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Measuring inhabitants' knowledge on technical features and physiological effects of light pollution

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Abstract

Light pollution is a new environmental challenge. We emit more light than necessary, and this is often done at wavelengths that are disturbing and even harmful to human health. In this situation, Dark Sky Parks, where there are no artificial light sources that burden the environment, have been established. Two of these parks are located in BAZ County, near Répáshuta, and in Hajdú-Bihar County, near Hortobágy. The present study reports on a questionnaire survey conducted in Répáshuta and in Hortobágy, inhabitants of which are informed about light pollution, and in Cserépváralja and Újszentmargita villages, located near the previous pair of settlements, not directly warned about the problem. With a direct on-site survey, we asked 21 questions to over 30-41 persons in the four settlements, and received answers taking full account of anonymity of the respondents. Recruitment took place in April-May, 2019 and November-January, 2020. The questions of the questionnaire are focused on the effects of lighting, the lighting habits, the relation of responding persons to the stellated sky, and additional knowledge on energy saving. The survey took place between November 2019 and January 2020. In the present study we have space for detailed presentation of eight questions.

Keywords: light pollution; lighting modes; human health; animals; astronomy

1. Introduction

Light plays a very important role in life on Earth, since there is no biosphere without it (Csörgits and Gyarmathy 2006; Kolláth 2009; Gyarmathy 2016). Organisms have adapted to the life cycles through historical geology by their evolution with various behavioural processes and characteristics: light is an essential source of energy for plants by photosynthesis; it is a key factor in the orientation of some birds, movement of insects, and feeding of mammals (Csörgits 2000; Csörgits and Gyarmathy 2006). As a biological being, people are affected through their

biorhythm, which is often completely deviated by artificial lighting, risking the physical and mental health in long-term (National Sleep Foundation 1 2020).

The use of light in the perception of visual stimuli is a process that can be learned, which is called light adaptation (Estefánné Varga et al. 2001). Separation of light and darkness is learned quickly as a child, but the emotional processing of it has a negative point as night-time anxieties. The intensity and the direction of the light source are also found instinctively, but the perception of different shapes, colours and movement in detail is a more complicated process.

However; we also know that the length and depth of rest phases also affect learning, especially for growing children; while the rest phases are also greatly influenced by the use of light in the pre-sleep period (National Sleep Foundation 2 2020).

Nowadays, the determination of the extent of disturbance and pollution is the main direction of the researches, which is analysed by various disciplines using different methods. One of the best-known indicators is the Human Influence Index (HII), created by the Institute of Earth Sciences at Columbia University and the Society for the Conservation of Wildlife (WCS - CIESIN 2005). This is significant for our study because a parameter of the complex HII is based on the NASA's light pollution model which represents the spatial extent and intensity of artificial light (NASA 2017).

The OTÉK (National Settlement Planning and Construction Requirements) (1997) defines light pollution as "Artificial disturbing light which illuminates above the horizon, or not exclusively on and in the direction of the surface to be illuminated, or at an inappropriate time, causing glare, artificial glare of the sky or adverse physiological and environmental effects, including adverse effects on wildlife.

In terms of ecosystems, the negative effects of light pollution are described on the lives of plants, insects and birds. In the case of the human body, it has a serious impact on the reduced production of the melatonin hormone known as "the hormone of darkness". This natural hormone plays an important role in regulating the functioning of the body. (Lelkes, 2013).

In the case of birds, three effects can be observed:

- choice of breeding or wintering area: as far as possible from the illuminated facilities.
- migration: disruption of orientation has a negative effect, which can lead to a location other than the intended landing area or a collision with buildings
- biorhythm: in areas where it is not possible for birds to avoid artificial lighting, their biorhythm is disturbed. Daytime species are also active at night.

In the insect world, light pollution can have the following adverse effects:

- lure from their habitats, including reproduction and feeding places;
- separation of reproductive partners;
- greater exposure to predators;
- direct or indirect death of individuals; -
- local extinction, population collapse (Kolláth and Gyarmathy, 2015).

In natural landscapes, astronomers encountered difficulties in studying the starry sky, which led to the question that the starry sky, such as the sight of the Milky Way, would not play a significant role in the lives of people today. In order to stop this harmful process, a new program was launched as an initiative of the International Dark Sky Association (IDA). The point is to create starry sky parks around the world in areas where natural features can be preserved due to the negligible presence of light pollution. The IDA homepage (IDA 2020) lists 82 Dark Sky Parks worldwide, and provides links to the homepages of the individual Parks. According to its definition "An IDA International Dark Sky Park (IDSP) is a land possessing an exceptional or distinguished quality of starry nights and a nocturnal environment that is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment."

Hungary boasts starry sky parks in Zselic, the Hortobágy and Bükk National Parks, all acknowledged by the above mentioned IDA homepage. The parks offer a wide range of programs with astronomical and nature exhibitions, guided night tours, and take an active role in informing the population about in the significance of light pollution. We can read about their work, but many other related national activities in two new Hungarian summaries (Ministry of Agriculture 2020, Elektrotechnika 2020).

2. The questionnaire and process of data collection

The aim of the present study is to establish whether, or not the inhabitants of those settlements know more about light pollution and they apply more healthy and contemporary sources of light which are the centres of a Dark Sky Park, compared to those which are not. The difference may be caused by the informative programs sometimes held for inhabitants of the Dark Sky Park settlements, only. In the Bükk region this key settlement is Répáshuta, whereas Cserépváralja is chosen for control. For Hajdú-Bihar the key settlement is Hortobágy, with Újszentmargita chosen for control.

To provide more insight about the location of the settlements and their light pollution, a pair of maps was edited with ArcGIS software, as presented in Fig. 1. They are based on the light pollution layer of the Human Influence Index, mentioned in the Introduction. The map for the Bükk has already been edited by previously by Balogh et al. (2018), whereas the other map has been created for the present study.

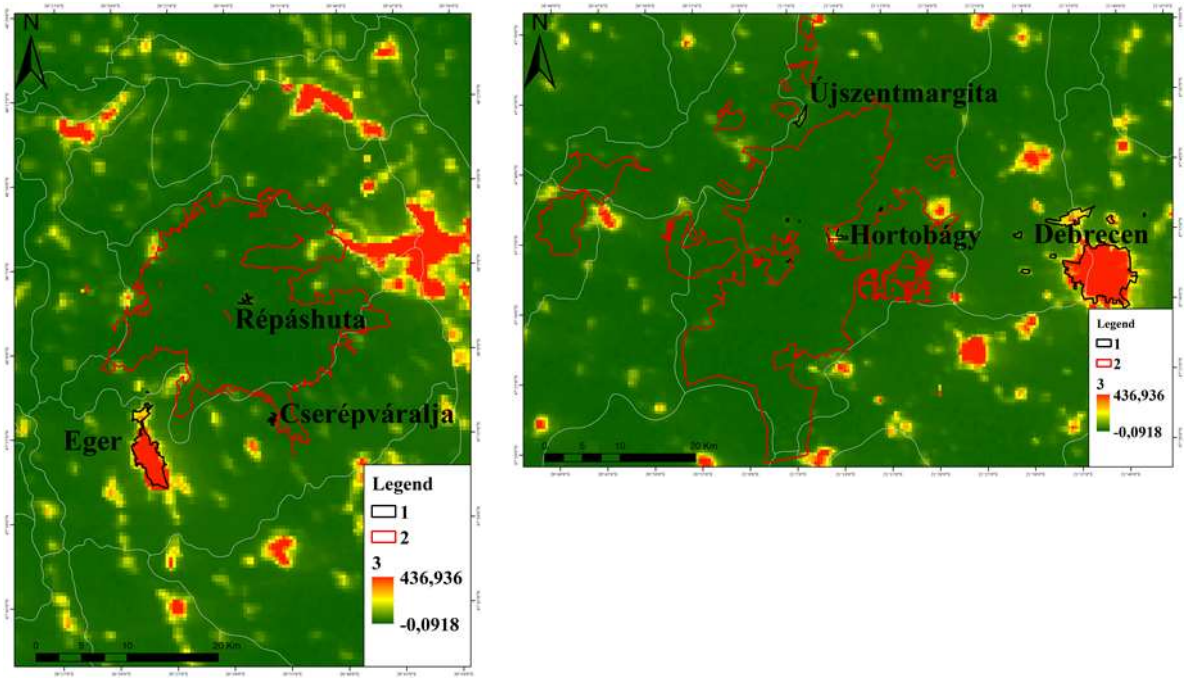

Figure 1. Maps of the Dark Sky Parks and the investigated settlements in the mirror of light pollution. Legends: 1 – settlements, 2 – National Parks, 3 – administrative regions. The unit of the coloured radiances is 10^{-9} W/cm^2 *Sr. Note 1: identical distance proportions are kept, this is why size of the two maps is different. Note 2: Eger and Debrecen are marked just for orientation.

Population data of the selected settlements located in one of the districts of the country are presented by Tab. 1 according to the Central Statistical Office (CSO) of Hungary. (Districts are administrative units of Hungary since 2013. Present number of districts is 174.)

The absolute numbers of people who responded to the questionnaire and their proportions to the settlements' population can be found in Tab. 2.

Table 1. CSO number of inhabitants and population density in 2019 (http://nepesseg.com/)

Target settlement			**Control settlement**		
Settlement	District	Inhabitants/ population rate head/km^2	Settlement	District	Inhabitants/ population rate head/km^2
Répáshuta	Miskolci	441/ 26	**Cserépváralja**	Mezőkövesdi	410 / 28
Hortobágy	Balmazújvárosi	1470/ 5	**Újszentmargita**	Balmazújvárosi	1473/15

Table 2. Number of the filled questionnaires and their rates compared to the population

Target settlement			**Control settlement**		
Settlement	Number of responses	Rate of responses	Settlement	Number of responses	Rate of responses
Répáshuta	33	7,5%	**Cserépváralja**	30	7,3%
Hortobágy	41	2,8%	**Újszentmargita**	36	2,4%

We tried to find equal number of responders from the five age groups *(19-30, 31-40, 41-50, 51-60 and over 60 years)* but we were not able to fulfil it due to the asymmetric age distributions and rare availability of younger people even on the week-ends when the questionnaires were exclusively collected. In the settlements of Bükk the survey was performed in March-April of 2019, while the same period in Hajdú-Bihar was November 2019 – January 2020. The inquiry took place in person, each household was represented by maximum one response.

The questionnaire contains 21 questions from which eight questions will be presented in detail, together with the possible alternatives. Short, unequivocal answers were expected in cases of open ended questions. The answers were written to the questionnaire sheets by the students who performed the surveys and finally entered into an Excel based numerical evaluation program, elaborated by one of the authors (JM). Before the survey, a preliminary trial was also performed in Egerbocs (Heves County) which led to reduction of the originally 30 questions to 21.

3. Results

3.1 Lighting habits

In the Figures of this sub-section the questions included into Tab 3 will be presented. Concerning the first question of this Table, we should mention another one which is the very first question among the 21 ones illustrated by Fig 2. The rate of good answers to the question testing the knowledge of present lighting devices was 91% in Répáshuta with only 50% in its control settlement. The same proportions were 72% in Hortobágy but 86% in its control settlement! It means fair average knowledge (75% i.e. 3 good answers from the four possible).

Figure 2. The first question to answer in the questionnaire: “Please find the right pairs of the technical expressions among the drawings!”

Table 3. Questions about lighting habits and optional alternatives

Which of the following light sources do you use in your home? (more than one answer indication is also possible)
_ standard filament lamp _ halogen lamps _ compact fluorescent lamps _ LED _ I don't know _ other:
Please indicate 3 main features that affect your purchase when buying a new lamp?
_ luminous flux (lumen - lm) _ wattage (watt - w) _ luminous efficacy (lm/w) _ colour temperature _ colour class (warm white, natural white, white) _ technology (halogen lamps, LED, compact fluorescent lamps) _ lifespan _ energy savings' _ polluting effect _ manufacturer/brand, country of origin _ price _ servicing _ design _ other:
Which of the following light sources do you use in your workplace/school? (more than one answer indication is also possible)
_ standard filament lamp _ halogen lamps _ compact fluorescent lamps _ LED _ I don't know _ other:
What do you think about the street lighting in your place of residence?
_ fully adapted to the degree of illumination required _ lower than the required lighting, it should be increased _ higher than the required lighting, it should be reduced _ I don't know _ other:

In Fig. 3 lighting habits of the homes are firstly evaluated. The traditional bulbs and LED lamps lead the list in both settlements surveyed in the Bükk-mountains. In Répáshuta both types are represented by identical 70% frequency, whereas in Cserépváralja almost all homes use traditional bulbs, with slightly over 40 % appearance of the LEDs. Frequency of halogen and compact lamps is 10-20% in these to settlements. Traditional lamps are the most popular in Hortobágy and Újszentmargita, as well. Almost all households use this type, whereas frequency of use for contemporary technologies varies between 10 and 40 percent.

The product characteristics that are considered when people buy a new bulb into their lamps are fairly similar in both regions: wattage, nominal life span and price are most often mentioned in two settlements of Hajdú-Bihar, whereas technology is also important in the Bükk. The remained 11 or 10 other characteristics, specified in Tab 3, together got similar "votes", only.

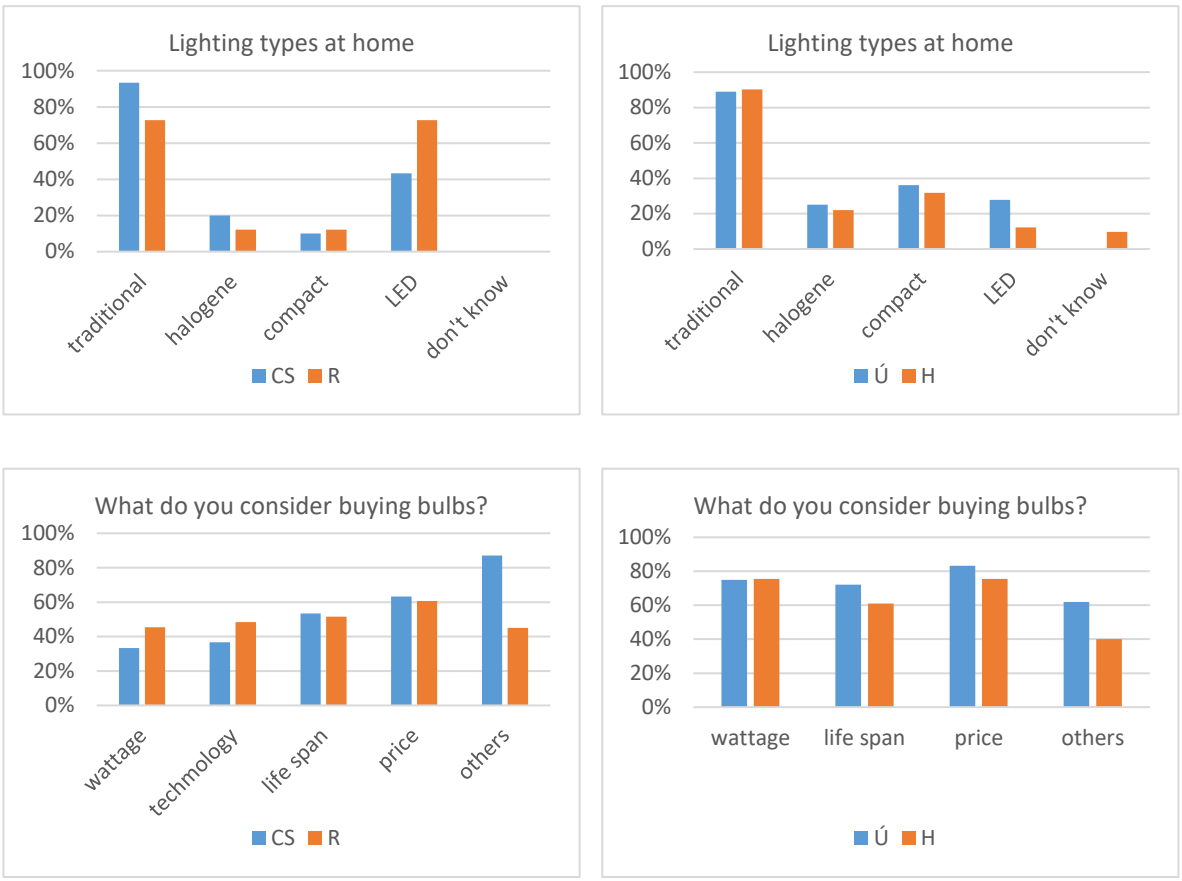

Figure 3. Types of lighting at home (upper pair) and points of view in buying a new bulb (lower pair). Figures of Bükk are found left, those of Hajdú-Bihar to the right. Répáshuta (R) and Hortobágy (H) are target settlements, Cserépváralja (CS) and Újszentmargita (Ú) are controls.

Lighting types of the workplace (Fig.4) are less considered, as it is concluded from the even distribution of responses and high proportion of 'I do not know' and 'something else' responses.

Communal lighting for the streets of Répáshuta is based on a new and modern system ensuring low energy consumption and healthy return to the yellowish light, realised at lower light intensity. At the start of this development a dissemination forum was held for the settlement to inform the inhabitants. Almost 100% of the responders are satisfied with the new system at Répáshuta. In its control settlement, where no innovation happened, more than half of the responders are satisfied with lighting of the settlement. Too few light is mentioned by 30 % whereas complains about too much light count a few percent, only.

Over the half of Hortobágy inhabitants found the communal lights too few, with the same proportion of satisfied responses in its control settlement. Personal experience of the students working with the questionnaires supports the opinion on insufficient lights in Hortobágy.

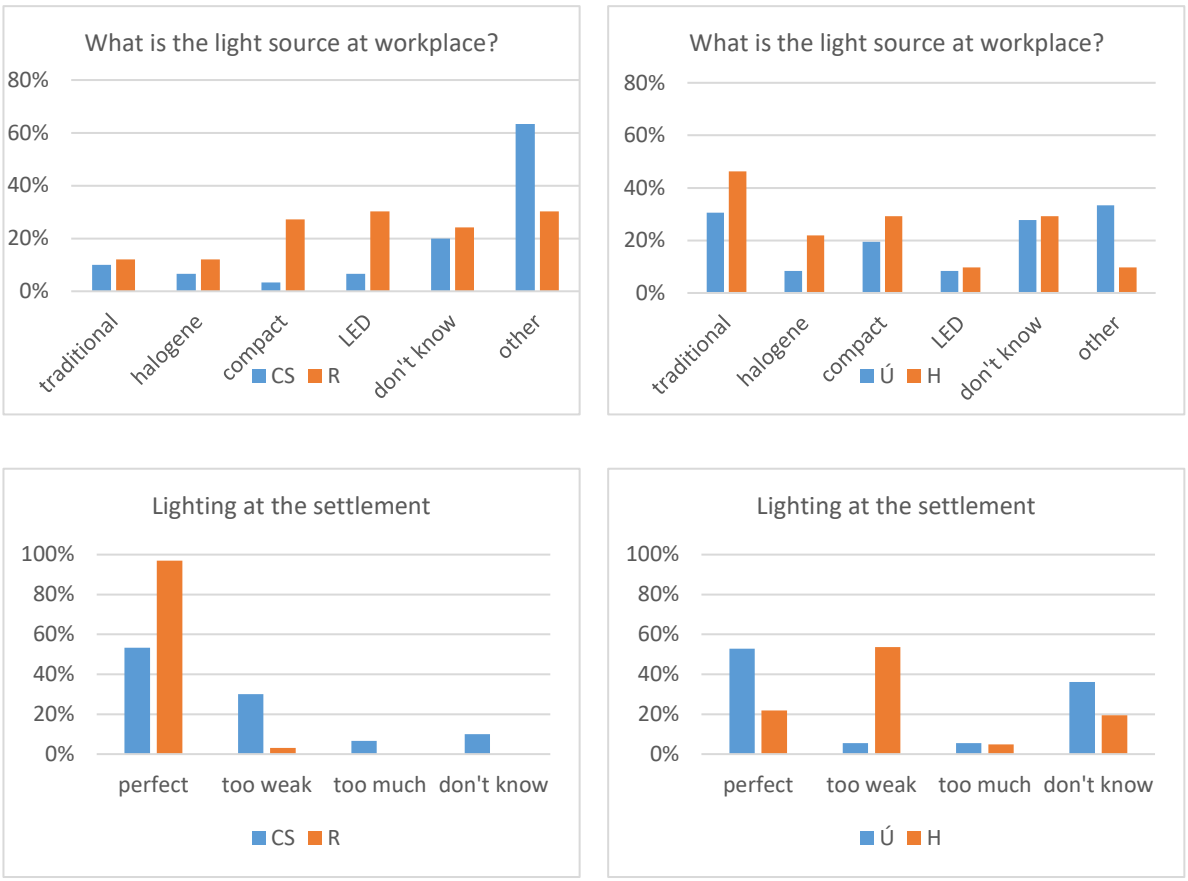

Figure 4. Types of lighting at work (upper pair) and quality of lighting in the settlement (lower pair). Figures of Bükk are found left, those of Hajdú-Bihar to the right. Répáshuta (R) and Hortobágy (H) are target settlements, Cserépváralja (CS) and Újszentmargita (Ú) are controls.

3.2 Knowledge of the impacts

Figures of the present sub-chapter comprehend the responses to the questions included into Tab. 4, together with the possible alternatives also included in the Table.

Table 4. Questions about effects of light pollution and optional alternatives

What can be eliminated by dimming artificial night lights? (more than one answer indication is also possible)	
	_ squandered energy _ glare-inducing effects _ disturbance of wildlife _ starry sky sink out of sight _ artificial light isn't harmful _ other:
Do you think that nightlife animals are affected by artificial light sources?	
	_ yes, all in a favourable direction _ yes, all in an unfavourable direction _ no _ I don't know _ other:

Do artificial night lights affect a person's health?
_ yes, with serious health risks _ yes, but it only makes it harder to fall asleep, which is why we wake up more tired the next day _ has no effect on human health _ I do not know _ other:
Do you usually admire, explore the starry sky?
_ often _ rarely _ no

In the upper lines of Fig. 5 evaluation of the harmful effects is seen. Among them waste of energy and disturbance of animals is mostly accepted, whereas in the settlements of Hajdú-Bihar the loss of starry sky is often mentioned, as well.

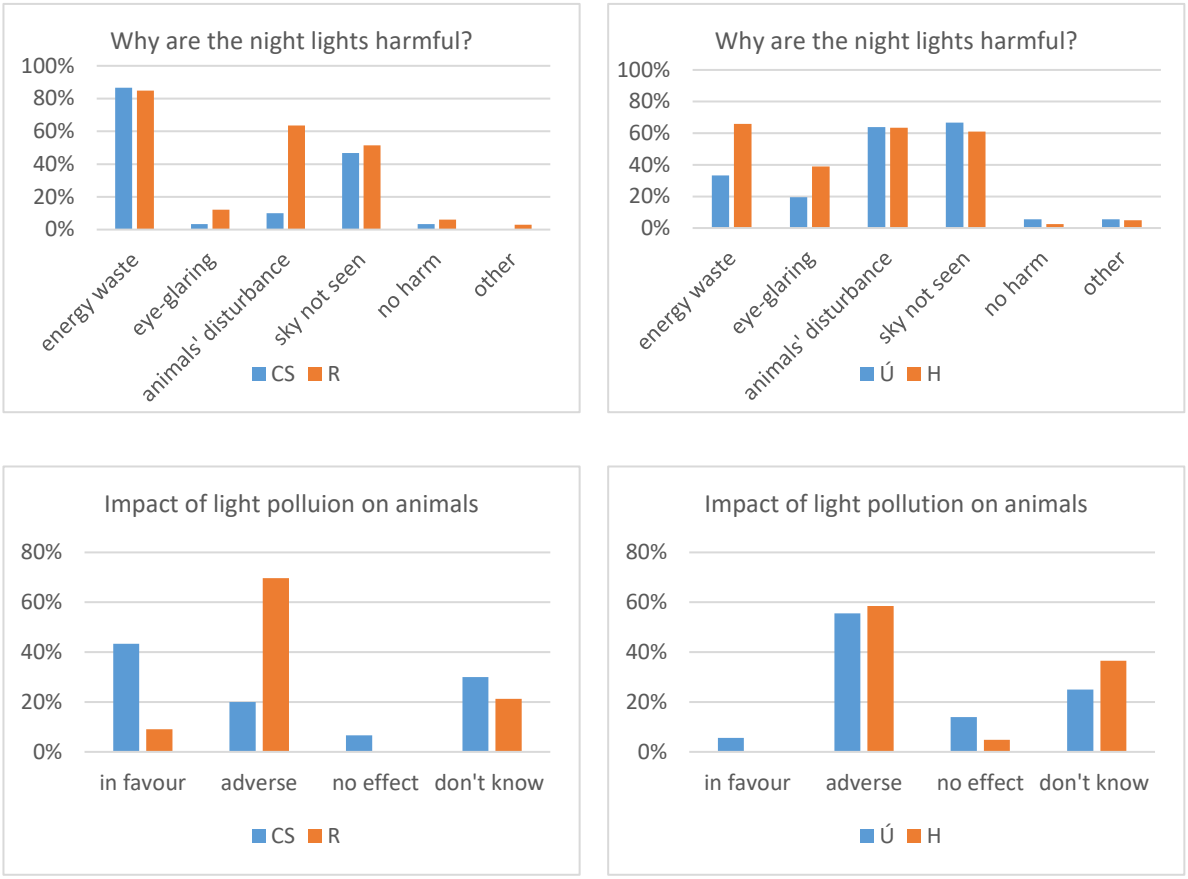

Figure 5. Harms of night lights (upper pair) and impact of light pollution on animals (lower pair). Figures of Bükk are found left, those of Hajdú-Bihar to the right. Répáshuta (R) and Hortobágy (H) are target settlements, Cserépváralja (CS) and Újszentmargita (Ú) are controls.

Effect of light pollution on animals is not denied by any Répáshuta inhabitant and almost 70% considers the effects as negative. The opposite opinion is represented by a few percent of the responders. In Hortobágy the situation is similar: very few responses denies this impact, and over 50% think that it is negative. Proportions of vacillating responses are always smaller in the target settlements than in the control one, in this question.

Fig. 6 evaluates impacts of light pollution on humans. In Bükk, almost 25% of responders from Répáshuta is not sure about the existence of impact on humans. One third of the responses definitely denies such an effect. In Cserépváralja the sum of vacillating and denying answers is similar, but the latter is as frequent as 40%. In Répáshuta strong multiple effect is attributed to the light pollution, while inhabitants of the control complain on sleeping, only. In Hortobágy the numbers are even worse: almost the half of the responders is not sure about any effect on humans and 25% definitely denies it. Strong effect is attributed by few people but according to almost 50% of the control settlement responses sleeping is disturbed by light pollution.

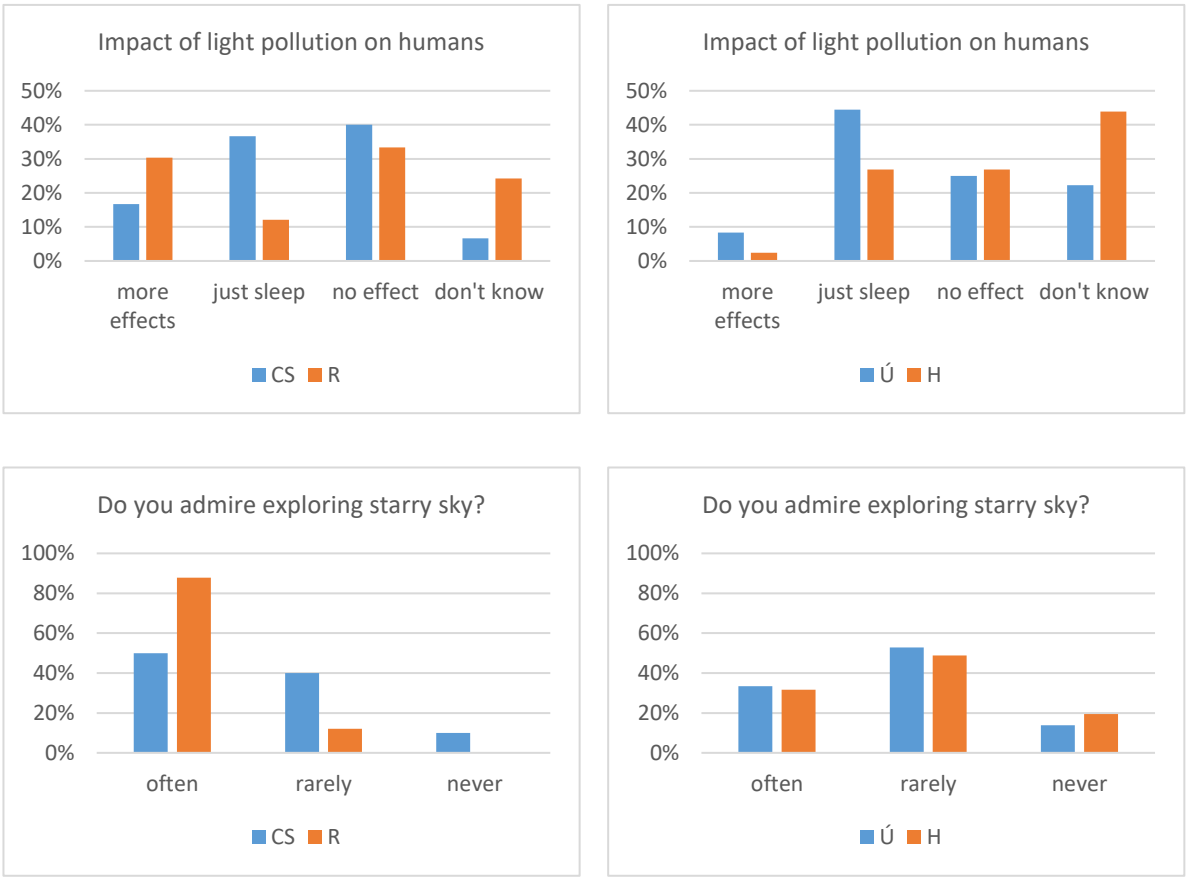

Figure 6. Impact of much light on humans (upper pair) and frequency of sky exploration (lower pair). Figures of Bükk are found left, those of Hajdú-Bihar to the right. Répáshuta (R) and Hortobágy (H) are target settlements, Cserépváralja (CS) and Újszentmargita (Ú) are controls.

Last line of Fig. 6 indicate how strong is the loss of starry sky which depends mostly on how often one tries to explore it. Almost 90% of responders often admires and enjoys it. In its control settlement 50% does it often and 40% rarely. In Hajdú-Bihar only 1/3 of the responders often enjoy the non-cloudy sky, with ca. half of the responses ‘rarely’.

4 Conclusion

The above investigations may have double importance for education. On one hand they indicate how successful the thematic education, performed in connection with the Dark Sky Park, was. On the other hand they may be useful in creation of any education program concerning light pollution. Most likely not the answers, but the questions will be useful if the education is planned for different settlements.

The presented results indicate that inhabitants of Répáshuta i.e. the target settlement in the Bükk region know more about the light pollution, and use more modern light sources than inhabitants of its control settlement. At the same time, Hortobágy, i.e. target settlement in Hajdú-Bihar has no advantage over its control settlement either in aspect. It is very likely that existence of a nearby Dark Sky Park and occasional knowledge dissemination is just one of the factors. The topical knowledge may also depend on the age of responders, as well, as on their degree of education and economic status. In a further study these aspects should also be included.

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