University of Sopron

Faculty of Forestry

Theses of doctoral (PhD) dissertation

The effect of environmental illumination on the composition of light-trapped insects

Edit Pintérné Nagy

Sopron

2017

Doktoral School:	Pál Kitaibel Doctoral School of Environmental Sciences
Program:	K1 Bioenvironmental Sciences
Supervisor:	Prof. Dr. Ferenc Lakatos

Importance of the topic, objectives of the research

The number of the Earth population increases briskly and due to this the number and the extent of settlements grows. The streets, places, buildings lightened in the night mean safety for the inhabitants of cities; however the positive effects include also the negative environmental effects connected with developed civilization.

The illumination level of the natural night environment is changed by the lights resulting from human activities, which is called light pollution (CINZANO et al. 2001).

Insects are creatures in the biggest number among every group of the animal kingdom. According to some estimates their global race number on Earth is approx. 1 – 30 million (MINELLI 1993), according to other sources 5 – 10 million, from which approx. 1 million insect species were described and officially named (NEW 2009). The race number of the moths (Macrolepidoptera) occuring in Hungary is 1274, within the number of the nocturnal moth races (Lepidoptera: Macroheterocera) is 1102 (VARGA 2010). The insects of night life mode, within the nocturnal moths are very important plant pollenizers (MCGREGOR et al. 2015), further they mean important aliment basis for several animal groups e.g. spiders (HEILING 1999), reptilian, amphibia (HENDERSON & POWELL 2001) birds and bats (RYDELL 1992).

Light pollution alters the seeing, life rhythm, protection mechanism, alimentation and reproduction (oviposition and copulation) of insects of night life mode and especially moths (SOWER et al. 1970, NEMEC 1969, PFRIMMER et al. 1955, BROWN 1984) and the orientation thereof (FRANK 1988).

The purpose of the essay is to investigate the composition of insect communities collected in light-trap on examination areas with different light pollution, to discover the relationship between the light-source types, further the value of the background illumination of the environment and the individual numbers. Based on literature information the essay represents the most important negative effects of light pollution to fauna and especially night insects.

The author has looked for the answer to following questions:

1. Based on literature information which is the effects of light pollution related to individual animal?
2. To which rate do the observed night insects (on order level), further nocturnal moths (on the speciel level) attract to artificial light-sources of different performance and colour temperature applied in the research?
3. Can significant difference be experienced between the individual numbers of insect orders light-trapped in an environment of different light pollution?
4. Which insect orders are dominant in the individual time interval of the night?
5. Is a relationship between the background illumination of the environment and the number of light-trapped individuals demonstrable?
6. What kind of deviations can be demonstrated in the spring and autumn light-trapped periods between diversity values according to the specific light-sources?
7. Can light pollution be determined on the basis of different light measurement data (lux, magnitude)?

Matherials and methods

Study area

We selected three areas of different illumination intensity in Sopron and its surrounding for light-trapping. We termed the sites as follows: seminatural, transitional and urban. The seminatural study area is devoid of artificial lights, has virtually no light pollution, and is located in the Sopron highlands. The transitional area had slight to moderate light pollution in the area caused by street lamps and illumination of local residences. The transitional site of our study is located in Bánfalva, which is a suburb of Sopron. The urban area is located at the meteorological station, which is in the centre of Sopron; there is significant light pollution from artificial light in this area.

Sampling design

Nocturnal insects specimens were collected with Jermy-type light-traps in the summers (June, July and August) of 2012 and 2013 as well as in the spring (March, April) and autumn (October, November) of 2014. I used the following three kinds of light sources: a high-pressure sodium lamp, a HMLI mixed-light lamp, and a compact fluorescent tube The sampling times were in three day cycles adjusted to the new moon, the prime of the moon, the wane of the moon, and full moon. Light trapping went on for the entire duration of the night, from sunset to sunrise. The individuals collected by light-trapping were killed with ethyl acetate. I measured the light in different area.

Data analysis

I have identified the collected insect individuals on the order level in 2012 and in 2013, and the collected lepidopteran on the species level in 2014. In the first two years, the number of individuals was evaluated, while in year three, the number of Lepidopteran species was evaluated.

2012 and 2013:

- *Dominance categorization of orders based on dominance values*
- *Dominance investigation of orders according to different time intervals*
- *Comparison of light-sources and places with the H-test of Kruskal – Wallis (Statistica 12 program) based on the average number of light-trapped insect individuals*
- *Investigation of coherence between background illumination resulting from light-sources and the individual number of light-trapped insects with linear correlation calculation..*

2014:

- *To determine the species dominance of the lepidopteran communities I utilized the Berger-Parker dominant index*
- *Comparing investigations: I used the Jaccard and Bray-Curtis index and Rényi diversity profiles*
- *Diversity analysis (Simpson index, Shannon-Weaver index, Pielou-type equitability)*

Summary of results

In the first two years I have classified 170 688 individuals in 8 orders, in the third year I have determined 985 individuals of 23 nocturnal moth species.

In 2012 on the transitional area in July the individual number was the highest with HMLI mixed-light lamp, on the seminatural and urban area in June with high-pressure sodium and HMLI mixed lamp. In June 2013 on the seminatural area the individual number was the highest with HMLI mixed-light lamp, in July on the seminatural area with the high-pressure lamp and on the transitional area with the compact fluorescent tube. Comparing the average individual numbers per each area and light-source type there were substantially deviation between areas than between light-sources. As result of the dominance investigations the Hemiptera order can be classified into the eudominant category on the seminatural area in case of all three light-source types, while on the transitional and urban area the Diptera order. The investigation according to time intervals has demonstrated tha the dominance value of the Diptera order was high on the urban area; on the seminatural area additional to the Diptera order also the dominance value of Hemiptera, Coleoptera and Lepidoptera orders was high.

The values of the indexes used for the diversity analysis of nocturnal moths (Simpson, Shannon, Pielou) were different per each light-sources and seasonally. According to the comparing investigations in the spring months the compact fluorescent tube and the HMLI mixed-light lamp and during the autumn light-trapping the high-pressure sodium lamp and the compact fluorescent tube were most similar; if considering also bulk relations in spring time the high-pressure sodium lamp and the compact fluorescent tube, in autumn the HMLI mixed-light lamp and the compact fluorescent tube were most similar. The diversity profile of the nocturnal moth communities trapped at the investigated light-sources could be ranked in two cases. Based on this diversity is higher in autumn in case of the HMLI mixed-light lamp than in case of the compact fluorescent tube, in spring it is higher in case of the fluorescnet tube than in case of the high-pressure sodium lamp. Positive correlation ratio could be demonstrated between the background illumination value and the individual number on the seminatural area at the HMLI mixed-light lamp. The method represented in the essay is suitable for the calculation of the light pollution values expressed in lux, which in the possession of further data can be succesfully used for researches of entomological, ornithological, traffic safety purpose as well.

Theses of the dissertation

1 During his investigation the author has stated that the highest individual number of insects was attracted to the HMLI mixed-light lamp on the seminatural area.

In the summer months of 2012 és 2013 on the seminatural area the number of the light-trapped individulas was more in case of every light-source type than on the transitional and urban area. In 2012 due to the mass swarm of the individulas belongong to the Hemiptera order dated June 20 the deviation is extremely high compared to the individual number of other orders. In 2013 the most insect individuals were clearly collected by the HMLI mixed-light lamp on the seminatural area.

2 The individuals belonging to the Lepidoptera order attract to the investigated light-source types in different individual number, which is of different extent per each area.

In 2012 and 2013 in the summer months at the three investigated locations I have performed light-trapping with the three investigated light-sources types. The individual number of the collected insects was examined in case of the Lepidoptera order and I have stated that ont he seminatural area the deviation was the biggest between the number of the individuals trapped at the high-pressure sodium lamp and the compact fluorsecent tube (904 deviation of the individual numbers); on the transitional and urban area the deviation was the biggest between the HMLI mixed-light lamp and the compact fluorescnet tube (792 and 532 deviations of the individuals numbers).I have compared the investigation areas for each light-sources and I have experienced the biggest deviation in individual numbers at the high-pressure sodium lamp between the seminatural and transitional area (2187 deviation of the individual numbers); at the HMLI mixed-light lamp and the compact fluorescent tube between seminatural and urban area (1625 and 1363 deviations of the individual numbers).

3 The background illumination of the altering investigation locations affects the amount of insects arriving to the artificial light-sources.

Comparison based on the average of the individual number of light-trapped insects in case of every investigation location anlampd light-source type. Based on this it can be stated that the most significant difference was between the investigation locations at the HMLI mixed-light lamp. In case of the examination of each location the investigation has not demonstrated significant difference between the light-source types on the seminatural area, however it has on the transitional area four cases.

4 The author has stated that the dominance relations of the investigated insect groups are of different extent per each area and light-source type.

On the seminatural area the dominance value of the Lepidoptera, Hemiptera and Coleoptera orders is high, on the transitional and urban area the dominance value of the Diptera order. Investigating the dominance value of the orders according to each light-source type the dominance value of the Diptera order was extremely high at the high-pressure sodium lamp, at the a HMLI mixed-light lamp additional to the Diptera order the dominance value of the Hemiptera order and at the compact fluorescent tube the dominance value of the Diptera order is the highest.

5 Due to the low number of investigations it is not possible to draw clear consequences about the flying activity of the individuals belonging to the specific orders per each time interval.

I have performed the time interval investigations on the urban and the transitional area at the HMLI mixed-light lamp and the high-pressure sodium lamp, on te seminatural area at the high-pressure sodium lamp and the compact fluorescent tube. According to the first examination on the urban area the dominance value of the Diptera order was the highest in every time interval, on the seminatural area additional to the Diptera order the values of the Hemiptera, Coleoptera and Lepidoptera orders are also high.The examination of each order has shown variable values regarding the case, in which time interval the flying activity of the insect individulas within the specific orders is the biggest, so it is not possible to draw exact consequence about that.

6 Positive correlation between the background illumination resulting from artificial light-sources and the number of the light-trapped individuals can be experienced only on the seminatural area, which can be caused by the contrasty, strong light, due to which collecting distance increases.

I have examined the relation between the background illumination and the individual number with correlation method. On the seminatural area in case of the Lepidoptera, Hymenoptera, Coleoptera, Neuroptera, Heteroptera and Trichoptera ordres I have stated that there is a positive correlation at the HMLI mixed-light lamp between the strength of illumination and the number of individuals, namely the higher is the strength of the environment illumination the higher is the number of the individuals trapped. This correlation could not be demonstrated on the other two areas.

7 The result of the colection of nocturnal moths (Macrolepidoptera) is seasonally defined; further the optical characteristics of different light-sources play an important role regarding species.

On the seminatural area I have simultaneously light-trapped with three light-source in spring and in autumn. The light-traps were separated with fence. The evaluation was performed on the basis of the nocturnal moths (Macrolepidoptera). In spring at the HMLI mixed-light lamp and the compact fluorescent tube I have stated the dominance of the species *Lycia hirtaria,* at the high-pressure sodium lamp that of the *Colocasia coryli;* in autumn in case of all three light-sources types *Operophtera brumata* was the dominant species.

8 The light contamination of a particular area can be calculated from the values of the environment measured in lux or magnitude/arcsecond^2. In case the current environment illumination is measured in magnitude/arcssecond^2 on site, then at first it has to be converted to lux value.

For the calculation of the value of the natural environment illumination in lux György Tóth astronomer has elaborated a mathematic coherence. In this program data required for the characterization of the area are necesarry such as e.g. geographic coordinate of the measuring site, calendar date, time of measurement in world time and the extent of sky covered by clouds, namely the nebulosity code expressed in octa. The measurement can be performed with magnitude measuring device or lux measuring device and the measuring data shall be converted to the appropriate unit, then light pollution shall be calcul.

References

BROWN, L.N. (1984): Population outbreak of Pandora moths (Coloradia Pandora Blake) on the Kaibab plateau, Arizona (Saturniidae). Journal of the Lepidopterists' Society, 38 65.

CINZANO, P., FALCHI, F. & ELVIDGE, C.D. (2001): The first of World Atlas of the artificial night sky brightness. Monthly Notices of the Royal Astronomical Society. 328:689-707.

FRANK, K. D. (1988): Impact of outdoor lighting on moths: an assessment. Journal of The Lepidopterist's Society Volume 42 number 2: 63-93.

HEILING, A. M. (1999): Why do nocturnal orb-web spiders (Araneidae) search for light? Behavioral Ecology and Sociobiology, 46: 43-49.

HENDERSON, R. W. & POOWELL, R.(2001): Responses by the West Indian herpetofauna to human-influenced resources. Caribbean Journal of Science, 37: 41-54.

MAC GREGOR, M.J., O. POCOCK, R., FOX & D.M. EVANS (2015): Pollination by nocturnal Lepidoptera and the effects of light pollution: a review. Ecological Entomology, 40:187-198.

MINELLI, A. (1993): Biological Systematics The State of Art. Chapman c Hall, New York

NEMEC, S.J. (1969): Use of artificial lighting to reduce Helithis spp. populations in cotton fields. Journal of Economic Entomology 62: 1138-1140.

NEW, T.R. (2009): Insect Species Conservation. Ecology Biodiversity and Conservation Cambridge University Press, UK. p:19. www.cambridge.org/9780521510776

PFRIMMER, T.R., LUKEFAHR, M.J.& HOLLINGSWOTH, J.P. (1995): Experiments with Light Traps for Control of the Pink Bollworm. ARS-33-6. U.S. Department of Agriculture, Agricultural Research Service, Washington, District of Columbia

RYDELL, J. (1992): Exploitation of insects around streetlamps by bats in Sweden. Funct Ecology 6: 744-750.

SOWER, L. L., SHOREY, H.H. & GASTON, L.K. (1970): Sex pheromones of noctuid moths. XXI. Light: dark cycle regulation and light inhibition of sex pheromone release by females of Trichoplusia ni. Annals of the Entomological Society of America 63: 1090-1092.

VARGA, Z. (szerk): (2010): Magyarország nagylepkéi. Heterocera Press, Budapest

Publications

Articles in English

Pintérné Nagy E. – Pödör Z. (2017): The Effect of Artificial Lights on Nocturnal Macrolepidoptera (Lepidoptera: Macroheterocera) Communities. Acta Silcatica & Lignaria Hungarica 13:(1). *Accepted for publication.*

Pintérné Nagy E. (2012): Light Pollution and Its Effect on the Living World. In Neményi M., Heil B., Kovács J.A., Facskó F. (szerk.): International Scientific Conference on Sustainable Development and Ecological Footprint, The Impact of Urbanization, Industrial and Agricultural Technologies on the Natural Environment, Investigation and Research Methodology of Biotic and Abiotic Environment, University of West Hungary Press, Sopron. ISBN 978-963-334-047-9 (*reviewed*)

Articles in Hungarian (with ISNN number)

Pintérné Nagy E. (2016): Fénycsapdázás Jermy-típusú fénycsapdával három különböző mesterséges fényforrás alkalmazásával lepidoptera rend esetében. EDU, Szakképzés-, és Környezetpedagógia Elektronikus Szakfolyóirat 6(1): 66-74. ISSN:2062-3763

Pintérné Nagy E. (2013): Különböző fényforrások hatásának vizsgálata a rovarokra eltérő megvilágítottságú területeken Jermy-típusú fénycsapdával. Erdészettudományi Közlemények, 3(1): 239-249. ISSN 2062-6711

Articles in proceedings in English (with ISBN number)

Pintérné Nagy E. (2013): Light Trapping with Diverse Artificial Lights in Sopron. In Neményi M., Varga L., Facskó F., Lőrinc I. (Eds.): Science for Sustainability International Scientific Conference for PhD Students, Application of Geoinformatics in Environment

Sciences, University of West Hungary Press, Sopron: 121-125. ISBN 978-963-334-103-2

Articles in proceedings in Hungarian (with ISBN number)

Pintérné Nagy E. (2013): Három különböző teljesítményű mesterséges fényforrás rovarokra gyakorolt hatásainak vizsgálata. In Keresztes (szerk.): DOSZ „Tavaszi Szél 2013" Nemzetközi Tudományos Konferencia Konferenciakötet 2: 429-439. Sopron, ISBN 978-963-89560-2-6

Pintérné Nagy E. (2013): A 2012 és 2013 év nyarán három lámpatípussal végzett fénycsapdázás eredményeinek értékelése két mintaterületen. XIX. Nemzetközi Környezetvédelmi és Vidékfejlesztési Diákkonferencia, Szolnok, 2013. szeptember 27. Konferencia Kötet-CD Kiadvány: 1-10. ISBN 978-963-89935-0-2

Pintérné Nagy E. (2012): Különböző fényforrásokkal végzett fénycsapdázás eredménye Sopron környékén. In Koncz I., Nagy E. (szerk.): Nemzetközi Tudományos Doktorandusz Konferencia, Professzorok az Európai Magyarországért Egyesület: Elektronikus könyv: 9-14. Budapest. ISBN 978-963-88433-7-1.

Pintérné Nagy E. (2012): A mesterséges fényforrások hatása az állatokra. In Fülöp (szerk.): Tavaszi Szél 2012 Konferenciakötet: 32-38., Doktoranduszok Országos Szövetsége Budapest. ISBN 978-963-89560-0-2

Conference abstracts in English

Pintérné Nagy E. (2013): Light Trapping with Diverse Artificial Lights in Sopron. Science for Sustainability International Scientific Conference for PhD Students, Application of Geoinformatics in Environment Sciences, Abstracts, Győr

Pintérné Nagy E. (2012): Light Pollution and Its Effect on the Living World. International Scientific Conference on Sustainable Development and Ecological Footprint, The Impact of Urbanization, Industrial and Agricultural Technologies on the Natural Environment, Investigation and Research Methodology of Biotic and Abiotic Environment, Abstracts, Sopron

Conference abstracts in Hungarian

Pintérné Nagy E. – Horváth B. (2014): Három különböző fényforrással megvilágított mintaterületen fénycsapdával befogott lepkék számának statisztikai elemzése. In: Puskás (szerk.) IX. Regionális Természettudományi Konferencia. Program és az előadások összefoglalói: 5. Szombathely, 2014. január 30.

Pintérné Nagy E. (2013): Mesterséges fényforrásokkal végzett fénycsapdázás Sopron környékén. In Puskás (szerk.): VIII. Regionális Természettudományi Konferencia, Absztrakt kötet, NYME-SEK-TTK: 12. Szombathely

Pintérné Nagy E. (2013): A 2012 és 2013 év nyarán három lámpatípussal végzett fénycsapdázás eredményeinek értékelése két mintaterületen. XIX. Nemzetközi Környezetvédelmi és Vidékfejlesztési Diákkonferencia, Szolnok, 2013. szeptember 27. Absztrakt Kötet: 24-25. ISBN 978-963-89339-9-7

Pintérné Nagy E. – Horváth B. (2013): Különböző megvilágítottságú mintaterületeken fénycsapdával befogott lepkék összehasonlító értékelése. Nyugat-magyarországi Egyetem Erdőmérnöki Kar, Kari Tudományos Konferencia, Sopron, 2013. december 10. Absztrakt kötet: 126.

Pintérné Nagy E. (2012): A fényszennyezés és hatása az élővilágra. In Puskás (szerk.): VII. Regionális Természettudományi Konferencia, Absztrakt kötet, NYME-SEK-TTK: 8. Szombathely

Conference posters in English

Pintérné Nagy E. (2013): Light Trapping with Diverse Artificial Lights in Sopron. Science for Sustainability International Scientific Conference for PhD Students, Application of Geoinformatics in Environment Sciences, Győr, 2013. march 19-20.

Pintérné Nagy E. (2012): Light Pollution and Its Effect on the Living World. International Scientific Conference on Sustainable Development and Ecological Footprint, The Impact of Urbanization, Industrial and Agricultural Technologies on the Natural Environment Sopron, 2012. march 26-27.

Conference poster in Hungarian

Pintérné Nagy E. – Horváth B. (2013): Különböző megvilágítottságú mintaterületeken fénycsapdával befogott lepkék összehasonlító értékelése. Nyugat-magyarországi Egyetem Erdőmérnöki Kar, Kari Tudományos Konferencia, Sopron, 2013. december 10.