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Light-Trap Catch of Moth Species (Lepidoptera) in Connection with the Retention Time of the Moon above Horizon

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Abstract

The study deals with light trapping of moths in connection between retention time of the Moon above horizon. The authors suggest the retention time is an independent of the lunar phase and a stationary characteristic of the effect of the Moon on the result of light trapping.

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Introduction and Review of Literature

Researchers have been researching the effect of the Moon on light-trapping of insect for decades.

Williams (1936) have published fundamental studies in this field. According to his statements, three times more specimen of noctuid moths (Noctuidae) would fly to light on a clear night at a New Moon than at a Full Moon. He extended his investigations to several orders of insects and observed a stronger decrease in the the strong moonlight. He established two reasons, which may be responsible for lower catch levels at Full Moon periods:

Moonlight reduces the activity of insects and so the active population accessible for the light trap is smaller,

The light of the lamp collects moths from a smaller area in moonlit environment.

The past few decades did not come up with a satisfactory answer to that dilemma. The conclusions are contradictory and up to this day a good many questions have remained unclarified. It is true, the authors usually collected differing species at the most different geographical locations. Some authors find an explanation by accepting the theory of the impact of a collecting distance, others refer to decreased activity.

Relatively few authors have observed increased light trap catch in the vicinity of a Full Moon (Edwards 1961, Duviard 1974, Jeyakumar et al. 2007).

Initially, the researchers studied the influence of light of Moon on the effectiveness of light trapping, mainly in the context of Moon phases. The aim of our study is not to summarize the literature on the topic, so we only briefly present the most important research directions. However, we refer to one of our books (Nowinszky, 2008), which contains detailed references to the studies available at the time.

We therefore refer to those authors who have made a significant contribution to a more complete understanding of the lunar effect.

Moonlight reduces the flying activity of the insects

Nemec (1971) collected Corn Earworm (*Heliothis zea* Boddie) in highest numbers at a New Moon and in lowest at a Full Moon. He is on the view that moths are having an inactive period at a Full Moon.

Baker and Sadovy, (1978), Baker (1979) and Sotthibandhu and Baker (1979) believe that moonlight cannot have an influence on the collecting distance. Thus, in their point of view, increased light intensity moderates flight activity.

However, Dufay (1964) refuted this hypothesis with convincing arguments:

Nocturnal moths can be seen in the light of car lights also on moonlit nights, At a Full Moon collecting decreases but does not stop, In case of lunar eclipses, the catch is high when the Moon is obscured, although closely before and after it is low. This observation is quite demonstrative, as the eyes of nocturnal insects adapt to darkness only 5-9 minutes after it sets in.

Besides the points made by Dufay (1964), the following facts prove this theory. It is a justified fact, that certain insects use polarized moonlight for their orientation.

Some researchers have compared the capture results of light traps emitting polarized and non-polarized light (Kovarov and Monchadskiy 1963, Danthanarayana and Dashper 1986, Szentkirályi et al. 2005). Although most species were collected by traps emitting non-polarized light, there were species that flew to polarized light in greater numbers. We have already pointed out in an early study that polarized moonlight increases light trapping (Nowinszky et al. 1979). In the following years, the same conclusion was drawn from the light trap catching results of several insect species (Nowinszky et al. 2012a, 2012b, 2014, Nowinszky and Puskás 2013, 2014).

Generally, illumination by the Moon does not hamper the flight activity of insects. Besides the points made by Dufay (1964), the following facts prove this theory. It is a justified fact, that certain insects use polarized moonlight for their orientation. It is unthinkable that the activity of these insects would decrease when polarized moonlight is present in a high ratio. Our investigations have also proved the catch to be higher in case of higher polarization

Moonlight decreases the collecting distance

Before we start to discuss the different views in scientific literature regarding the role of the collecting distance as a modifying factor, it is important to define and distinguish the concepts of a theoretical and a true collecting distance.

By collecting distance, we mean the radius of the circle in the centre of which the trap is located and along the perimeter of which the illumination caused by the artificial light source equals the illumination of the environment (Nowinszky, 2003).

The actual collection distance depends on many factors, but most importantly we believe that individuals of a given species be able, or whether he wants to fly away from the theoretical collection distance to the trap?

Some researchers have calculated the collection distance of the light traps they use in different lunar phases (Dufay 1864, Mukhopadhyay 1991).

Studies by Bowden (1973a, 1973b, Bowden and Church, 1973, Bowden 1981, 1982, Bowden & Morris, 1975) discuss in detail the decline of luminous intensity between civil and astronomical twilight as a function of the lunar phases. According to McGeachie (1989), the attracting distance of a 125 W mercury vapour lamp is about 10 m. In an earlier work (Nowinszky and Tóth, 1987), we determined these distances as 18 m and 298 m for the Jermy-type trap working with a100W normal bulb.

Most authors observed a decline in the catch under the influence of the Moon.

We refer to some important studies.

Cleve (1954), Agee et al. (1972), Persson (1976), Douthwaite (1978), Vaishampayan and Verma (1982), Bowden (1981), Vaishampayan and Shrivastava (1982), Tucker (1983), Taylor (1986), Shrivastava et al. (1987), Dent and Pawar (1988), Nag and Nath (1991), Nowinszky et al. (2010).

The results of these researchers were real, because in those years, light pollution was not yet significant.

A description of our calculation method can be found in our earlier mentioned book (Nowinszky, 2008).

In an earlier book, to calculate the collection distance of light traps used in Hungary for a full lunar month, taking into account light pollution. Light pollution was determined based on the work of Cinzano et al. (2001). Without light pollution, the collection distance of Jermy type light-trap is 255 meters at New Moon and 21.1 meters at Full Moon. If the light pollution is only equal to the 0.11 lux (it is equal with the averaged brightness of the Full Moon), the collection distance is 21.1 meters at the New Moon and 14.9 meters at the Full Moon.

The light pollution is now much higher than the calculations in 2008. Therefore, with the New Moon and the Full Moon, there is almost no difference in collection distance.

Nowinszky and Puskás (2011) also proved the correctness of these calculations.

The Scarce Bordered Straw (*Helicoverpa armigera* Hbn.) was caught by light-trap to ascertain whether the behaviour of European population is the same with Indian ones in connection with moon phases, collecting distance and polarized moonlight. The Indian authors, Vaishampayan and Verma (1982) used Pennsylvania-type light-trap, near Jabalpur between 1975–76 and 1978–79. They have found that the caught moths were very low at Full Moon, and high around the New Moon.

The light-trap catching data were taken from the registers of Hungarian Light-Trap Network for 1994-2006. The Jermy-type light-traps were used in these years. We also processed from these catching data of the Scarce Bordered Straw (*Helcoverpa armigera* Hbn.).

We did not establish difference between these catching data at Full Moon and New Moon in Hungary between 1993 and 2006.

The light pollution in India was lower at that time than this time in Hungary. The collecting distance in India was differing significantly at New Moon and Full Moon. The light pollution equalized the collecting distance all the lunar months in Hungary. Hungarian catch results are modified primarily by polarized moonlight in the period between the First and the Last Quarters.

Results of Truxa and Fiedler (2012) confirm that the radius of attraction of low powered light traps for moths is very small often even below 10 m. Thus, moths are good indicators of habitat quality and fragmentation as they are rarely attracted from distant habitats to such light traps.

This finding is an extremely important guide for future research.

Based on literature references and our own results, we consider it justified that nowadays moonlight does not affect insect activity or collection distance. But if that is the case, then the question arises as to whether we still need to study the lunar effect?

Most research to date has examined the lunar effect in the context of moon phases. This was simple because moon phase data are published in astronomer yearbooks. However, insects do not perceive the moon phases, but the various characteristics of the Moon. However, these can be very different in each moon phase.

In a single lunar month (lunation), of course, the individual lunar characteristics (moonlight, etc.) are related to the phase angle, but in different lunations they are very different. Therefore, individual lunar parameters cannot be replaced by lunar phases when working with collection data from different periods.

Nowinszky and Tóth (1987) have already reported changes in moonlight as a function of changes in the Moon according to longer period. This is because the brightness of the Moon is not only on different days of lunation as a function of phase angle, but also due to the different zenith distance of the 18,61year period of lunar orbit migration, the same on the same phase angle on the same days of years and even seasons. Tóth and Nowinszky (1985) calculated the luminance of all lunar fillings over an 18,61year period. The two extreme values differed by orders of magnitude: 0.219 and 0,0012 lux.

In our recent works, we examined the effectiveness of light trapping of different insect species in the context of different characteristics of the Sun and Moon. They were as follows: Night sky polarization created by the Sun and the Moon (%), Gravitational polarization created by the Sun, Moon and Sun+Moon (μJ/kg) (Nowinszky et al. 2018). In our book published last year (Nowinszky et al. 2019), we examined the effect of the following lunar characteristics on light trapping in addition to those listed above:

Altitude of the Moon's Babinet point, Azimuth value, zenith distance and height above the horizon of the Moon (°), Apparent magnitude, fraction of illuminated surface (%) of the Moon and moonlight (lux).

In our current study, we examined the effectiveness of light trapping in the context of another characteristic of the Moon, it's the retention time above horizon (minutes).

Material

The Hungarian forestry and agricultural light-trap network with the same Jermy-type light-traps (Jermy, 1961) has been operating continuously to this day since 1958. Between 1962 and 1970, 20 forestry and 23 agricultural light-traps operated in all regions of the country.

Both the forestry light-traps and agricultural ones have provided invaluable data for scientific researches. The light source of this light-trap is a 100W normal electric bulb and the killing agent is chloroform. Lepidoptera is the best-processed taxon. During these years, all caught moths were identified and the number of catching moths of all species recorded daily in the light-trap registers.

From this vast amount of collection data, we selected species to represent as many families and subfamilies as possible (Table 2. 1). Our aim was to determine whether different species would react identically or differently to the effect of the retention time of the Moon above horizon.

The retention time of the Moon above the horizon was calculated for the geographical coordinates of Budapest (47°03′N and 19°05′E) for all the nights between 1962-1970. For this, we used the dates of the Moon's rise and set data of Astronomical Applications Dept. U.S. Naval Observatory, Washington DC. From these, we calculated the retention time in minutes, taking into account the time of switching the light-traps on and off.

Methods

Relative catch values were calculated from the number of caught moths for each species and sampling night until the trap of the year worked. The relative catch was defined as the quotient of the number of moth caught during a sampling time unit (1 night) per the average catch (number of moths) within the same catching period to the same time unit. For example, when the actual catch was equal to the average moth number caught in the same catching period, the relative catch was 1 (Nowinszky, 2003).

We first performed calculations to verify that the phase angle values in the three characteristic lunar quarters, (First Quarter, Full Moon, and Last Quarter) have very different residence values. Thus, as a function of the phase angle, we plotted the distribution of retention times of the Moon above horizon in the First Quarter, Full Moon, and Last Quarter. Our results are illustrated.

The values of retention times were arranged into groups. The number of groups was determined according to Sturges' methods (Odor and Iglói, 1987). Following we arranged the data of averaged retention times in classes. The averaged data of relative catch values were placed according to the features of the given night, and then were summed up and averaged. The data are plotted for each relative catch values in Figures.

Results and Discussion

Our results demonstrate that the effectiveness of light trapping by different moth species depends on the length of time the Moon stays above the horizon. Three basic types can be distinguished from the Figures. It increases, decreases, or initially increases and then decreases approximately parallel to the Moon's retention time above the horizon. However, this relationship is not related to the taxonomic position of each species. From the results, a cautious valuation can be made as to which period of the night the species is active. The Moon is shorter above the horizon in the First Quarter than in the Last Quarter, and in its visible above the horizon almost throughout the night before and after the Full Moon. We also demonstrated that the lunar retention time above the horizon is independent of the lunar phases.

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. Baker R.R. (1979): Celestial and light-trap orientation of moths. Antenna. 3. 44-45.
3. Baker R.R., Sadovy Y. (1978): The distance and nature of the light-trap response of moths. Nature. 276. 818-821.
4. Bowden J. (1973a): The influence of moonlight on catches of insects in light-traps in Africa. Part I. Bull. Ent. Res. 63. 115-128.
5. Bowden J. (1973b): The significance of moonlight in photoperiodic responses of insects Bull. Ent. Res. 63. 605-612.
6. 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.
7. Bowden J. (1982): An analysis of factors affecting catches of insects in light-traps. Bull. Ent. Res. 72. 535-556.
8. 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.
9. 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.
10. Cinzano P., Falchi F., Elvidge C.D. (2001): The first World Atlas of the artificial night sky brightness. Mon. Not. R. Astron. Soc., 328. 689-707.
11. Cleve K. (1954): Einfluss der Wellenglange des Lichtes auf den Lichtfang der Schmetterlinge. Deutsch. Entomologtag in Hamburg.
12. 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.
13. Dent D. R., Pawar C. S. (1988): The influence of moonlight and weather on catches of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in light and pheromone traps. – Bull. Ent. Res. 78: 365-377.
14. 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

15. Dufay C. (1964): Contribution a l'Étude du phototropisme des Lépidopteres noctuides. Annales des Sciences Naturelles, Zoologie, Paris. 12. 6. 281-406.
16. Duviard D. (1974): Flight activity of *Belastomatidae* in central Ivory Coast. Oecologia (Berlin). 15. 321-328.
17. Edwards J.S. (1961): Observations on the Ecology and ehaviour of the Huhu Beetle, *Prionoplus reticularis* White. (Col. Ceramb.). Transactions of the Royal Society of New Zealand, 88 (4). 733-741.
18. Jermy T. (1961): Investigation of the swarming of harmful insects using light-traps (in Hun-garian). A Növényvédelem Időszerű Kérdései. 2: 53-61.
19. Jeyakumar P., Chander S., Amar Singh A., Jat M. C., Monga D. (2007): Effects of light trap and lunar cycle on the insects of cotton (*Gossypium hirsutum*) ecosystem. Indian Journal of Agricultural Sciences, 77 (5): 327-328.
20. 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
21. 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.
22. Mukhopadhyay S. (1991): Lunation-induced variation in catchment areas of light-traps to monitor rice green leafhoppers (*Nephotettix* species) in West -Bengal. Indian Journal of Agricultural Sciences, 61 (5): 337-340.
23. Nemec S. J. (1971): Effects of lunar phases on light-trap collections and populations of bollworm moth. J. Econ. Ent. 64: 860-864.
24. 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.
25. Nowinszky L. [ed.] (2003): The Handbook of Light Trapping. Savaria University Press. p. 276.
26. Nowinszky L. (2008): Light Trapping and the Moon. Savaria University Press, Szombathely. p. 70.
27. Nowinszky L., Kiss O., Puskás J. (2014): Light-trap catch of caddisflies (Trichoptera) in the Carpathian Basin and Anatolia in the four quarter of the Moon. Journal of the Entomological Research Sciences, 16 (3): 11-25.
28. Nowinszky L., Kiss O., Szentkirályi F., Puskás J., Kádár F., Kúti Zs. (2010): Light trapping efficiency in case of *Ecnomus tenellus* Rambur (Trichoptera: Ecnomidae) depending on the moon phases. Advances in Bioresearch, 1 (2): 1-5.
29. Nowinszky L., Hirka A., Csóka Gy., Petrányi G., Puskás J. (2012a): The influence of polarized moonlight and collecting distance on the catches of winter moth *Operophthera brumata* L. (Lepidoptera. Geometridae) by light-traps. Eur. J. Entomol., 109. 29-34.
30. Nowinszky L., Kiss O., Szentkirályi F., Puskás J., Ladányi M. (2012b): Influence of illumination and polarized moonlight on light-trap catch of caddisflies (Trichoptera). Research Journal of Biology, 2. 3. 79-90.
31. Nowinszky L., Puskás J. (2011): Light trapping of *Helicoverpa armigera* in India and Hungary in relation with moon phases. The Indian Journal of Agricultural Sciences. 81 (2): 152-155.
32. Nowinszky L., Puskás J. (2013): The Influence of Moonlight on Forestry Plants Feeding Macrolepidoptera Species, Research Journals of Life Sciences, 1 (3): 1-10.
33. Nowinszky, L., Puskás, J. (2014): Light-trap catch of Lygus sp. (Heteroptera: Miridae) in connection with the polarized moonlight, the collecting distance and the staying of the Moon above horizon. Journal of Advanced Laboratory Research in Biology, 5 (4): 102 -107.
34. Nowinszky L., Szabó S., Tóth Gy., Ekk I., Kiss M. (1979): The effect of the moon phases and of the intensity of polarized moonlight on the light-trap catches. Z. ang. Ent. 88. 337-353.
35. Nowinszky L., Tóth Gy. (1987): Influence of cosmic factors on the light-trap catches of harmful insects (in Hungarian). Ph.D. Dissertation. Keszthely. 123.
36. Nowinszky L., Kiss M., Puskás J. (2018): Light- and Pheromone Trap Catch of Insects. GLOBE, p. 118.

37. Nowinszky L., Hill, L., Puskás J. (2019): Influence of the Little-Studied Sun's and Moon's Charachteristics on the Trapping of Night Active Insects in Central Europe, Australia and USA. Savaria University Press, Szombathely p.130.
38. Odor P, Iglói L (1987) An introduction to the sport's biometry (in Hungarian). ÁISH Tudományos Tanácsának Kiadása. Budapest, p. 267.
39. 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.
40. 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 Agricultural Sciences. 57. 2: 117-119.
41. Sotthibandhu S., Baker R.R. (1979): Celestial orientation by the large yellow moth, *Noctua pronuba* L. Anim. Behav. 27: 786-800.
42. Szentkirályi F., Bernáth B., Kádár F., Retezár I. (2005): Flight of ground beetles towards polarized and unpolarized light sources. European Carabidology 2003. Proceedings of the 11th European Carabidologist Meeting DIAS Report, 114: 313-324
43. 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.
44. Tóth and Nowinszky (1985): Connection between the light-trap catches and the long-term changes in the environmental illumination. (in Hungarian), Növényvédelem, 21. 10:433-438.
45. Truxa Ch. Fiedler K. (2012): Attraction to light – from how far do moths (Lepidoptera) return to weak artificial sources of light? Eur. J. Entomol. 109: 77–84
46. 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.
47. 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.
48. 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. 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.