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Summary of evidence from the Royal Astronomical Society (RAS) Conference on 'Light Pollution and its impacts'

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- Light pollution (LP) caused by artificial light at night (ALAN) have significant impacts on the environment and optical astronomy. ALAN can alter habitats, fragment ecosystems, and accelerate biodiversity loss, especially among the many nocturnal species that rely on natural darkness to survive. ALAN and LP also compromise the view of the night sky for both astronomers and the general public.
- In terrestrial ecosystems, ALAN has multifaceted impacts on invertebrate species, and the disruption caused by LP spans behavioural and physiological responses, as well as altering patterns of competition, predation, and symbiosis in different species. Artificial lighting near rivers and lakes interferes with species' natural behaviours and movements. In the marine environment, ALAN has impacts across a range of habitats, including sandy and rocky shores, coral reefs, and surface oceans.
- LP impacts both physical and psychological health. Exposure to LP and lack of natural sunlight can lead to poor metabolism and the development of diseases such as type 2 diabetes, obesity, dementia, Parkinson's, and retinal problems. Evidence also suggests that LP directly impacts mood and increases the prevalence of affective disorders such as depression and anxiety.
- Some European countries have already adopted specific regulations or amended their exciting environmental regulations by incorporating measures directly addressing light emissions, such as Croatia, France and Germany. Such measures include curfews, a complete ban on lighting in protected natural areas, a prohibition on directing light sources onto water surfaces, and restrictions on light brightness.
- In the UK, current LP policy is limited compared to other environmental pollutants such as water, air, and plastic. As a suggestion, the discussion about LP should be placed within the broader context of the UK's environmental governance set out in the 2021 Environment Act.
- LP is increasingly being addressed in international frameworks. The first to recognise its harmful effects was the UN Convention on the Conservation of Migratory Species of Wild

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Animals (CMS), which has produced guidance for states, including the International Light Pollution Guidelines. The UN Convention on Biological Diversity (CBD) has also called for action. Although the Kunming-Montreal Global Biodiversity Framework does not explicitly mention LP, its Target 7 on pollution from "all sources" has been interpreted by the CBD to include LP. In response, several countries, including Austria, Malta, France, Germany and Luxembourg, have included LP targets in their National Biodiversity Strategies and Action Plans.

- It is crucial to legally recognise ALAN as a pollutant, acknowledging its various negative environmental impacts. Additionally, the night should be recognised as an integral part of the natural environment (and as a part of our shared human heritage), requiring its equal protection with daytime activities to strengthen nature conservation efforts.[1]

Light pollution (LP) is a growing concern rising up the political and regulatory agenda of different countries. LP is a form of environmental pollution that is a consequence of artificial light at night (ALAN), which, although quite beneficial in terms of social safety and comfort, it becomes an environmental pollutant when humans, other organisms, or the environment are exposed to unwanted or unnecessary lighting. Indeed, when ALAN is poorly designed, installed in unsuitable locations, used at inappropriate times, or applied excessively, it can alter habitats, fragment ecosystems, and accelerate biodiversity loss, especially among the many nocturnal species that rely on natural darkness to survive.[2]

For optical astronomy, ground-based LP has proved to be significantly damaging, which alongside its impacts on the environment, biodiversity, and human health, amounts to an urgent matter to be addressed by policymakers and legislators. In the UK, LP is also an issue of social justice and inclusion. More affluent groups are more likely to live in less light-polluted areas and to have the time and resources to visit dark sky sites, while disadvantaged communities are more likely to live in heavily lit urban areas with little access to natural darkness. As a result, access to dark skies has increasingly become a luxury rather than a shared public good,

[1] Yakushina, Y. (2025). The endangered night: The challenge of light pollution within the international environmental legal context. *Journal of Environmental Law*, *37*(3), 467-491. https://doi.org/10.1093/jel/eqaf025

[2] Yakushina, Y., et al. (2025). *Policy Brief: Restoring the Night: A Policy Agenda for Light Pollution Mitigation in Europe*. (p. 4) https://zenodo.org/records/15707106

limiting the cultural, educational, psychological, and health benefits associated with experiencing the night sky.

The RAS advocates for the reduction of LP in order to protect optical astronomy, and it collaborates with legislative initiatives in pursuit of this aim. One of these initiatives is the All-Party Parliamentary Group (APPG) for Dark Skies, which was created in January 2020 by its current co-chairs, Andrew Griffith, MP for Arundel & South Downs, and Lord Rees of Ludlow, the Astronomer Royal and a former President of the Royal Astronomical Society. The RAS provides the Secretariat for this APPG.

Since its creation, the APPG for Dark Skies has been providing a forum for parliamentarians and organisations across the public, private and third sectors to discuss issues regarding ground-based light pollution and visibility of the night sky, advocating for dark sky lighting and reformed planning policies. To date, the APPG has twenty-six members, including two co-chairs and two officers.[3]

In support of the APPG, on 30 January 2025 the RAS organised a one-day conference on LP and its impacts. The conference featured four sessions, covering topics such as policy and regulation, the environment and biodiversity, and human health. Delegates explored approaches to tackling LP, assessing the current regulatory landscape in the UK, opportunities for improvement, local interventions, and best practices here and elsewhere in the world. This document presents a summary of the discussions and evidence presented by experts during this conference, including specific recommendations for policy implementation in the UK. This document is divided into four main sections: Firstly, it presents a brief definition of LP and ALAN. Secondly, it presents a summary of the applicable regulatory framework in the UK, together with references to European cases regarding mitigation of LP. Thirdly, it presents key scientific evidence regarding the impact of LP on the environment, biodiversity, and human health. And fourthly, from this compelling evidence specific actions for policy implementation are proposed.

[3] *All-Party Parliamentary Group (APPG) for Dark Skies:* https://appgdarkskies.co.uk/

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i. Understanding the problem with ALAN and LP

Outside the UK, the adoption of policies and regulations aiming at reducing ALAN and its impacts began to increase during the past five years mainly due to (i) energy efficiency concerns, (ii) environmental concerns, and (iii) concerns about the future of astronomy and space sustainability.[4] Recent years have shown a visible trend towards more energy-efficient lighting, such as LED, to help reduce energy consumption.[5] Studies estimate that on average outdoor lighting contributed from 3 to 15% of global electricity consumption, which constitute approximately 1–5% of worldwide greenhouse gas (GHG) emissions.[6]

The energy crisis that began in 2022 in the wake of the full-scale Russian invasion of Ukraine also prompted various governments to push harder for energy reduction measures, such as curfew or light dimming by public lighting sources.[7] The exclusive focus on energy efficiency concerns related to ALAN, however, can have the opposite effect. The gradual transition to LEDs has placed additional pressure on the environment and contributed to an even greater

[4] Yakushina, Y. (2024). Light pollution regulations and where to find them. *Journal of Environmental Management*, 373, 123757. https://doi.org/10.1016/j.jenvman.2024.123757

[5] Such as, the European Parliament, & Council of the European Union, 2023. Directive (EU) 2023/ 1791 of the European parliament and of the Council of 13 September 2023 on energy efficiency and amending regulation (EU) 2023/955. Off. J. Eur. Union L 231/1. https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001

[6] Gaston, K. J., & Sánchez de Miguel, A. (2022). Environmental impacts of artificial light at night. *Annual Review of Environment and Resources*, *47*(1), 373-398. https://doi.org/10.1146/annurev-environ-112420-014438

[7] LUCI Association. (n.d.). Cities tackling the energy crisis. https://www.luciassociation.org/cities-tackling-theenergy-crisis/

increase in light pollution levels.[8] Therefore, other impacts of LP triggering regulatory changes must also be considered, such as environmental impacts.[9]

ii. Regulation in Europe and the UK relating to ALAN and LP

As a response to a growing body of research evidence confirming major negative impacts on the environment, habitats and biodiversity,[10] several countries amended their environmental regulations by incorporating measures to directly address light emissions, notably Croatia, France and Germany. Such measures include curfews, a complete ban on lighting in protected natural areas, a prohibition on directing light sources onto water surfaces, and restrictions on light brightness. The protection of dark skies from increased LP for astronomical observations and future space sustainability was also a contributory factor in the adoption of measures to reduce ALAN levels.[11]

In 2021, Croatia adopted the Act on Protection Against LP and supplemented it with three ordinances that specified its provisions.[12] This comprehensive national law aims to address all forms of LP while protecting the environment and human health and includes the following measures:

- The development of a nationwide lighting plan;
- The division of the country into lighting zones with specific restrictions based on each zone;
- Measures to prevent excessive light emissions; and

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[8] Ibid [3].
[9] This paragraph was provided by Yana Yakushina, expert on ground-based LP and regulation.
[10] See, for example, Barentine, J.C., 2023. Artificial Light at Night: State of the Science 2023. Zenodo. https://doi.org/10.5281/zenodo.8071915; Candolin, U., Filippini, T. Light pollution and its impact on human health and wildlife. BMC Environ Sci 2, 1 (2025). https://doi.org/10.1186/s44329-025-00017-7; Welch, D., Dick, R., Treviño, K., Longcore, T., Rich, C., Hearnshaw, J., Ruggles, C., Dalton, A., Barentine, J. & Gyarmathy, I. (2024). The world at night: Preserving natural darkness for heritage conservation and night sky appreciation. IUCN WCPA Good Practice Guidelines Series No. 33, Gland, Switzerland: IUCN, https://portals.iucn.org/library/node/51414
[11] Yakushina, Y., Valdivia-Lefort, M., Martin, C., et al. (2024). National Approaches to the Protection of Dark and Quiet Skies. *Zenodo*. https://doi.org/10.5281/zenodo.14566125
[12] Croatia, 2019. Law on protection against light pollution. NN 14/19 [30 January 2019], https://narodnenovine.nn.hr/clanci/sluzbeni/2019_02_14_271.html

- Provisions for lighting monitoring

Germany, on the other hand, chose the approach of changing environmental regulations. In 2022, the Federal Nature Conservation Act was amended to recognise ALAN as a major driver of insect decline.[13] The amendment introduced several measures to mitigate its impacts, including a general ban on new street lighting and illuminated advertising systems in nature reserves, as well as time-limited use of lighting. France adopted a combined approach by implementing specific decrees to protect the nocturnal environment while also amending general environmental law provisions.[14] Furthermore, LP was included as a target in the French National Biodiversity Strategy 2030, aiming to halve lighting emissions within a decade.[15]

Currently, regulations addressing LP and its impacts can be found across various regulatory areas, including energy efficiency and environmental protection regulations, as well as the protection of cultural heritage, indigenous communities, space regulations, urban planning, public procurement, and specific legislation aimed at reducing LP and protection of the nocturnal environment.[16] In the UK, current LP policy is limited compared to other environmental pollutants such as water, air, and plastic. While these pollutants are addressed through comprehensive legal frameworks, monitoring systems and enforcement powers, LP lacks national legislation formally recognising it as a pollutant. It is not subject to standardised monitoring, and existing enforcement mechanisms are minimal. Although the 1990 Environmental Protection Act explicitly excludes light as a pollutant and the 2005 Clean Neighbourhoods and Environment Act merely classifies it as a nuisance, there has been some policy-level guidance within planning systems.

[13] Germany, 2021. Act on the protection of insect diversity in Germany and on the amendment of other provisions. Bundesgesetzblatt 2021. P I, N 59. https://www.gesetze-iminternet.de/bnatschg_2009/BJNR254210009.html#BJNR254210009BJNG000300000
[14] France, 2000. Environmental code. https://www.legifrance.gouv.fr/codes/id/LEGISCTA000022496027/2010- 07-14; France, 2018. Order relating to the prevention, reduction and limitation of light pollution. https://www.legifrance.gouv.fr/loda/id/LEGIARTI000038748380/#LEGIARTI000038748380
[15] France, 2022. National Biodiversity Strategy 2030: living in harmony with nature. https://www.ecologie.gouv.fr/sites/default/files/National-Biodiversity-Strategy-2030.pdf
[16] Ibid [1].

iii. The impacts of LP and ALAN on the environment and human health

There is increasing scientific evidence on the environmental impact of LP and ALAN. Both terrestrial and marine ecosystems are significantly disrupted in different ways, including day-night cycles, species' ability to navigate, predator-prey dynamics, and camouflage strategies.

In terrestrial ecosystems, LP is widely recognised as one of the drivers of the global decline in invertebrate populations. Indeed, ALAN has multifaceted impacts on invertebrate species across terrestrial and freshwater ecosystems, and the disruption caused by LP spans behavioural and physiological responses, as well as ecosystem-level interactions, including altered patterns of competition, predation, and symbiosis. Evidence indicates that nocturnal invertebrates are disproportionately affected. For instance, caterpillar populations have declined by 52% in areas exposed to street lighting. Approximately one-third of insects drawn to artificial light sources perish due to exhaustion, predation, or disorientation. Moreover, LP reduces plant-pollinator interactions by up to 62%, significantly impairing pollination services and plant reproduction. Bioluminescent species such as glow-worms and fireflies, reliant on their own light signalling for mating and foraging, exhibit steep population declines in illuminated habitats. In Europe, half of the known firefly and glow-worm species are now threatened with extinction.

Freshwater ecosystems are equally vulnerable. Artificial lighting near rivers and lakes interferes with species' natural behaviours and movements. Illuminated bridges create behavioural barriers to aquatic invertebrates, while skyglow disrupts the diel vertical migration of zooplankton. Riparian lighting also attracts emergent aquatic insects away from water bodies, weakening key trophic linkages between aquatic and terrestrial systems. The significance of these findings is underscored by IUCN Red List assessments, in which 45% of species listing LP as a threat are classified as at risk of extinction. These species span various taxonomic groups and ecosystems, highlighting the broad ecological reach of LP.

In the marine environment, the known impacts of ALAN on marine biodiversity[17] are found across a range of habitats, including sandy and rocky shores, coral reefs, and surface oceans.

[17] Davies, T.W., Duffy, J.P., Bennie, J. and Gaston, K.J. (2014), The nature, extent, and ecological implications of marine light pollution. Frontiers in Ecology and the Environment, 12: 347-355. https://doi.org/10.1890/130281

To date, the scientific evidence confirms impacts on zooplankton migration (daily movement between surface and deeper waters suppressed); bird strikes (increased risk of strikes to lit ships and infrastructure such as oil rigs and lighthouses at night); bird feeding (nighttime feeding behaviour of coastal birds extended, impacting prey); invertebrate larvae (settlement site selection disrupted); fish mortality (increased vulnerability to predation due to aggregation under piers); coral reproduction (broadcast spawning, which usually follows lunar phases, de-synchronized); sea turtle nesting (preferred beaches avoided), and turtle hatchlings (seaward migration confused).[18] Moreover, a recent study reveals that around 22% of global coastlines are impacted by ALAN over an area of approximately 2 million km^2. This is crucial as coastal seas are the most biologically productive areas as well as the most economically significant. The study used a species of zooplankton which is highly light sensitive but also critical to the functioning of marine ecosystems as they undertake the largest migration in the living world: away from the lit surface waters during the day to avoid predation, and towards the surface at night to feed.[19]

Human health is also impacted by ALAN and LP. For physical health, exposure to LP and lack of natural sunlight (broadly known as NIR-starvation, a result of vitamin C starvation) can lead to poor metabolism and the development of diseases such as type 2 diabetes, obesity, dementia, Parkinson's, and retinal problems. This then becomes a significant contributor towards increased public healthcare costs.[20]

For psychological health, the existing evidence demonstrates that LP directly impacts mood and increases the prevalence of affective disorders such as depression and anxiety. Furthermore, LP directly impacts an individual's connection to the night, particularly when ALAN is used

[18] Marangoni, L. F. B., Davies, T., Smyth, T., Rodríguez, A., Hamann, M., Duarte, C., Pendoley, K., Berge, J., Maggi, E., & Levy, O. (2022). Impacts of artificial light at night in marine ecosystems—A review. *Global Change Biology*, 28, 5346–5367. https://doi.org/10.1111/gcb.16264

[19] T. J. Smyth, A. E. Wright, D. McKee, S. Tidau, R. Tamir, Z. Dubinsky, D. Iluz, T. W. Davies; A global atlas of artificial light at night under the sea. *Elementa: Science of the Anthropocene* 21 January 2021; 9 (1): 00049. https://doi.org/10.1525/elementa.2021.00049

[20] For more information about the impacts of LP on human health, please see the House of Lords' report on *The neglected pollutants: The effects of artificial light and noise on human health:* https://committees.parliament.uk/publications/40937/documents/199438/default/

needlessly or ineffectively.[21] Numerous studies have established the benefits of nature connectedness, including improved mental and physical well-being,[22] increased pro-environmental attitudes and behaviours,[23] greater engagement in conservation efforts,[24] and enhanced emotion regulation.[25] A recent study with adult populations suggests that LP directly reduces an individual's connection to the natural environment at night and the night sky, and that Night Sky Connectedness (NSC) is a significant independent predictor of both mental well-being and happiness.[26] Additionally, evidence indicates that when individuals feel a stronger connection to the night, NSC becomes the single strongest predictor of whether they will care for and protect the natural environment at night from LP.[27]

In parliament, the impacts of LP on human health were investigated by the House of Lords Science and Technology Committee. The committee's 2023 report found that ALAN can significantly disrupt human circadian rhythms and sleep, with potential consequences for mood, alertness, cardiovascular health, and metabolic conditions like diabetes. While typical LED use is not directly harmful, issues such as glare, flicker, and excessive brightness, especially from vehicle headlights, were identified as concerns. The report also highlighted a lack of

[21] Barnes, C., Richardson, M. & Lengieza, M. (2025, in prep.) Light Pollution and Human Psychological Health.
[22] Dopko, R. L., Capaldi, C. A., & Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: A preliminary investigation. *Journal of Environmental Psychology*, 63, 134-138; Pritchard, A., Richardson, M., Sheffield, D., & McEwan, K. (2020). The relationship between nature connectedness and eudaimonic well-being: A meta-analysis. *Journal of happiness studies*, 21, 1145-1167.
[23] Chawla, Louise, and Victoria Derr, ' The Development of Conservation Behaviors in Childhood and Youth', in Susan D. Clayton (ed.), T*he Oxford Handbook of Environmental and Conservation Psychology*, Oxford Library of Psychology (2012; online edn, Oxford Academic, 21 Nov. 2012), https://doi.org/10.1093/oxfordhb/9780199733026.013.0028; Rosa, C. D., & Collado, S. (2019). Experiences in nature and environmental attitudes and behaviors: Setting the ground for future research. *Frontiers in psychology*, 10, 763.
[24] Richardson, M., Passmore, H. A., Barbett, L., Lumber, R., Thomas, R., & Hunt, A. (2020). The green care code: How nature connectedness and simple activities help explain pro-nature conservation behaviours. *People and Nature*, 2(3), 821-839.
[25] Richardson, M., & McEwan, K. (2018). 30 days wild and the relationships between engagement with nature's beauty, nature connectedness and well-being. *Frontiers in Psychology*, 9, 1500.
[26] Barnes, C. and Passmore, H. (2024). Development and testing of the Night Sky Connectedness Index (NSCI). *Journal of Environmental Psychology*. 93, 1-11. https://doi.org/10.1016/j.jenvp.2023.102198
[27] Barnes, C. (2025, in prep.) Development and testing of the Dark Sky Protection Scale (DSPS): A measure of pro-environmental - light pollution-oriented – behaviour.

standardised methods for measuring light exposure and called for better monitoring and regulation to assess and mitigate health impacts.[28]

iv. Potential next steps

The compelling evidence presented at the conference calls for further actions at the level of policy implementation and regulation. In 2021, the APPG for Dark Skies released the document *Ten Dark Sky Policies for the Government*, which was produced following a consultation with over 170 academics, legal professionals, national park associations, professional and amateur astronomers, members of local and national government, lighting professionals, engineers and businesses. The document recommends a range of actions, including updating the existing legal framework and strengthening the National Planning Policy framework; expanding the scope of the planning permission process; strengthening Statutory Nuisance Provisions; creating a statutory Commission for Dark Skies and appointing a designated 'Minister for Dark Skies'; and setting standards for the brightness, colour temperature, direction and density of lighting, among others.[29] Nevertheless, none of these recommendations have been adopted in the UK.

Therefore, new and more concrete recommendations are required. In the absence of a unified regulatory approach, the most effective solutions appear to lie in the integration of measures within environmental protection regulations or the adoption of dedicated regulations to address the full spectrum of ALAN impacts within a single legislative driver would provide the most comprehensive and effective regulation, ensuring meaningful reductions in the rapidly growing problem of LP. Future efforts should focus on the legal recognition of ALAN as a pollutant, acknowledging its various negative environmental impacts. Additionally, the night should be recognised as an integral part of the natural environment, requiring protection on a par with daytime activities to strengthen nature conservation efforts. New provisions addressing LP should be based on the five principles of responsible outdoor lighting, which include: (1) lighting

[28] House of Lords Science and Technology Committee. 2nd Report of Session 2022–23. The neglected pollutants: The effects of artificial light and noise on human health. https://committees.parliament.uk/publications/40937/documents/199438/default/
[29] APPG for Dark Skies (2021). *Ten Dark Sky Policies for the Government*. Available here: https://appgdarkskies.co.uk/policy-plan

with a clear purpose; (2) directing light only where it is needed; (3) reducing light intensity; (4) using light only when necessary; and (5) choosing warmer coloured lighting.[30]

In the case of the UK, the discussion about LP should be placed within the broader context of the UK's environmental governance, especially considering the Environment Act 2021. This Act enshrines the Environmental Improvement Plan (EIP) into law and introduces binding targets, such as halting species declines by 2030, as well as strengthening environmental governance through mechanisms like the Office for Environmental Protection. While the Act does not yet include LP as a direct target, it opens a potential policy window for its inclusion through secondary legislation. LP was acknowledged in the 25-Year Environment Plan (2018) and proposed to be included in the Environment Act via amendments during its progress through the House of Lords, these efforts ultimately failed despite promises from the then Minister. The first Environmental Improvement Plan published under the Environment Act in 2023, intended to build on the 25-Year Plan, the plan omitted LP entirely, marking a regression in policy on this issue.

Moreover, there is also an opportunity to address LP issues under the UN Convention on Biological Diversity, to address LP through the Kunming-Montreal Global Biodiversity Framework. Progress has been made in raising LP in the context of Target 7 (*Reduce pollution risks and the negative impact of pollution from all sources, by 2030*) of the GBF and discussions are underway to continue work in this area with international partners. On a more technical level, reducing LP could be achieved by shading lights to prevent photons appearing where they are unwanted (i.e. to reduce skyglow as well as direct beam); using lower temperature LED lighting rather than bright white; to switch off lights where and when they are not needed. Within the UK Marine Strategy, Descriptor 11 refers to energy in the marine environment and is currently interpreted as only referring to underwater noise. This should be extended to include artificial LP as originally intended. New builds and retrofits of lighting infrastructure should be subject to policy and licensing. The natural extension of Marine Protected Areas should include Dark Sky Reserves.

[30] International Dark-Sky Association, 2024. Lighting principles. International Dark-Sky Association. https://darksky.org/resources/guides-and-how-tos/lighting-principles/