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ARTIFICIAL LIGHT AT NIGHT AS A NEW THREAT FOR NATURE CONSERVATION IN UKRAINE

M. Peregrym[1], O. Vasyliuk[2], E. Pénzesné Kónya[1]

[1]*Eszterházy Károly University, Leanyka st., 6-8, Eger, 3300, Hungary*
E-mails: mykyta.peregrym@uni-eszterhazy.hu, konya.erika@uni-eszterhazy.hu
[2]*Schmalhausen Institute of Zoology, NAS of Ukraine,*
vul. B. Khmelnitskogo, 15, Kyiv, 01030 Ukraine
E-mail: vasyliuk@gmail.com

Artificial Light at Night as a New Threat for Nature Conservation in Ukraine. **Peregrym, M., Vasyliuk, O., Pénzesné Kónya, E.** — Human society benefits a lot from artificial light at night (ALAN), but in the same time it has led to a significant increase in light pollution of the night sky during the past decades. It has serious consequences on reproduction, navigation, foraging, habitat selection, communication, trophic and social interactions of the biota. Also widespread incursion of ALAN within protected areas has been evidenced for some countries, including the National Nature Parks (NNPs), Biosphere and Nature Reserves in the Steppe Zone and Crimea Mountains of Ukraine. However, the common situation with ALAN impact on protected areas within Ukraine is unclear yet. This research attempted to estimate the level of light pollution on the NNPs, Biosphere and Nature Reserves in the Forest, Forest-Steppe zones and Carpathian Mountains within Ukraine. Kmz layers of these protected areas and the New World Atlas of Artificial Sky Brightness, through Google Earth Pro, were used to calculate the level of artificial sky brightness for 33 NNPs, 2 Biosphere Reserves and 9 Nature Reserves. The results show that majority of studied protected areas are impacted by ALAN, but some of them stay almost under the dark sky still. The situation is unique for Europe, therefore these areas have the special value for biodiversity conservation and can be recognized as refugia where natural habitats are not influenced by ALAN. Based on obtained results, recommendations for improving of nature conservation management are given in the context of ALAN problem.
Key words: artificial light at night (ALAN), ecological light pollution, nature conservation, protected areas, Ukraine.

Introduction

Humans benefit a lot from artificial light at night (ALAN), but in the same time it has led to a significant increase in light pollution of the night sky during the past decades (Cinzano et al., 2001; Falchi et al., 2016). It has serious consequences on reproduction, navigation, foraging, habitat selection, communication, trophic and social interactions of the biota (Bennie et al., 2016; Dominoni et al., 2016; Gaston & Bennie, 2014; Hölker et al, 2010 b; Longcore & Rich, 2004; Navara & Nelson, 2007; Rich & Longcore, 2006). Moreover, evidences

for consideration of ALAN as a driver of evolution across urban-rural landscapes are present (Hopkins et al., 2018). Also widespread incursion of ALAN within protected areas has been evidenced for some countries and regions (Gaston et al., 2015; Guetté et al., 2018; Jiang et al., 2017), including the National Nature Parks (NNPs), Biosphere and Nature Reserves in the Steppe Zone and Crimea Mountains of Ukraine (Peregrym et al., 2018). However, the common situation with ALAN impact on protected areas within Ukraine is unclear yet. Besides, it seems that the results of influence of this anthropogenic factor on biodiversity are not taken into account neither scientists nor authority in the country, because any, even public, information about the control or combating with it has not been found.

Nevertheless there are a lot of facts of direct and indirect impact of ALAN on many animal taxa and ecosystems represented in Ukraine: mammals (Beier, 2006; Robert et al., 2015; Rowse et al., 2015; Stone et al., 2012; Stone et al., 2015), birds (Da Silva & Kempenaers, 2017; Da Silva et al., 2015; Dominoni et al., 2013; Gauthreux & Belser, 2006; Kempenaers et al., 2010; Montevecchi, 2006; Raap et al., 2015, 2016, 2017, 2018; Sierro & Erhardt, 2019), amphibians (Buchanan, 2006; Hearnshaw, 2012; Perry et al., 2019), fishes (Nightingale & Longcore, 2006), and invertebrates (Davies et al., 2012, 2015; Degen et al., 2016; Desouhant et al., 2019; Dominoni et al., 2013; Eisenbeis, 2006; Frank, 2006; Macgregor et al., 2015, 2017; Owens & Lewis, 2018; Perkin et al., 2014; van Geffen et al., 2014, 2015 a, 2015 b, 2018; van Langevelde et al., 2011, 2017; Verovnik et al., 2015). Separately it is important to underline that ALAN has also been documented as a contributing factor to the global decline in insect populations (Grubisic et al., 2018; Hallmann et al., 2017; Leather, 2018; Macgregor et al., 2015). Also data about results of ALAN impact on some habitats have been obtained during the last years. For example, light pollution can cause cascading effects in habitats, restructuring ecological communities by modifying the interactions between species and impacting pollination and seed dispersal (Bennie et al., 2015 a). As well ALAN implications in estuaries from individuals to habitats (Zapata et al., 2019) as well as in stream and riparian habitats (Manfrin et al., 2018; Perkin et al., 2011) have been analised.

Thus, considering the facts mentioned above, it has been decided to estimate the level of ecological light pollution on the NNPs, Biosphere and Nature Reserves in the Forest, Forest-Steppe Zones and Carpathian Mountains within Ukraine as well as to suggest some recommendations for improving of nature conservation management in the context of the problem.

Material and methods

Our study covers the Carpathian Mountains, the Forest and the Forest-Steppe zones in Ukraine. The borders of these areas are considered according to the National Atlas of Ukraine (Rudenko, 2007). Within the study there are 33 NNPs (Biloozerskyi NNP, Carpathian NNP, Cheremoskyi NNP, Dermano-Ostrozkyi NNP, Desnyansko-Starohutskyi NNP, 'Dnistrovskyi Kanion' NNP, Halytskyi NNP, Hetmanskyi NNP, Holosiivskyi NNP, 'Hutsulshchyna' NNP, Ichnyanskyi NNP, 'Karmelyukove Podillya' NNP, Khotynskyi NNP, 'Kremenetski Hory' NNP, 'Male Polissya' NNP, Mezynskyi NNP, Nyzhnosulskyi NNP, 'Pivnichne Podillya' NNP, 'Podilski Tovtry' NNP, 'Prypyat'-Stokhid' NNP, Pyryatynskyi NNP, Shatskyi NNP, 'Skolivski Beskydy' NNP, Slobozhanskyi NNP, 'Synevir' NNP, 'Syniohora' NNP, 'Tsumanska Pushcha' NNP, Uzhanskyi NNP, Verkhovynskyi NNP, Vyzhnytskyi NNP, Yavorivskyi NNP, 'Zacharovanyi Krai' NNP, ZZalissya' NNP), 2 Biosphere Reserves (Carpathian Biosphere Reserve with 8 branches — Chornohirskyi, 'Dolyna nartsysiv', Kuziiskyi, Maramaroskyi, Svydovetskyi, and Uholsko-Shyrokoluzhanskyi massifs; Botanical Reserve 'Chorna Hora', Botanical Reserve 'Yulivska Hora';, Chornobyl Radiation and Ecological Biosphere Reserve) and 9 Nature Reserves (Cheremskyi Nature Reserve, Drevlyanskyi Nature Reserve, 'Gorgany' Nature Reserve, Kaniv Nature Reserve, 'Medobory' Nature Reserve, 'Mykhailivska Tsilyna' Nature Reserve, Poliskyi Nature Reserve, Rivnenskyi Nature Reserve, 'Roztochchya' Nature Reserve) which are objects of our study (fig. 1).

The study has been 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).

Results

The results are presented separately for the Forest zone (table 1), for the Forest-Steppe zone (table 2), and for the Carpathian Mountains (table 3) within Ukraine. To quantify an error within the calculations, we have added two columns to each tables, 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. The highlighted discrepancy is generally not more than 3–5 % for studied areas, except Poliskyi Nature Reserve (6.8 %), Male Polissya NNP (6.4 %), Hutsulshchyna NNP (16.3 %),

Fig. 1. National Nature Parks, Biosphere and Nature Reserves of the Carpathian Mountains, the Forest and the Forest-Steppe zones within Ukraine.

and some branches of the Carpathian Biosphere Reserve: Chornohirskyi and Svydovetskyi massifs (17.2%), Kuziiskyi massif (22.9 %), Uholsko-Shyrokoluzhanskyi massif (10.6 %). Unfortunately, there is no satisfactory explanation for these discrepancies and either there are mistakes in kmz layers or the official data are incorrect. The second variant is possible, because borders of protected areas in Ukraine often are not noted in nature, so official calculated data can have some differences from real data (Brygynets, 2013).

Also total areas with different levels of artificial sky brightness in the NNPs, Biosphere and Nature Reserves in Ukraine have been calculated using data from tables 1, 2 and 3, as well as recently published data for the Steppe Zone and Crimea Mountains (Peregrym et al., 2018). This summarizing information is given in table 4. Two columns with the total calculated areas and the total official areas have been added in table 4 for every category of studied protected areas too. As can be seen from the table, the highlighted discrepancy is 1.7 % for Biosphere Reserves, 0.1 % for Nature Reserves, 4.8 % for NNPs, and 3.5 % for all types of studied protected areas.

Discussion

The obtained results (table 1–3) for the NNPs, Biosphere and Nature Reserves of Carpathian Mountains, the Forest and the Forest-Steppe zones have shown a widespread incursion of ALAN in their territories. The same situation is for mentioned types of protected areas for all Ukraine that is seen from the table 4. These data correspond with

Table 1. Areas with different levels of artificial sky brightness in the National Nature Parks and Nature Reserves of the Forest-Steppe Zone within Ukraine

Protected area	Square of areas with different level of artificial brightness (μcd/m²), km²											Calculated area, km²	Official area, km²
	<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	> 890–1780	> 1780–3560		
Kaniv Nature Reserve	–	–	–	55.81	20.89	9.65	–	–	–	–	–	86.35	86.43
Medobory Nature Reserve	–	–	2.75	74.83	17.00	–	–	–	–	–	–	94.58	95.21
Mykhailivska Tsilyna Nature Reserve	–	–	8.79	–	–	–	–	–	–	–	–	8.79	8.83
Roztochchya Nature Reserve	–	–	–	–	1.89	13.61	5.35	–	–	–	–	20.85	20.85
Biloozerskyi NNP	–	–	–	69.70	1.08	–	–	–	–	–	–	70.78	70.14
Dnistrovskyi Kanion NNP	–	–	46.14	27.64	26.24	5.49	1.50	0.72	0.19	–	–	107.92	108.29
Halytskyi NNP	–	–	8.05	48.73	79.79	8.52	–	–	–	–	–	145.09	146.85
Hetmanskyi NNP	–	–	–	65.68	89.09	62.94	14.90	1.99	–	–	–	234.60	233.60
Holosiivskyi NNP	–	–	–	–	–	–	–	3.16	69.08	31.65	6.84	110.73	109.88
Ichnyanskyi NNP	–	–	30.05	58.71	6.55	0.90	–	–	–	–	–	96.21	96.66
Karmelyukove Podillya NNP	–	94.15	106.59	0.77	–	–	–	–	–	–	–	201.51	202.03
Khotynskyi NNP	–	–	16.89	43.80	28.18	3.49	2.04	–	–	–	–	94.40	94.46
Kremenetski Hory NNP	–	–	38.25	22.72	6.12	1.93	–	–	–	–	–	69.02	69.51
Nyzhnosulskyi NNP	–	–	98.83	83.99	4.21	–	–	–	–	–	–	187.03	186.35
Pivnichne Podillya NNP	–	–	86.53	70.44	10.65	0.32	–	–	–	–	–	167.94	155.88
Podilvski Tovtry NNP	–	–	178.89	1042.68	729.93	435.87	131.09	50.74	28.15	3.28	–	2,600.63	2,613.16
Pyryatynskyi NNP	–	–	4.06	54.86	44.07	13.68	3.23	–	–	–	–	119.90	120.28
Slobozhanskyi NNP	–	–	–	–	–	42.15	7.55	2.81	–	–	–	52.51	52.44
Yavorivskyi NNP	–	–	–	–	41.50	28.93	–	–	–	–	–	70.43	71.08
Total	–	94.15	625.82	1,720.36	1,107.19	627.48	165.66	59.42	97.42	34.93	6.84	4,539.27	
Total, %	–	2.07	13.79	37.90	24.39	13.82	3.65	1.31	2.15	0.77	0.15	100	

Table 2. Areas with different levels of artificial sky brightness in the National Nature Parks, Biosphere and Nature Reserves of the Forest Zone within Ukraine

Protected area	Square of areas with different level of artificial brightness (μcd/m²), km²													Calculated area, km²	Official area, km²
	< 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	> 890–1780	> 1780–3560	> 3560–7130		
Chornobyl Radiation and Ecological Biosphere Reserve	–	7.02	1002.95	927.51	243.10	56.83	21.27	3.23						2,261.91	2269.65
Cheremskyi Nature Reserve	–	29.14	–	–	–	–	–	–	–	–	–	–	–	29.14	29.76
Drevlyanskyi Nature Reserve	–	30.56	289.59	–	–	–	–	–	–	–	–	–	–	320.15	308.73
Poliskyi Nature Reserve	111.98	65.87	8.52	0.99	–	–	–	–	–	–	–	–	–	187.36	201.04
Rivnenskyi Nature Reserve	56.28	218.66	101.82	40.37	7.88	–	–	–	–	–	–	–	–	425.01	422.89
Dermano-Ostrozkyi NNP	–	–	–	54.05	–	–	–	–	–	–	–	–	–	54.05	54.48
Desnyano-Starohutskyi NNP	–	39.66	96.58	20.14	5.36	–	–	–	–	–	–	–	–	161.74	162.15
Male Polissya NNP	–	–	–	–	44.74	22.98	25.51	–	–	–	–	–	–	93.23	87.63
Mezenskyi NNP	–	232.99	62.48	11.44	2.42	0.19	–	–	–	–	–	–	–	309.52	310.35
Prypyat'-Stokhid NNP	–	333.41	42.96	10.35	–	–	–	–	–	–	–	–	–	386.72	393.16
Shatskyi NNP	–	–	40.47	329.72	105.73	10.76	–	–	–	–	–	–	–	486.68	489.77
Tsumanska Puscha NNP	–	–	181.68	102.29	38.16	8.01	21.50	1.74	–	–	–	–	–	353.38	334.68
Zalissya NNP	–	–	–	–	–	–	–	15.40	42.07	36.15	33.26	13.27	2.25	142.40	148.36
Total	168.26	957.31	1,827.05	1,496.86	447.39	98.77	68.28	20.37	42.07	36.15	33.26	13.27	2.25	5,211.29	
Total, %	3.23	18.37	35.06	28.72	8.59	1.90	1.31	0.39	0.8	0.69	0.64	0.25	0.04	100	

Table 3. Areas with different levels of artificial sky brightness in the National Nature Parks, Biosphere and Nature Reserves of Carpathian Mountains within Ukraine

Protected area		Square of areas with different level of artificial brightness (μcd/m²), km²								Calculated area, km²	Official area, km²
		< 3.48	> 3.48 – 6.96	> 6.96– 13.9	> 13.9– 27.8	> 27.8– 55.7	> 55.7– 111	> 111– 223	> 223		
Carpathian Biosphere Reserve	Chornohirskyi and Svydovetskyi massifs	–	57.14	205.22	6.77	–	–	–	–	269.13	229.55
	Maramaroskyi massif	–	–	81.39	2.84	–	–	–	–	84.23	89.90
	Kuziiskyi massif	–	–	2.31	56.44	1.78	–	–	–	60.53	49.25
	Uholsko-Shyrokoluzhanskyi massif	–	24.44	96.17	18.62	–	–	–	–	139.23	155.80
	"Dolyna nartsysiv" massif	–	–	–	–	–	2.44	–	–	2.44	2.57
	Botanical reserve "Chorna Hora"	–	–	–	–	–	5.99	1.74	–	7.73	8.23
	Botanical reserve "Yulivska Hora"	–	–	–	–	1.75	–	–	–	1.75	1.76
Gorgany Nature Reserve		–	–	17.61	30.75	3.38	1.17	–	–	52.91	53.44
Carpathian NNP		–	125.30	97.03	63.40	157.92	43.71	12.60	–	499.96	504,95
Ceremoshskyi NNP		–	66.81	3.47	–	–	–	–	–	70.28	71.18
Hutsulshchyna NNP		–	–	9.69	172.77	187.67	5.21	–	–	375.34	322.71
Skolivski Beskydy NNP		–	–	64.25	183.49	57.67	45.20	0.78	–	351.39	356.84
Synevir NNP		–	286.58	113.14	–	–	–	–	–	399.72	404.00
Syniohora NNP		–	4.64	81.76	23.02	–	–	–	–	109.42	108.66
Uzhanskyi NNP		–	–	337.99	47.47	4.03	–	–	–	389.49	391.59
Verkhovynskyi NNP		–	120.72	–	–	–	–	–	–	120.72	120.23
Vyzhnetskyi NNP		–	–	9.63	69.87	31.33	0.64	–	–	111.47	112.38
Zacharovanyi Krai NNP		–	–	–	60.37	–	–	–	–	60.37	61.01
Total		–	685.63	1,119.66	735.81	445.53	104.36	15.12	–	3,106.11	
Total, %		–	22.07	36.05	23.69	14,34	3.36	0.49	–	100	

Table 4. Total areas with different levels of artificial sky brightness in the National Nature Parks, Biosphere and Nature Reserves in Ukraine

Type of protected areas	Square of areas with different level of artificial brightness (µcd/m²), km²/%													Calculated area, km²	Official area, km²
	< 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	> 890–1780	> 1780–3560	> 3560–7130		
Biosphere Reserves	14.3	924.02	1,927.33	1,483.7	365.47	64.16	29.70	4.97	–	–	–	–	–	4,813.65	4,734.91
%	0.30	19.20	40.04	30.82	7.59	1.33	0.62	0.10	–	–	–	–	–	100	
Nature Reserves	168.26	364.63	491.33	90.01	377.37	215.56	107.13	48.75	99.2	12.2	–	–	–	1,974.44	1,972.78
%	8.52	18.47	24.88	4,56	19.11	10.92	5.43	2.47	5.02	0.62	–	–	–	100	
National Nature Parks	213.1	1,105.06	1,641.57	2,603.33	3,188.22	2,235.47	1,289.59	434.03	169.39	142.37	68.19	20.11	2.25	13,112.68	12,514.39
%	1.63	8.43	12.52	19.85 %	24.31	17.05	9.83	3.31	1.29	1.09 %	0.52	0.15	0.02	100	
Total	395.66	2,393.71	4,060.23	4,177.04	3,931.06	2,515.19	1,426.42	487.75	268.59	154.57	68.19	20.11	2.25	19,900.77	19,222.08
%	1.99	12.03	20.40	20.99	19.75	12.64	7.17	2.45	1.35	0.78	0.34	0.10	0.01	100	

the common situation for protected areas around the world (Bennie et al., 2015 c; Gaston et al., 2015), but Ukrainian NNPs, Biosphere and Nature Reserves are unique for Europe in the context of their level of light pollution at the present, because there are some clean plots without ALAN incursion in the country (Falchi et al., 2016). They are located in the western part of the Forest zone as well as in the Steppe Zone: Poliskyi and Rivnenskyi Nature Reserves, Azov-Syvash NNP and Danubian Biosphere Reserve have some areas where artificial brightness is less than 1 % of the natural background, namely their skies can be considered “pristine”. Besides, the common 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., 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., 2015 b).

The impact of ALAN on the NNPs, Biosphere and Nature Reserves of the Steppe Zone and Crimean Mountains within Ukraine have been analyzed early (Peregrym et al., 2018). Below we consider the current situation in Carpathian Mountains, the Forest and the Forest-Steppe zones separately. So, NNPs and Nature Reserves of the Forest-Steppe are the strongest polluted by ALAN in comparison with another zones of Ukraine. There are no such protected areas, in which the artificial brightness is less than 3.48 µcd/m^2, and there is the only one plot in Karmelyukove Podillya NNP with artificial brightness in the range 3.48–6.96 µcd/m^2 or from 2 to 4% of the natural background. Also there are two NNPs which have plots with very polluted skies by ALAN, that is because some their territories are situated in borders of big cities. It is Holosiivskyi NNP near Kyiv City and Podilski Tovtry NNP near Kamianets-Podilskyi town. However, most of NNPs and Nature Reserves of the Forest-Steppe zone (62.29 %) have level of artificial brightness in the range from 13.9 to 55.7 µcd/m^2 or 8–32 % of the natural background. Of them 8–16 % are indicated as the approximate level where the sky can be considered polluted from an astronomical point of view (Falchi et al., 2016), though it is important to note that the minimal level of artificial brightness, which has a significant influence on biodiversity, is unknown yet.

Protected areas of studied types are the cleanest from ALAN in the Forest zone of Ukraine. As it was mentioned above, here is Poliskyi and Rivnenskyi Nature Reserves in the western part of the zone which have plots of the "pristine" night sky. Moreover, 56.66 % of territory of all NNPs, Biosphere and Nature Reserves of the Forest zone have level of artificial brightness in the range from 0 to 6.96 μcd/m^2 or 0–4 % of the natural background. In the same time, only 37.31 % of their territories have the level of artificial brightness in the range from 6.96 to 27.8 μcd/m^2 or 4–16 % of the natural background. One exception is Zalissya NNP, because its territory is polluted by ALAN from 111 to 7130 μcd/m^2, and it is the highest level for all studied protected areas in Ukraine. Such situation is a result of location of the NNP near Kyiv City and very big agrarian greenhouse complex with enormous light pollution in Brovary District.

The situation with ALAN incursion into NNPs, Biosphere and Nature Reserves in Carpathian Mountains looks better than in the Forest-Steppe zone, but worse than is the Forest zone. There are 58.12 % of these protected areas with level of artificial brightness in the range from 3.48 to 13.9 μcd/m^2 or 2–8 % of the natural background, as well as 38.03 % of studied areas, which have the artificial brightness of their night skies in the range from 13.9 to 55.7 μcd/m^2 or 8–32 % of the natural background. However, protected plots without ecological light pollution are absent here.

Though the level of ALAN has never been taken into account during the creation of any protected areas within Ukraine, the current situation for NNPs, Biosphere and Nature Reserves in whole Ukraine is optimistic. That is because 1.99 % (395.66 km^2) of their territories have the "pristine" night skies, and 53.42 % (10,630.98 km^2) territory have the level of artificial brightness in the range from 1.74 to 13.9 μcd/m^2 or 1–8 % of the natural background that can be considered as enough clean sky even from an astronomical point of view. The common situation among studied types of protected areas is the best for Biosphere Reserves.The level of artificial brightness in the range from 1.74 to 13.9 μcd/m^2 or 1–8 % of the natural background is present in 90.06 % of their territories; however, 8.52 % of all Ukrainian Nature Reserves are located under the clean night skies. Unfortunately, territories of NNPs are under the highest impact of ALAN in Ukraine. All the spectrum of artificial brightness levels is present in their borders.

Conclusions

Today it is obvious that ALAN impact has significant consequences for biota and its habitats within NNPs, Biosphere and Nature Reserves of Ukraine. Therefore, the affirmation that ALAN is a new threat for nature conservation in the country, unfortunately, is a *fait accompli*. That is confirmed by our results of the investigation too. Despite the data accumulation about mechanisms of artificial light influence on biodiversity at the present is in progress, there is no doubt that combating for decreasing the level of ecological pollution must be already begun. Protected areas will have to be the first objects for it. These actions must be directed both practical and education activity. Approaches to street light and lighting of buildings in protected areas and their surrounding areas should be changed the first among practical steps. Today is enough published recommendations for it (Dick, 2014, 2018; Hölker, Moss, et al., 2010 a). Secondly, creation of buffer zones is needed for many nature reserves, because it will allow decreasing the ALAN impact in strict protected areas (Peregrym et al., 2018). Moreover, it is obligatory to take into account the ALAN level when creating new protected areas, and developing conservation management for them. Also an education strategy in this context must be designed, because even scientific popular information about the problem is limited, especially in countries of the East Europe. Ukrainian protected areas with staff will have to become peculiar information centers for local population. They have to show benefits and importance of saving the dark sky for human well-being. It can be done in international collaboration, as an example

in framework of 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.

In the same time, some NNPs, Biosphere and Nature Reserves of Ukraine could be perfect locations for future studies of the influence of ALAN on biodiversity and ecosystems. Also they can be considered as refugia with a currently unpolluted natural night sky and they probably should be recognized as territories with a special official state status.

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