Research Article

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The impact of artificial light at night (ALAN) on the National Nature Parks, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains within Ukraine

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Abstract: Artificial light at night (ALAN) and sky glow are a recognized anthropogenic pressure, but the consequences of this pressure on protected areas within Ukraine are unclear. This research attempted to estimate the level of light pollution on the protected territories of the National Nature Parks (NNPs), Biosphere and Nature Reserves in the Steppe Zone and Crimea Mountains of Ukraine. Kmz layers of these protected territories and the New World Atlas of Artificial Sky Brightness, through Google Earth Pro, were used to calculate the level of artificial sky brightness for 15 NNPs, three Biosphere Reserves and 10 Nature Reserves. The results show that even some of the most protected areas within the Steppe Zone and Crimean Mountains are impacted by ALAN. Of the studied protected areas 44.2% have a natural dark night sky, 40.1% have artificial brightness ranging between 8 and 16%, and the remainder (15.7%) are polluted with an artificial brightness greater than 16%. Areas with light pollution greater than 16% are often situated near big cities or industrial centers. It was noted that light pollution levels were not taken into account during the creation of any protected areas within Ukraine.

Keywords: artificial light at night (ALAN); Crimea; light pollution; nature conservation; protected area; sky glow; steppe; Ukraine.

Abbreviations: ALAN = artificial light at night; NNP = National Nature Park.

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Introduction

The Ukrainian steppes is a habitat that has declined in area over the last 300 years, decreasing from approximately 40% of the modern territory of Ukraine to the current situation where only about 3% of the natural and semi-natural steppes remain (Korotchenko & Peregrym 2012; Kolomytsev & Vasyliuk 2013; Wesche et al. 2016). The Steppe Zone and Crimean Mountains are two areas within Ukraine where steppe ecosystems are still widely distributed. Unfortunately, anthropogenic pressures, such as plowing, burning, and afforestation (Burkovskyi et al. 2013), continue to impact on the remaining areas of semi-natural steppe vegetation, as is the case for many semi-natural systems across Europe (Dengler et al. 2014; Török & Dengler 2018; Török et al. 2018). One of the more recent pressures on the Steppe Zone and Crimean Mountains is artificial light at night (ALAN).

Over the last decade research on the impact of light pollution from a biological, ecological, medical, sociological and economic perspective has been published (Longcore & Rich 2004; Hölker et al. 2010; Navara & Nelson 2012; Gaston at al. 2013; Gaston et al. 2014; Gaston & Bennie 2014; Bennie et al. 2015b; Kurvers & Hölker 2015; Falchi et al. 2016).

The direct study of the influence of ALAN on grasslands and their biodiversity is a new area of research. Research by Bennie et al. (2018) has demonstrated that ALAN can affect changes in grasslands, leading to significant differences in vegetation biomass and the cover of dominant plant species, as well as changes in flowering phenology. Phenological changes within trees under the influence of urban night light was first documented over 80 years ago (Matzke 1936; Schroeder 1945), and more recently research has been undertaken on the physiological responses of plants to artificial lighting (Briggs 2006) and its

ecological effects (Bennie et al. 2016). Field experiments in Swiss ruderal meadows which were exposed to ALAN demonstrated that nocturnal pollinator behavior changed with visits to the species *Cirsium oleraceum* decreasing by 62% in illuminated plots and fruit production by a focal plant fell by 13% (Knop et al. 2017). ALAN has also been documented as a contributing factor to the global decline in insect populations (Macgregor at al. 2015; Hallmann et al. 2017; Grubisic et al. 2018). Moreover, light pollution can cause cascading effects in grasslands, restructuring ecological communities by modifying the interactions between species and impacting pollination and seed dispersal (Bennie et al. 2015a).

There are examples of grassland genera (e.g. *Hesperis* and *Matthiola* from the *Brassicaceae* and some *Caryophyllaceae* such as *Dianthus* and *Silene*) that are pollinated by nocturnal insects and it can be expected that ALAN would impact these genera and the grassland communities that they occur in. In addition, the flowers of some bulb species provide important shelter at night for insects, especially during cold spring periods. Within grasslands interactions between plants and nocturnal insects, such as moths (Frank 2006; van Langevelde et al. 2011; van Geffen et al. 2014, 2015), will be impacted by ALAN. It has also been shown that nocturnal mammals are impacted by ALAN (Beier 2006).

Considering the current status of the Ukrainian steppes, the high recreational load within the Crimean Mountains, and recent data on the impact of ALAN on biodiversity, we decided to investigate the level of light pollution on the National Nature Parks (NNPs) and Biosphere and Nature Reserves within these regions.

Study area

The research covers the Steppe Zone and the Crimean Mountains of Ukraine, both areas where steppe ecosystems are still widely distributed. The borders of these areas are considered according to Didukh & Shelyah-Sosonko (2003) with clarifications by Mala (2016) for the Right-bank Ukraine. Within the study there are 15 NNPs (Azov-Syvash NNP, Dvorichna NNP, Dzharylgach NNP, Nyzhniodniprovsky NNP, Nyzhniodnistrovsky NNP, NNP “Biloberezhzhia Sviatoslava”, NNP “Buz’kyi Gard”, NNP “Charivna Havan’”, NNP “Homilshanski Forests”, NNP “Meotyda”, NNP “Oleshky Sands”, NNP “Svyati Hory”, NNP “Tuzlovs’ki Lymany”, NNP “Velykyi Luh”, Pryazovsky NPP), three Biosphere Reserves (Askania-Nova Biosphere Reserve, Black Sea Biosphere Reserve and Danubian Biosphere Reserve) and 10 Nature Reserves (Cape Martian Nature Reserve, Crimea Nature Reserve with the Swan islands branch , Dnieper-Oril Natural Reserve, Karadag Nature Reserve, Kazantyp Nature Reserve, Lugansk Natural Reserve (4 branches – “Provalsky Steppe”, “Stanychno-Luganske”, “Striltsivsky Steppe”, “Triokhizbensky Steppe”), Nature Reserve “Yelanets Steppe”, Opuk Nature Reserve, Ukrainian Steppe Nature Reserve (4 branches – “Khomutovsky Steppe”, “Kamyani Mohyly”, “Kreidyana Flora”, “Kal’mius’ke”), Yalta Mountain -Forest Nature Reserve) which are objects of our study (Fig. 1).

It is important to note that although steppe ecosystems often dominate protected territories the diversity of other habitats can also be high. For example, some NNPs and Reserves include marine areas (Dzharylgach NNP, Black Sea Biosphere Reserve, Karadag Nature Reserve etc.), or large forest massifs (NNP “Svyati Hory”, NNP “Homilshanski Forests”, Crimea Nature Reserve etc.). Unfortunately, there is an absence of detailed information on the total area of all habitats within NNPs, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains. General information on the landscape diversity of all protected areas of the Lugansk region (Vasyliuk et al. 2012) is available, as is information on the distribution of steppe biotopes in the Lugansk region (Vasyliuk et al. 2012) is available, as is information on the distribution of steppe biotopes in the Kherson and Odesa regions (Shyriaieva et al. 2014a, 2014b), as well as inventory data on chalky steppes in Lugansk, Donetsk and Kharkiv regions (Krivohizha et al. 2014; Vasyliuk et al. 2014).

Methods

The study was carried out using available tools from Google Earth Pro (version 7.3.2.5487; https://www.google.com/earth/). We used the New World Atlas of Artificial Sky Brightness in the form of a kmz (Keyhole Markup language Zipped) layer which was created by Falchi et al. (2016) and is available through its 3D Globe version (https://cires.colorado.edu/Artificial-light). GIS layers showing the borders of NNPs, Biosphere and Nature Reserves were received in kmz format from the working group on the improvement of activities in the field of nature conservation within the Ministry of Ecology and Natural Resources of Ukraine. Some of these data are available online (http://pzf.gis.kh.ua/ru/services/#uanposm). We overlaid the GIS layer of the borders of the protected areas with the artificial sky brightness layer and counted the number of squares of each index of level of artificial sky brightness according to the legend of the atlas (Falchi et al. 2016). An example of the process for the NNP "Meotyda" is shown in Fig. 2.

Results

The results are presented in Table 1. To quantify an error within the calculations, we have added two columns to Table 1, one column with the calculated area and the other with the official area (according to information from the Ministry of Ecology and Natural Resources of Ukraine; http://pzf.menr.gov.ua/) for every protected area. Although the highlighted discrepancy is generally not more than 5% it is more than 10% for Dzharylgach NNP and approximately 31% for the branch “Kal’mius’ke” of the Ukrainian Steppe Nature Reserve. Unfortunately, there is no satisfactory explanation for these two discrepancies and either the official data are incorrect, or there are mistakes in kmz layers.

Fig. 1. National Nature Parks, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains in Ukraine.

Discussion

We found that there is a widespread incursion of ALAN within the Steppe Zone and Crimea Mountains and these results correspond with the general situation for protected areas around the world (Gaston at al. 2015). Within Ukraine there are examples of protected areas with very low levels of artificial brightness that are less than 1%, such as Azov-Syvash NNP and Danubian Biosphere Reserve (Table 1). Such low levels of light pollution are unique for Europe. The New World Atlas of Artificial Sky Brightness shows that there are very high levels of light pollution across the continent: approximately 99% of the European population live under light-polluted skies; the Milky Way is hidden for 60% of Europeans; and 88% of Europe experiences light-polluted nights (Falchi et al. 2016). In general, the level of light pollution within protected areas in other European countries is higher and the rate of increase in light pollution is faster than for Ukraine (Gaston et al.

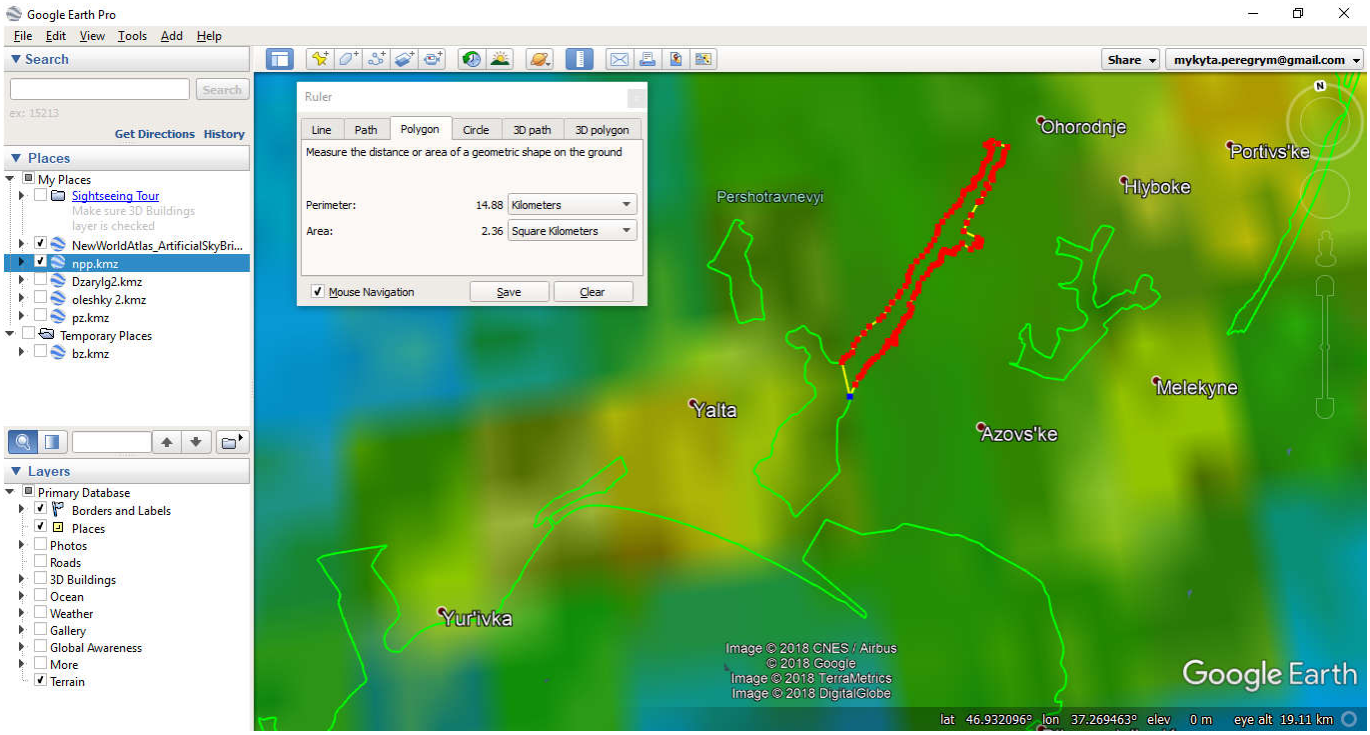

Fig. 2. An example of calculation of area (km^2) for every index of level of artificial sky brightness using Google Earth Pro and the kmz layer which was obtained from Falchi et al. (2016).

2015). The low levels of light pollution within areas of Ukraine can be attributed to economic and industrial decline after the collapse of the Soviet Union (Bennie et al. 2014).

The minimal level of artificial brightness which has a significant influence on biodiversity is unknown. However, a sky with light pollution between 8 and 16% (from 6.96 to 55.7 mcd/m^2), can be considered polluted from an astronomical point of view (Falchi et al. 2016). This study has shown that 44.2% of the studied areas in Ukraine have a natural dark night sky. The night sky above 40.1% of the protected territories has an artificial brightness from 8 to 16%, and the remainder (15.7%) are light polluted by more than 16%. These last areas are often situated near big cities or industrial centers. Also these urban areas have significantly higher air pollution levels that could be increasing the impact of the artificial brightness of the sky (McColgan 2003).
It is important to note that the level of ALAN was not taken into account during the creation of any protected areas within Ukraine. We estimate that the level of light pollution in NNPs, Biosphere and Nature Reserves of the Steppe Zone and Crimea Mountains could be reduced with the development of educational and conservation strategies. As a first step, combating the direct sources of ALAN, such as street lights and lighting in buildings, should be initiated for protected areas and their surrounding areas. It is especially important to address light pollution surrounding nature reserves as these are often small areas with no buffer zone, as traditionally they were created for the conservation of specific species such as rare plants (Sytnik 1979). Unfortunately, the majority of the studied nature reserves are polluted by ALAN and for some NNPs, such as Dnieper-Oril, which are situated near large cities and industrial complexes, the situation will be difficult to change. For other reserves it is hoped that light pollution can be reduced as a result of collaboration and educational work with local communities.

The NNPs, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains would be ideal locations for future investigations to study the influence of ALAN on biodiversity and ecosystems, particularly as some of the protected areas represent refugia where there is currently an unpolluted natural night sky. Protected areas within the Steppe Zone and Crimean Mountains already play a key role in the study of biodiversity and habitat conservation within the Emerald Network (Polyanska et al. 2017). It is recommended that the majority of NNPs, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains participate in the International Dark Sky Places conservation program (http://darksky.org/idsp/) which has been initiated by the International Dark-Sky Association since 2001 (Barentine 2016). Fulfilling the requirements for International Dark Sky Places should provide benefits for both biodiversity conservation and tourism within protected areas.

Author contributions

The investigation was planned and conducted by M.P. and E.P.K. M.P. and O.V. prepared maps and figures for the

Table 1. Areas with different levels of artificial sky brightness in the National Nature Parks, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains in Ukraine.

Protected area		Square of areas with different level of artificial brightness (mcd/m^2), km^2											Calculated area, km^2	Official area, km^2
		<1.74	1.74 – 3.48	>3.48 – 6.96	>6.96 – 13.9	>13.9 – 27.8	>27.8 – 55.7	>55.7 – 111	>111 – 223	>223 – 445	>445 – 890	>890		
Azov-Syvash NNP		213.1	244.7	42.5	7.2	4.3	-	-	-	-	-	-	511.8	521.5
Dvorichna NNP		-	-	-	23.9	9.1	1.2	-	-	-	-	-	34.2	31.3
Dzharylgach NNP		-	1.0	50.5	46.2	1.7	6.8	3.4	0.9	0.2	-	-	110.7	100.0
Nyzhniodniprovsky NNP		-	-	11.9	223.1	242.8	111.2	86.8	106.5	50.5	3.9	-	836.7	801.8
Nyzhniodnistrovsky NNP		-	-	-	-	-	99.1	97.4	18.6	-	-	-	215.1	213.1
NNP “Biloberezhzhia Sviatoslava”		-	-	50.9	205.6	81.2	11.4	0.9	-	-	-	-	350.0	352.2
NNP “Buz’kyi Gard”		-	-	-	3.6	15.1	25.9	9.8	2.0	4.6	0.3		61.3	61.4
NNP “Charivna Havan’”		-	2.7	56.0	32.8	14.3	1.5	-	-	--	-	-	107.3	109.0
NNP “Homilshanski Forests”		-	-	-	-	22.3	79.9	39.9	-	-	-	-	142.1	143.2
NNP “Meotyda”		-	-	-	16.7	55.5	89.0	47.3	10.8	1.1	0.2	-	220.6	207.2
NNP “Oleshky Sands”		-	-	-	53.5	27.1	-	-	-	-	-	-	80.6	80.2
NNP “Svyati Hory”		-	-	-	-	61.1	112.7	166.9	77.0	8.6	4.4	-	430.7	406.1
NNP “Tuzlovs’ki Lymany”		-	191.8	67.5	11.3	1.6	-	-	-	-	-	-	272.2	278.7
NNP “Velykyi Luh”		-	-	-	-	108.6	52.6	0.5	1.9	2.1	-	-	165.7	167.6
Pryazovsky NPP		-	58.8	239.9	120.2	137.0	96.2	90.7	25.5	0.8	-	-	769.1	781.3
Askania-Nova Biosphere Reserve		-	194.1	117.7	13.8	5.8	-	-	-	-	-	-	331.4	333.1
Black Sea Biosphere Reserve		-	516.3	608.0	24.3	6.8	-	-	-	-	-	-	1,155.4	1,092.6
Danubian Biosphere Reserve		14.3	206.6	117.1	133.0	25.1	3.8	-	-	-	-	-	499.9	502.5
Cape Martian Nature Reserve		-	-	-	-	-	-	-	-	2.4	-	-	2.4	2.4
Crimea Nature Reserve	- Mountain part	-	-	-	-	156.1	120.5	37.2	29.2	0.3	0.7	-	344.0	345.6
	- Swan islands part	-	20.4	59.1	18.3	-	-	-	-	-	-	-	97.8	96.1
Dnieper-Oril Nature Reserve		-	-	-	-	-	-	-	-	33.5	4.0	-	37.5	37.7
Karadag Nature Reserve		-	-	-	-	19.9	4.0	4.4	-	-	-	-	28.3	28.7
Kazantyp Nature Reserve		-	-	-	0.3	2.3	1.9	-	-	-	-	-	4.5	4.5
Lugansk Nature Reserve	-“Provalsky Steppe”	-	-	-	-	-	-	5.9	-	-	-	-	5.9	5.9
	-“Stanychno-Luganske”	-	-	-	-	-	4.9	-	-	-	-	-	4.9	5.0
	-“Striltsivsky Steppe”	-	-	-	0.5	10.1	-	-	-	-	-	-	10.6	10.4
Nature Reserve “Yelanets Steppe”		-	-	16.7	-	-	-	-	-	-	-	-	16.7	16.8
Opuk Nature Reserve		-	-	15.6	0.4	-	-	-	-	-	-	-	16.0	15.9
Ukrainian Steppe Nature Reserve	“Khomutovsky Steppe”	-	-	-	-	10.2	-	-	-	-	-	-	10.2	10.3
	“Kamyani Mohyly”	-	-	-	-	4.1	-	-	-	-	-	-	4.1	4.0
	“Kreidova Flora”	-	-	-	-	-	8.3	3.3	-	-	-	-	11.6	11.3
	“Kal’mius’ke”	-	-	-	-	5.4	2.2	-	-	-	-	-	7.6	5.8
Yalta Mountain-Forest Nature Reserve		-	-	-	-	-	30.6	31.9	14.2	63.0	7.5	-	147.2	145.2
		227.4	1,436.4	1,453.4	934.7	1,027.5	863.7	626.3	286.6	167.1	21.0	0	7,044.1	
		3.2%	20.4%	20.6%	13.2%	14.6%	12.3%	8.9%	4.1%	2.4%	0.3%	0	100%	

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References

Barentine, J. 2016. Going for the Gold: quantifying and ranking visual night sky quality in International Dark Sky Places. *International Journal of Sustainable Lighting* 35: 9–15.

Beier, P. 2006. Effects of artificial night lighting on terrestrial mammals. In: Rich, C. & Longcore, T. (eds.) *Ecological consequences of artificial night lighting*, pp. 15–42. Island Press, Washington, DC, US.

Bennie, J., Davies, T.W., Duffy, J.P., Inger, R. & Gaston, K.J. 2014. Contrasting trends in light pollution across Europe based on satellite observed night time lights. *Scientific Reports* 4: Article 3789.

Bennie, J., Davies, T.W., Cruse, D., Inger, R. & Gaston, K.J. 2015a. Cascading effects of artificial light at night: resource-mediated control of herbivores in a grassland ecosystem. *Philosophical Transactions of the Royal Society B* 370: Article 20140131.

Bennie, J., Duffy, J.P., Davies, Y.W., Correa-Cano, M.E. & Gaston, K.J. 2015b. Global trends in exposure to light pollution in natural terrestrial ecosystems. *Remote Sensing* 7: 2715–2730.

Bennie, J., Davies, T.W., Cruse, D. & Gaston, K.J. 2016. Ecological effects of artificial light at night on wild plants. *Journal of Ecology* 104: 611–620.

Bennie, J., Davies, T.W., Cruse, D., Bell, F. & Gaston, K.J. 2018. Artificial light at night alters grassland vegetation species composition and phenology. *Journal of Applied Ecology* 55: 442–450.

Briggs, W.R. 2006. Physiology of plant responses to artificial lighting. In: Rich, C. & Longcore, T. (eds.) *Ecological consequences of artificial night lighting*, pp. 389–412. Island Press, Washington, DC, US.

Burkovskyi, O.P., Vasyliuk, O.V., Yena, A.V., Kuzemko, A.A., Movchan, Y.I., Moysiyenko, I.I. & Sirenko, I.P. 2013. *Ostanni stepy Ukrainy: buty chy ne buty?* [*The last steppes of Ukraine: to be or not to be?*]. Geoprynt, Kyiv, UA. [In Ukrainian]

Dengler, J., Janisová, M., Török, P. & Wellstein, C. 2014. Biodiversity of Palaearctic grasslands: a synthesis. *Agriculture, Ecosystems & Environment* 182: 1–14.

Didukh, Y.P. & Shelyah-Sosonko, Y.R. 2003. Heobotanichne raionuvannya Ukrainy ta sumizhnykh terytoriy [Geobotanical zoning of Ukraine and adjacent territories]. *Ukrains'kyi Botanichnyi Zhurnal*, 60 (1): 6–11. [In Ukrainian]

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C.C.M., Elvidge, C.D., Baugh, K., Portnov, B.A., Rybnikova, N.A. & Furgoni, R. 2016. The new world atlas of artificial night sky brightness. *Science Advances* 2: Article e1600377.

Frank, K.D. 2006. Effects of artificial night lighting on moths. In: Rich, C. & Longcore, T. (eds.) *Ecological consequences of artificial night lighting*, pp. 389–412. Island Press, Washington, DC, US.

Gaston, K.J. & Bennie, J. 2014. Demographic effects of artificial nighttime lighting on animal populations. *Environmental Reviews* 22: 323–330.

Gaston, K.J., Bennie, J., Davies, T.W. & Hopkins, J. 2013. The ecological impacts of nighttime light pollution: a mechanistic appraisal. *Biological Reviews* 88: 912–927.

Gaston, K.J., Gaston, S., Bennie, J. & Hopkins, J. 2014. Benefits and costs of artificial nighttime lighting of the environment. *Environmental Reviews* 23: 14–23.

Gaston, K.J., Duffy, J.P. & Bennie, J. 2015. Quantifying the erosion of natural darkness in the global protected area system. *Conservation Biology* 29: 1132–1141.

van Geffen, K.G., van Grunsven, R.H.A., van Ruijven, J., Berendse, F. & Veenendaal, E.M. 2014. Artificial light at night causes diapause inhibition and sex-specific life history changes in a moth. *Ecology and Evolution* 4: 2082–2089.

van Geffen, K.G., van Eck, E., de Boer, R.A., van Grunsven, R.H.A., Salis, L., Berendse, F. & Veenendaal, E.M. 2015. Artificial light at night inhibits mating in a Geometrid moth. *Insect Conservation and Diversity* 8: 282–287.

Grubisic, M., van Grunsven, R. H. A., Kyba, C. C. M., Manfrin, A. & Hölker, F. 2018. Insect declines and agroecosystems: does light pollution matter? *Annals of Applied Biology* 173: 180–189.

Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., (…) & De Kroon, H. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS ONE* 12: Article e0185809.

Hölker, F., Wolter, C., Perkin, E. K. & Tockner, K. 2010. Light pollution as a biodiversity threat. *Trends in Ecology & Evolution* 25: 681–682.

Knop, E., Zoller, L., Ryser, R., Gerpe, Ch., Hörler, M. & Fontaine, C. 2017. Artificial light at night as a new threat to pollination. *Nature* 548: 206–209.

Kolomytsev, G. & Vasyliuk, O. 2013. Prostorovyi rozpodil stepovykh ecosystem skhodu Ukrainy [Spatial distribution of steppe ecosystems in the Eastern Ukraine]. *Proceedings of the National Museum of Natural History* 11: 87–92. [In Ukrainian]

Korotchenko, I.A. & Peregrym, M.M. 2012. Ukrainian steppes in the past, at present and in the future. In: Werger, M.J.A. & van Staalduinen, M.A. (eds.) *Eurasian steppes. ecological problems and livelihoods in a changing world*, pp. 173–196. Springer, Dordrecht, NL.

Krivohizha, M.V., Vasyliuk, O.V., Kolomytsev, G.O. & Balashov, I.O. 2014. Poshyrennya ta problem okhorony vykhodiv kreidyanykh pored I kharakternykh dlya nykh ridkisnykh vydiv Roslyn na terytorii Lugans'koi oblasti [Distribution and conservation problems of the chalky outcrops and their characteristic rare plants species in Lugansk region]. *Herald of the Taras Schevchenko National University of Kyiv*, *Series Introduction and Conservation of Plant Diversity* 20(1): 32–38. [In Ukrainian]

Kurvers, R.H.J.M. & Hölker, F. 2015. Bright nights and social interactions: a neglected issue. *Behavioral Ecology* 26: 334–339.

van Langevelde, F., Ettema, J.A., Donners, M., WallisDeVries, M.F. & Groenendijk, D. 2011. Effect of spectral composition of artificial light on the attraction of moths. *Biological Conservation* 144: 2274–2281.

Longcore, T. & Rich, C. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2: 191–198.

Macgregor, C.J., Pocock, M.J.O., Fox, R. & Evans, D.M. 2015. Pollination by nocturnal *Lepidoptera*, and the effects of light pollution: a review. *Ecological Entomology* 40: 187–198.

Mala, Y.I. 2016. *Mezha mizh Lisostepom I Stepom: ekolohotsenotychna otsinka* [*The border between forest-steppe and steppe: ecological-cenototic evaluation*]. Naukova Dumka, Kyiv, UA. [In Ukrainian]

Matzke, E.B. 1936. The effect of street lights in delaying leaf-fall in certain trees. *American Journal of Botany* 23: 446–452.

McColgan, M.W. 2003. Light Pollution. *Lighting Answers* 7(2): 2–16.

Navara, K.J. & Nelson, R.J. 2012. The dark side of light at night: physiological, epidemiological, and ecological consequences. *Journal of Pineal Research* 43: 215–224.

Polyanska, K.V., Borysenko, K.A., Pawlaczyk, P., Vasyliuk, O.V., Maruschak, O.Y., Shyriaieva, D.V., Kuzemko, A.A., Oskyrko O.S., Nekrasova, O.D., (...) & Bezsmertna, O.O. 2017. *Zaluchennya hromadskosti ta naukovtsiv do proektuvannya merezhi Emerald (Smaragdovoi merezhi) v Ukraini* [*Involvement of the public and scientists to the design of the Emerald network in Ukraine*]. Kyiv, UA. [In Ukrainian]

Rotics, S., Dayan, T. & Kronfeld-Schor, N. 2011. Effect of artificial night lighting on temporally partitioned spiny mice. *Journal of Mammalogy* 92: 159–168.

Sanders, D., Kehoe, R., Tiley, K., Bennie, J., Cruse, D., Davies, T.W., van Veen, F.F.J. & Gaston, K.J. 2015. Artificial nighttime light changes aphid-parasitoid population dynamics. *Scientific Reports* 5: Article 15232.

Schroeder, C.A. 1945. Tree foliation affected by street lights. *Arborists News* 10: 1–3.

Shyriaieva, D., Vasyliuk, O. & Kolomytsev, G. 2014a. Prostorovyi rozpodil stepovykh biotopiv Odes'koi oblasti v konteksti heobotanichnoho raionuvannya terytorii [Spatial distribution of steppe biotops of Odesa region in the context of geobotanical zoning]. *Materialy Mizhnarodnoi naukovo-praktychnoi konferencii "Teoretychni ta prykladni aspekty rozvytku pryrodnychykh dystsyplin"* (Poltava, November, 20–21, 2014). Drukars'ka maisternya. pp. 115–118. Poltava, UA. [In Ukrainian]

Shyriaieva, D., Vasyliuk, O. & Kolomytsev, G. 2014b. Rozpodil stepovykh biotopiv Khersons'koi oblasti zhidno heobotanichnoho raionuvannya [Distribution of steppe biotops of Kherson region according to geobotanical zoning]. *Materialy Mizhnarodnoi naukovo-praktychnoi konferencii molodykh uchenykh, studentiv, aspirantiv "Ekolohizatsiya staloho rozvytku informatsiinoho suspilstva"* (Kharkiv, November, 5-6, 2014). pp. 315–317. KhNAU, Kharkiv, UA. [In Ukrainian]

Sytnik, K.M. (ed.) 1979. *Okhrana vazhneishykn botanicheskikh ob'ektov Ukrainy, Belorussii, Moldavii* [*Conservation of the most important botanical objects of Ukraine, Belorussia, Moldavia*]. Naukova Dumka, Kiev, UA. [In Russian]

Török, P. & Dengler, J. 2018. Palaearctic grasslands in transition: overarching patterns and future prospects. In: Squires, V.R., Dengler, J., Feng, H. & Hua, L. (eds.) *Grasslands of the world: diversity, management and conservation*, pp. 15–26. CRC Press, Boca Raton, US.

Török, P. Janišová, M., Kuzemko, A., Rūsiņa, S. & Dajic-Stevanovic, Z. 2018. Grasslands, their threats and management in Eastern Europe. In: Squires, V.R., Dengler, J., Feng, H. & Hua, L. (eds.) *Grasslands of the world: diversity, management and conservation*, pp. 64–88. CRC Press, Boca Raton, US.

Vasyliuk, O., Balashov, I., Krivohizha, M. & Kolomytsev, G. 2012. Landshaftnyi sklad pryrodno-zapovidnoho fondu Lugans'koi oblasti [Landscape structure of the nature reserve fund of Lugansk region]. *Nature Reserves in Ukraine* 18(1–2): 105–110. [In Ukrainian]

Vasyliuk, O., Kolomytsev, G. & Shyriaieva, D. 2014. Inventarizatsiya melovykh stepei v Ukraine. Soobshenie 2: Kharkovskaya i Donetskaya oblasti [Inventory of chalky steppes in Ukraine. Report 2: Kharkiv and Donetsk regions]. *Steppe Bulletin* 41: 26–29. [In Russian]

Wesche, K., Ambarli, D., Kamp, J., Török, P., Treiber, J. & Dengler, J. 2016. The Palaearctic steppe biome: a new synthesis. *Biodiversity and Conservation* 25: 2197–2231.