Brief for GSDR 2015

Towards eco-efficient and enjoyable lighting

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Light pollution is a novel environmental issue widely affecting ecosystems, human cultures, societies, and health and well-being of individuals. Rapidly increasing use of new lighting technologies – in particular Light Emitting Diodes (LEDs) – may either increase or reduce disturbing and ecologically harmful outdoor night-time light pollution. Public attention and policy measures aimed to reduce light pollution helps to avoid energy wastage and to create efficiently illuminated and enjoyable outdoor spaces.

Fig. 1. Light pollution is typically a side-effect of economic development, population growth and urban sprawl. San Francisco Bay area in the west coast of the United States. Photo: ESA/NASA 2012.

Introduction: Too much of a good thing

The positive impact of artificial light on human advancement is undeniable, but bright lights come with a price. Light pollution has been coined as a concept aimed to capture various negative effects of the artificial lighting (e.g. Rich & Longcore 2006, Gaston et al. 2013). Light pollution can be defined as artificial night-time lighting causing adverse aesthetic, health or ecological effects.

Instead of natural darkness, all affluent or densely inhabited regions of the Earth are covered by the veil of artificial light (Fig 1). Global emissions of light energy to night environment increased rapidly since the advent of electric light. In the late 1990s about two thirds of the World population lived in areas where the night sky was classified as light polluted and about one fifth had lost the naked eye visibility to the Milky Way from their place of residence (Cinzano et al. 2001).

Satellite-based data allowing the evaluation of the long-term development of upward flux of artificial light has recently become available. Global emissions of artificial light have continued to increase, but considerable differences exist between regions (Elvidge et al. 2014). For example, emissions have decreased in large areas of the former Soviet Union while the use of light has increased radically in China and India. Results by Bennie et al. (2014) suggest that even though the trend in continental Europe during past 15 years has been towards increasing brightness, some economically developed regions show more complex patterns with large areas decreasing in observed brightness. This is at least partly because of the adoption of new and more efficient lighting practices and technologies.

The effects of light pollution are poorly known

Light pollution represents an easily observable global change but it has received surprisingly little attention outside the astronomy communities. Detrimental ecological effects of the loss of natural darkness are likely since the evolution of species has been guided by stable patterns of light and dark periods. Approximately two-thirds of the known invertebrates are nocturnal species

with high sensitivity to light (Hölker et al. 2010). Even very weak and temporary artificial light can disturb organisms that are adapted to natural levels and cycles of light. The impacts of artificial light to nocturnal and crepuscular species are increasingly studied and the first results focusing on community level have been recently published (e.g. Gaston et al. 2013). However, if compared with other environmental stressors, the knowledge base is still sparse.

The most well-known species is the vertebrate *Homo sapiens*. Disruption of natural circadian rhythmicity caused by artificial light may lead to various human health effects, such as elevated risk of breast or prostate cancer, obesity, diabetes, depression and sleep disorders (e.g. Haim & Portnov 2013). The health risks of the exposure to night-time light are increasingly studied but the long-term effects and the interplay of physiological and psychological factors are poorly known.

Moreover, little is known about the long-term cumulative effects of light pollution and other environmental changes such as climate change. More research is needed but the existing knowledge base is already sufficient to justify actions aimed at reducing light pollution

Attention to wise use of lighting technologies is needed

The rapid adoption of new lighting technologies that allow increased and more versatile illumination poses a new challenge for light pollution management. These technologies are often uncritically welcomed and justified by their assumed economic benefits and energy-saving potential. In particular, the need for accelerated deployment of LED-based outdoor lighting is often highlighted. This type of framing that focuses only on the positive effects of a new technology is likely to downplay relevant negative side-effects and risks, such as the erosion of cultural, provisioning, regulating and supporting ecosystem services provided by nocturnal nature (Lyytimäki 2013), increased total energy consumption because of a rebound effect (Kyba et al. 2014) and failures to solve safety and security problems (Marchant 2011).

Several laws, guidelines and policies have already been adopted in order to combat light pollution. Based on North American experiences, the International Dark-Sky Association and the Illuminating Engineering Society have developed a model lighting ordinance for responsible outdoor lighting (IDA & IES 2014). Countries such as France, Slovenia and South Korea have national level legislation aiming to reduce energy consumption caused by unnecessary use of lighting and to prevent nuisances caused by light spill, glare or over-illumination.

Falchi et al. (2011) have presented the following general level guidelines for effective legislation:

- do not allow luminaires to send any light directly at and above the horizontal,
- do not waste downward light flux outside the area to be lit,
- avoid over lighting,
- shut off lights when the area is not in use,
- aim for zero growth of the total installed flux,
- strongly limit the short wavelength 'blue' light.

Only few studies exist on the implementation and effectiveness of light pollution laws, regulations and voluntary initiatives. For example, a study focusing on the advertising signs in Taiwan found out that even though the luminance of almost all of the signs were much lower than the limit set by the International Commission of Illumination, they still cause serious light trespass due to their large coverage area, high density distribution and improper installation (Ho & Lin 2014).

Broader interdisciplinary research connecting different disciplines related to light pollution is clearly needed (Gaston et al. 2014). However, interdisciplinary approach is not sufficient. Determining the characteristics of adequate, pleasant and safe illumination – and the right place and time for natural darkness – is to a great

extent a value-based question that cannot be solved by scientific facts alone. This calls for a transdisciplinary approach, taking into account not only knowledge from different disciplines but also integrating non-academic expertise.

The United Nations has declared the year 2015 as the international year of light and light-based technologies. The aim of this theme year is to raise awareness of how optical technologies promote sustainable development and provide solutions to worldwide challenges in energy, education, agriculture, communications and health. The key part of such awareness-raising is the prevention and reduction of unnecessary and harmful light pollution.

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