33-40.

[75] Herczeg, É., Vojnits, A. (1981): The weather predicting living organisms (In Hungarian). – Natura. Budapest. 238.

[76] Ho, D. T., Reddy, K. V. S. (1983): Monitoring of lepidopterous stem-borer population by pheromone and light traps. – Insect Sci. Appl. 4. 1-2: 19-23. Abstract.

[77] Hock, J. W. Company (2000): Instructions for the SSAM light trap. http://www.acceleration.net/~jwhock/ins_2112.htm

[78] Holck, A. R., Meek, C. L. (1991): Nocturnal distribution of Louisiana riceland mosquito adults. – J. Am. Mosq. Control Assoc. 7. 4: 628-632.

[79] Horváth, G., Varju, D. (2004): Polarized light in animal vision. Polarization patterns in nature. Springer-Verlag, Berlin Heidelberg. 447.

[80] Hosny, M. M. (1955): Notes on the effect of some secondary environmental conditions on the activity of nocturnal Macrolepidoptera. – Bull. Soc. Ent. Egyipte. 39: 297-314.

[81] Howell, K. K. (1998): http://www.calacademy.org/calwild/fall98/mad.htm

[82] Hunt, G. L. (1977): Low preferred foraging temperatures and nocturnal foraging in a desert harvester ant. – Amer. Natur. 111: 589-591.

[83] Ito, K., Sugiyama, H., Salleh, N. M. N. b. N., Min, Ch, P. (1993): Effect of lunar phase on light trap catches of the Malayan black rice bug, Scotinophara coarctata (Heteroptera: Pentatomidae). – Bull. Ent. Res. 83: 59-66.

[84] Janousek, T. E., Olson, J. K. (1994): Effect of a lunar eclipse on the flight activity of mosquitoes in the upper Gulf Coast of Texas. – Journal of the American Mosquito Control Association. 10 (2 Part 1): 222-224.

[85] Járfás, J. (1979): Forecasting of harmful moths by light-traps (in Hungarian). PhD

Thesis. Kecskemét. 127.
[86] Járfás, J., Viola, M. (1981): The impact of meteorological factors onto the light-attraction of codling moth. – Acta Phytopathologica Academiae Scientiarum Hungaricae. 16. 3-4: 399- 404.
[87] Jeffrey, M. H., Dyck, V. A. (1983): Effect of moonlight on light-trap catches of brown plant-hopper. – Int. Rice Res. Newsl. 8. 6: 13.
[88] Jermy, T. (1972): Etology of food specialisation of insects (in Hungarian). Academical Thesis. MTA. Budapest.
[89] Jermy, T. (1974): Die Bedeutung der Lichtfallen für die Faunistik und die angewandte Entomologie. – Fol. Ent. Hung. 27. Suppl. 71-84.
[90] Johnson, C. G. (1969): Migration and dispersal of insects by flight. Methuen London 763.
[91] Kerfoot, W. B. (1967): The lunar periodicity of Sphecodogastra texana, a nocturnal bee (Hymenoptera: Halictidae). – Anim. Behav., 15: 479-486.
[92] Kovarov, B. G., Monchadskiy, A. S. (1963): About the application of polarized light in light-traps to catch of the insects (in Russian). – Ent. Obozr. 42: 49-55.
[93] Laboke, P. O., Ogenga-Latigo, M. W., Smit, N. E. J., Downham, M. C. A., Odongo, B., Hall, D. R., Farman, D. I. (2000): Environmental factors affecting catches of sweetpoptato weevils, Cylas brunneus (Fabricius) and C. puncticollis (Boheman) in pheromone traps. – African Potato Association Conference Proceedings, 5: 217-227.
[94] Leinonen, R., Soderman, G., Itamies, J., Rytkonen, S., Rutanen, I. (1998): Intercalibration of different light-traps and bulb used in moth monitoring in northern Europe. – Entomologica Fennica. 9. 1: 37-51.
[95] Linhares, A. X., Anderson, J. R. (1990): The influence of temperature and moonlight on flight activity of Culicoides variipennis (Coquillett) (Diptera: Certopogonidae) in Northern California. – Pan-Pacific Entomologist. 66. 3: 199-207.
[96] Lödl, M. (1987): Die Bedeutung des Lichtfanges in der zoologischen Forschung. – Beitr. Ent., Berlin. 37. 1. S. 29-33.
[97] Maag, T. (2001): Light catching in Venezuela. Part 2. http://www.meos.ch/terra-typica/berichte/automeris2/automerisengl2.htm
[98] Mahadevan, N. R., Chelliah, S. (1985): Population dynamics of the sorghum stem borer, Chilo partellus (Swinhoe) in light trap. – Behavioural and physiological approaches in pest management. National Seminar on Behavioural and Physiological Approaches in the Management of Crop Pests, Coimbatore (India), 1984: 104-106.
[99] Malicky, H. (1965): Frei Landversuche in Lepidopteren Populationen mit Hilfe der Jermischen Lichtfalle mit Diskussion biozönologischer Gesichtpunkte. – Z. ang. Ent. 56. 4: 358-377.
[100] Mazochin-Porshnyakov, G. A. (1954): Application of ultraviolet light against the harmful insects in the sea farms (In Russian). – Trudi Soveshchsaniya po ribovodstva 7. 2: 404-406.
[101] McCartney, E. J. (1976): Optics of the atmosphere. John Wiley. New York. 408.
[102] McGeachie, W. J. (1989): The effects of moonlight illuminance, temperature and wind speed on light-trap catches of moths. – Bull. Ent. Res. 79. 2: 185-192.
[103] Mészáros, Z. (1990): Variation of Lepidoptera populations on agricultural fields,

and its forecasting (in Hungarian). – Academic Thesis. Budapest. 48.
[104] Mikkola, K. (1972): Behaviour and electrophysiological responses of night-flying insects, especially Lepidoptera, to near ultraviolet and visible light. – Ann. Zool. Fennici. 9: 225- 254.
[105] Mirzayeva, A. G. (1963): The decrease of activity of Diptera connected with microclimatic relation at Prichulime near Tomsk (in Russian). – Tr. Biol. Inst. Sibirsk. Otd. A.N. SSSR. 10: 171-184.
[106] Mizutani, M. (1984): The influence of weather and moonlight on the light trap catches of moths. – Appl. Ent. Zool. 19. 2: 133-141.
[107] Monchadskiy, A. C. (1966): Night activity of gnats in nature and its epidemiological feature (in Russian). – Zool. Zhurn. 32. 5: 860-873.
[108] Morrison, A. C., Ferro, C., Morales, A., Tesh, R. B. (1993): Dispersal of the sand fly Lutzomyia longipalpis (Diptera: Psychodidae) at an endemic focus of visceral leishma-niasis in Colombia. – J. Med. Ent. 30. 2: 427-435.
[109] Morton, R., Tuart, L. D., Wardhaugh, K. G. (1981): The analysis and standardisation of light-trap catches of Heliothis armigera (Hübner) and H. punctiger Wallengreen (Lepidoptera: Noctuidae). – Bull. Ent. Res. 71: 207-225.
[110] Muirhead-Thomson, R. C. (1991): Trap responses of flying insects. – Academic Press. 287.
[111] Muradov, S. M. (1966): Night activity of Culicoides (Diptera, Heleidae) in Turkmenia (in Russian). – Zool. Zhurn. 45. 8: 1264-1266.
[112] Nabili, H., Baily, W. C., Necibi, S. (1999): Beneficial insect attraction to light traps with different wavelengths. – Biological Control. 16. 2: 185-188. Abstract.
[113] Nag, A., Nath, P. (1991): Effect of moon light and lunar periodicity on the light trap catches of cutworm Agrotis ipsilon. – J. Appl. Ent. 111. 4: 358-360.
[114] Negraeff, O. E., Brigham, R. M. (1995): The influence of moonlight on the activity of little brown bats (Myotis lucifugus). – Zeitschrift für Saugetierkunde-International Journal of Mammalian Biology. 60. 6: 330-336. Abstract.
[115] Nemec, S. J. (1971): Effects of lunar phases on light-trap collections and populations of bollworm moth. – J. Econ. Ent. 64: 860-864.
[116] Nielsen, E. T. (1963): Illumination and twilight. – Oikos. 14. 1: 9-21.
[117] Nowinszky, L. (1985): Comparison of richness and average individual number of Macro-lepidoptera species caught by light-traps at different trapping sites (in Hungarian). – Növényvédelem. 21. 8: 343-348.
[118] Nowinszky, L. (1998): Role of light-trap on the entomological researches and the plant-protecting prognosis (in Hungarian). – Habilitationes Savarienses. 5: 1-40.
[119] Nowinszky, L. (2003): The Moon. In: Nowinszky, L. [ed.] (2003): The Handbook of Light Trapping. – Savaria University Press. 108-125.
[120] Nowinszky, L., Puskás, J., Tóth Gy. (1999): Circadian rhythm of flying to light of the turnip moth (Scotia segetum Schiff.) and the fall webworm moth (Hyphantria cunea Drury) (in Hungarian). – Proceedings of Berzsenyi Dániel College Szombathely Natural Science Brochures 4: 55-62.
[121] Nowinszky, L., Puskás, J., Tóth, Gy. (2001): 4 Circadian rhythm of light trapping of turnip moth (Scotia segetum Schiff.) and fall webworm moth (Hyphantria cunea Drury). In: Nowinszky, L. [ed.] (2001): Light trapping of insects influenced by abiotic factors. Part III. Savaria University Press. 23-30.
[122] Nowinszky, L., Szabó, S., Tóth, Gy., Ekk, I., Kiss, M. (1979): The effect of the

http://www.ecology.kee.hu • ISSN 1589 1623

moon phases and of the intensity of polarized moonlight on the light-trap catches. – Z. ang. Ent. 88: 337-353.
[123] Nowinszky, L., Tóth, Gy. (1982): A connection between lunar phases and the swarming phenology of turnip moth (Scotia segetum Schiff.) (in Hungarian). – Tudomány és Mezőgazdaság. 20. 1: 39-41.
[124] Nowinszky, L., Tóth, Gy. (1984): The formation of the light-trap catches of turnip moth (Scotia segetum Schiff.) as a function of the staying above horizon, phases and polarized light of the Moon (in Hungarian). – Kertgazdaság. 16. 2: 83-91.
[125] Nowinszky, L., Tóth, Gy. (1987): Influence of cosmic factors on the light-trap catches of harmful insects (in Hungarian). – PhD Dissertation. Szombathely. 123.
[126] Nowinszky, L., Tóth, Gy. (1990): Lunar periodicity of light-trap catches and flight activity of the turnip moth (Scotia segetum Schiff.) and the greasy cutworm (Scotia ipsilon Hfn.). – Bull. SROP. 13. 3: 40-43.
[127] Nowinszky, L., Tóth, Gy. (1997a): Light trapping of insects influenced by the moon phases. In: Nowinszky, L. [ed.] (1997): Light trapping of insects influenced by abiotic factors. Part II. – Savaria University Press. 9-36.
[128] Nowinszky, L., Tóth, Gy. (1997b): Success of light trapping in connection with the moon phases (in Hungarian). – Kertészeti és Élelmiszeripari Egyetem Rovartani Tanszék, Budapest és a Magyar Agrártudományi Egyesület, Magyar Növényvédelmi Társaság Agrozoológiai Szakosztálya Kiadványa. 19-30.
[129] Nowinszky, L., Tóth, Gy. (2003): Illumination of the environment and twilight polarization phenomena. In: Nowinszky, L. [ed.] (2003): The Handbook of Light Trapping. Savaria University Press 95-105.
[130] Nowinszky, L., Tóth, Gy., Bürgés, Gy., Herczig, B. (1991): Vertical distribution related with migration and Moon phases of Macrolepidoptera species collected by light traps. – Georgicon for Agriculture. 3. 1: 27-38.
[131] Nowinszky, L., Tóth, Gy., Járfás, J. (1994): Illumination of environment, twilight polarization phenomena, and the moonlight. In: Nowinszky, L. [ed.] (1994): Light trapping of insects influenced by abiotic facors. Part I. Savaria University Press. 41-79.
[132] Odor, P., Iglói, L. (1987): An introduction to the sport's biometry (in Hungarian). – ÁISH Tudományos Tanácsának Kiadása. Budapest. 267.
[133] Oloy, I. N. (1978): Effect of some abiotic factor to fly for light-traps of the imagoes of fall webworm moth (Hyphantria cunea Drury) (In Russian). – Novie metodi zashchita rasteniy. 36-41.
[134] Oxley, E. R. B. (2004): Biodiversity in moths. – University of Wales. Bangor. http://www. bangor.ac.uk/~bss035/cal/moths/moth3.html
[135] Papp, J., Vojnits, A. (1976): Zoological collections by the Hungarian Natural History Museum in Korea. – Fol. Ent. Hung. 19: 59-74.
[136] Pedgley, D. E. (1986): Windborne migration in the Middle East by the moth Heliothis armigera (Lepidoptera: Noctuidae). – Ecological Entomology. 11: 467-470.
[137] Pedgley, D. E., Page, W. W., Mushi, A., Odiyo, P., Amisi, J., Dewhurst, C. F., Dunstan, W. R., Fishpool, L. D. C., Harvey, A. W., Megenasa, T., Rose,D.J.W. (1989): Onset and spread of an African armyworm upsurge. – Ecological Entomology. 14: 311-333.
[138] Pedgley, D. E., Tucker, M. R., Pawar, C. S. (1987): Windborne migration of

Heliothis armigera (Hübner) (Lepidoptera: Noctuidae) in India. – Insect Sci. Applic. 8. 4/5/6: 599-604.
[139] Pellicori, S. F. (1971): Polarizing properties of pulverized materials with special reference to the lunar surface. – Applied. Optics. 10. 2: 270-285.
[140] Perfect, T. J., Cook, A. G. (1982): Diurnal periodicity of flight in some Delphacidae and Cicadellidae associated with rice. – Ecol. Entomol. 7: 317-326.
[141] Persson, B. (1976): Influence of weather and nocturnal illumination on the activity and abundance of population of Noctuids (Lepidoptera) in South Coastal Queensland. – Bull. Ent. Res. 66: 33-63.
[142] Preuss, K. P., Preuss, N. C. (1971): Telescopic observation of the Moon as a means for observing migration of the army cutworm, Chorizagrotis auxiliaris (Lepidoptera: Noctuidae). – Ecology. 52. 6: 999-1007.
[143] Pristavko, V. P. (1969): Evaluation of influence of some abiotic factors on Laspeyresia pomonella caught by ultraviolet light-traps (in Russian). – Zool. Zhurn. 48. 8: 1177- 1184.
[144] Puskás, J., Nowinszky, L., Farkas, I., Kiss, M., Herczig, B., Tóth, Gy., Molnár, L. (2001): Light-trap experiment during the total solar eclipse, on 11th August 1999. In: Nowinszky, L. [ed.] (2001): Light trapping of insects influenced by abiotic factors. Savaria University Press. 19-22.
[145] Rajaram, V.; Janarthanan, R.; Ramamurthy, R. (1999): Influence of weather parameters and moon light on the attraction of light trap and pheromone trap catches of cotton pests under dry farming system. – Annals of Agricultural Research. Abstract. 20. 3: 282-285.
[146] Reinert, W. C. (1989): The New Jersey light trap: an old standard for most mosquito control programs. Proceedings of the Seventy-Sixth Annual Meeting of the New Jersey Mosquito Control Association, Inc.: 17-25.
[147] Rezbanyai-Reser, L. (1984): Zur Insektenfauna von Gersau-Oberholz, Kanton Schwyz. III. Lepidoptera 1: "Macrolepidoptera" (Grossschmetterlinge"). – Entomol. Ber. Luzern. 12: 1-127.
[148] Ribbands, C. R. (1945): Moonlight and the house-haunting habits of female Anophelines in West Africa. – Bull. Ent. Res. 36: 395-415.
[149] Riley, J. R., Reynolds, D. R., Farmery, M. J. (1983): Observations of the flight behaviour of the armyworm moth, Spodoptera exempta, at an emergence site using radar and infrared optical techniques. – Ecological Entomology. 8: 395-418.
[150] Riley, J. R., Reynolds, D. R., Farrow, R. A. (1987): The migration of Nilaparvata lugens (Stål) (Delphacidae) and other Hemiptera associated with rice during dry season in the Philippines: a study using radar, visual observations, aerial netting and ground trapping. – Bull. Ent. Res. 77: 145-169.
[151] Roach, F. E., Gordon, J. L. (1973): The light of the night sky. Reidel Dodrecht-Holland. 160.
[152] Robertson, I. A. D. (1977a): Records of insects taken at light traps in Tanzania IV. Seasonal changes in catches and effect of the lunar cycle on insects of the genus Dysdercus (Heteroptera: Pyrrhocoridae). – Centre for Overseas Pest Research. Misc. Rep. 30: 1-8.
[153] Robertson, I. A. D. (1977b): Records of insects taken at light traps in Tanzania V.

Seasonal changes in catches and effect of the lunar cycle on hawk moths of the subfamily Asemanophorinae (Lepidoptera: Sphingidae). – Centre for Overseas Pest Research. Misc. Rep. 31: 1-14.

[154] Robertson, I. A. D. (1977c): Records of insects taken at light traps in Tanzania VI. Seasonal changes in catches and effect of the lunar cycle on hawkmoths of the subfamily Semanophorinae (Lepidoptera: Sphingidae). – Centre for Overseas Pest Research. Misc. Rep. 37: 1-20.

[155] Robertson, I. A. D. (1977d): Records of insects taken at light traps in Tanzania VII. Seasonal changes in catches and effect of the lunar cycle on the adults of several pest species of Lepidoptera (Lepidoptera: Noctuidae). – Centre for Overseas Pest Research. Misc. Rep. 38: 1-11.

[156] Rozenberg, G. V. (1966): Twilight. A study in atmospheric optics. – Plenum Press. New York.

[157] Rubio-Palis, Y. (1992): Influence of moonlight on light trap catches of the malaria vector Anopheles nuneztovari in Venezuela. – J. Am. Mosq. Control Assoc. 8. 2: 178-180.

[158] Saha, S. K., Mukhopadhyaya, M. C. (1981): Semilunar rhythm in the mating activity of the grassland Millipede Orthomorpha coarctata (Saussure) (Polydesmida, Paradoxosomatidae). – Rev. Écol. Biol. Sol., 18. 4: 521-529.

[159] Sant'Ana, A. L., Lozovei, A. L. (2001): Influence of the lunar cycle on the trapping of Aedes scapularis (Diptera, Culicidae) in the Atlantic Forest of Parana (in Portuguese). – Iheringia, Serie Zoologia . 90: 175-182.

[160] Sáringer, Gy. (1976): On the diapause of insects (in Hungarian). – Növényvédelmi Kutató Intézet Évkönyve. 13: 107-166.

[161] Saroja, R., Raguraman, S., Paramasivan, K. S. (1990): Influence of lunar phase on green leafhopper (GLH) incidence. – Int. Rice Res. Newsl. 15. 6: 23-24.

[162] Schaefer, G. W. (1976): Radar observations of insect flight. In: Rainey (ed): Insect flight. Blackwells.: 157-197.

[163] Sekhar, P. R., Venkataiah, M., Venugopal Rao, N. (1995): Effect of moon light and lunar periodicity on the pheromone trap catches of Helicoverpa armigera (Hubner) moths. – J. Res. APAU 23. 3: 38.

[164] Sekhar, P. R., Venkataiah, M., Venugopal Rao, N. (1996): Effect of moon light and its periodicity on the light trap catches of Helicoverpa armigera (Hubner) moths. – Annals of Agricultural Research. 17. 1: 53-55.

[165] Sharma, B., Badan, P. (1993): Influence of lunar periodicity on activity and abundance of macrosteline leafhoppers caught in a light trap at Jammu (J & K). – Indian Journal of Ecology 20. 2: 182-184.

[166] Shrivastava, S. K., Shukla, B. C., Shastri, A. S. R. A. S. (1986): Effect of moon phase and lunar cycle on light trap catches of Nephotettix spp. – Comp. Physiol. Ecol. 11. 4: 164-165.

[167] Shrivastava, S. K., Shukla, B. C., Shastri, A. S. R. A. S. (1987): Effects of lunar cycle on light trap catches of Spodoptera litura Fabricius. – Indian Journal of Agriculural Sciences. 57. 2: 117-119.

[168] Siddorn, J. W., Brown, E. S. (1971): A Robinson light trap modified for segregating samples at predetermined time intervals, with notes on the effects of moonlight on the periodicity on catches of insects. – J. Appl. Ecol. 8: 69-75.

[169] Singh, N., Mishra, A. K., Curtis, C. F., Sharma, V. P. (1996): Influence of moon-

light on light-trap catches of the malaria vector Anopheles culicifacies (Diptera: Culicidae) in central India. – Bull. Ent. Res. 86: 475-479.
[170] Skuhravy, V., Zumr, V. (1981): Nocturnal and seasonal flight activity of the nun moth Lymantria monacha L. (Lepid. Lymantriidae) as determined by pheromone and light traps. – Z. ang. Ent. 92: 315-319.
[171] Sotthibandhu, S., Baker, R. R. (1979): Celestial orientation by the large yellow moth, Noctua pronuba L. – Anim. Behav. 27: 786-800.
[172] Southwood, T. R. E. (1978): Ecological methods with particular reference to the study of insect populations (Second ed.) – Chapman and Hall, London.
[173] Steinbauer, M. J. (2003): Using ultra-violet light traps to monitor Autumn Gum Moth, Mnesampela private (Lepidoptera: Geometridae), in south-east Australia. – Australian Forestry. 66. 4: 279-286.
[174] Summerville, K. S., Crist, T. O. (2003): Determinants of lepidopteran community composition and species diversity in eastern deciduous forests: roles of season, eco-region and patch size. – Oikos 100. 1: 134-148.
[175] Syed Nurul Alam (1994): Population dynamics, varietal reactions and microbial control of different species of mango leafhoppers. – Philippines Univ., Los Banos, College Laguna, (Philippines) Thesis (M. S. in Entomology) 114.
[176] Szabó, E., Járfás, J. (1974): The connection between the quantity of insect's order flying to light and the climatic factors (in Hungarian). – Állattani Közlemények. 61. 1-4: 119-132.
[177] Szabó, S., Tóth, Gy., Ekk, I., Kiss, M., Nowinszky, L. (1981): Changes of illumination and polarized light of the Moon in connection with the light-trap catches of insects (in Hungarian). – Növényvédelem. 17. 10-11: 429- 435.
[178] Szabóky, Cs. (1989): Lepidoptera fauna of the Salföld (Hungary) (in Hungarian). – Folia Musei Historico-Naturalis Bakonyiensis. 8: 31-46.
[179] Szeőke, K. (1973): The back-catch of indicated moths by mercury lamp light-trap as a function of emitting distance (In Hungarian). – Növényvédelem. 9. 11: 509-511.
[180] Taylor, R. A. J. (1986): Time series analysis of numbers of Lepidoptera caught at light traps in East Africa, and the effect of moonlight on trap efficiency. – Bull. Ent. Res. 76: 593-606.
[181] Theowald, B. R. (1963): Faunistische en fenologische waarnemingen met betrekking tot langpootmuggen (Diptera, Tipulidae). – Fenologisch en faunistisch ondezoek over boom-gardinsekten. Wageningen. – Versl. Landbounk. Onderz. 139: 185-202.
[182] Tigar, B. J., Osborne, P. E. (1999): Patterns of biomass and diversity of aerial insects in Abu Dhabi's sandy deserts. – Journal of Arid Environments. Abstract. 43. 2: 159-170.
[183] Toda, M. J., Kitching, R. L. (2003): Forest ecosystems: the assessment of plant and animal biodiversity in forest ecosystems. The Manual. Diversitas International Biodiversity Observation Year. 1-95.
[184] Tóth, Gy., Nowinszky, L. (1985): The connection between the long time variation of environment's illumination and the light-trap catches of insects (in Hungarian). – Növényvédelem. 21. 10: 433-438.
[185] Tóth, Gy., Nowinszky, L., Járfás, J. (1980): Computing method to obtain the night

illumination of environment applied for plant protecting prognoses (in Hungarian). – A Neumann János Számítógéptudományi Társaság Csongrád megyei Szervezetének és Orvosbiológiai Szakosztályának Kiadványa. Szeged. 183-193.
[186] Tóth, Gy., Nowinszky, L., Járfás, J. (1983): The night hourly distribution of the light-trap catches of turnip moth (Scotia segetum Schiff.) connected with the illumination of environment (in Hungarian). – Növényvédelem. 19. 3: 106-111.
[187] Tshernyshev, V. B. (1961): Time of fly of the insects into light (in Russian). – Zool. Zhurn. 40. 7: 1009-1018.
[188] Tshernyshev, V. B. (1984): The daily rhythm of the activity of insects (in Russian). – Edition of the Moscow University. 220.
[189] Tshernyshev, V. B., Bogush, P. P. (1973): The influence of weather on insects' flying to light in Central Asia (in Russian). – Zool. Zhurn. 52. 5: 700-708.
[190] Tshernyshev, W. B., Danthanarayana, W. (1998): Laboratory study of flight in some noctuids (Lepidoptera: Noctuidae: Heliothinae). 2. Activity from day to day. – Russian Entomol. J. 7. 1-2: 96-100.
[191] Tucker, M. R. (1983): Light-trap catches of African armyworm moths, Spodoptera exempta (Walker) (Lepidoptera: Noctuidae), in relation to rain and wind. – Bull. Ent. Res. 73: 315-319.
[192] Vaishampayan, S. M., Shrivastava, S. K. (1978): Effect of moon phase and lunar cycle on the light trap catch of tobacco caterpillar Spodoptera litura (Fabr.) (Lepidoptera: Noctuidae). – J. Bombay Natural Hist. Society. 75: 83-87.
[193] Vaishampayan, S. M., Verma, R. (1982): Influence of moon light and lunar periodicity on the light trap catches of gram podborer, Heliothis armigera (Hubner) moths. – Indian J. Ent. 44. 3: 206-212.
[194] Vanderplank, F. L. (1941): Activity of Glossina pallidipes and the lunar cycle (Diptera). – Proc. Roy. Soc. London. A. 16: 61-64.
[195] Voigt, E. (1967): Data for the swarming of moths damaging the grape (In Hungarian). – Fol. Ent. Hung. 20: 623-635.
[196] Wéber, M. (1957): The role of meteorological parameters in life of insects (in Hungarian). – Pécsi Műszaki Szemle. 3: 17-23.
[197] Wehner, R. (1984): Astronavigation in insects. – Ann. Rev. Entomol. 29: 277-298.
[198] Williams, C. B. (1936): The influence of moonlight on the activity of certain nocturnal insects, particularly of the family of Noctuidae as indicated by light-trap. – Phil. Trans. Roy. Soc. London. B. 226: 357-389.
[199] Williams, C. B. (1939): An analysis of four years captures of insects in a light-trap. Part I. General survey: sex flight. – Trans. Roy. Ent. Soc. London. 89: 79-132.
[200] Williams, C. B. (1940): An analysis of four years captures of insects in a light-trap. Part II. – Trans. Roy. Ent. Soc. London. 90: 228-306.
[201] Williams, C. B., Emery, B. A. (1935): A photographic moonlight recorder. – Journ. Sci. Instrum. 12: 111-115.
[202] Williams, C. B., Singh, B. P. (1951): Effect of moonlight on insect activity. – Nature. 853.
[203] Williams, C. B., Singh, B. P., El-Ziady, S. (1956): An investigation into the pos-

sible effects of moonlight on the activity of insects in the field. – Proc. Roy. Ent. Soc. London. A. 31: 135-144.
204] Yela, J. L., Holyoak, M. (1997): Effects of moonlight and meteorological factors on light and bait trap catches of noctuid moths (Lepidoptera: Noctuidae). – Environmental Entomology. 26. 6: 1283-1290.

http://www.ecology.kee.hu • ISSN 1589 1623