Light pollution **-** The bright future is dark

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Light pollution is a global problem. It does not require much effort to identify this type of pollution. Go outside during the night and look up at the sky, how many stars can you see? That is how bad light pollution is nowadays. Despite its extensive presence, light pollution is one of the most overlooked environmental issues that we face today. Unlike water or air pollution, light pollution is not perceived as harmful even though the consequences reach far enough, impacting both human health and ecosystems. The use of artificial light has significantly altered the natural light-dark cycles in the environment, disturbing biological processes. The present essay has the intention of examining the growing environmental concern caused by light pollution. The discussion centers on why light pollution should be considered a major environmental and public health concern and what can be done to reduce its negative effects. Starting by defining what light pollution is, then examines the ecological consequences and the impact it has on human health, leading finally to the presentation of possible mitigation strategies to reduce the negative effect that light pollution has.

Light pollution is the human-made alteration of outdoor light levels by excessive, misdirected or misused artificial light at night (Rodrigo et al, 2021). We perceive light pollution in different forms. For instance glare, when excessive brightness causes visual discomfort, for example the dazzling light from advertisements when driving. Sky glow when we brighten the night sky of inhabited areas, attempting to recreate daylight conditions during the night. Light trespass when light falls where it is not intended or needed to go, like streetlight illuminating a bedroom window. And finally clutter referring to bright, confusing and excessive groupings of light sources, clearly seen in New York's Times Square. (Rodrigo et al, 2021).
The main cause of this problem is human activity and industrial development. Whether it's at a big scale coming from cities or suburbs, factories, oil or gas production, electronic advertising, greenhouses and satellites to small scale like outdoor or street light, parking lots and sport lighting, human activity is the one to blame. Much of Earth's population lives under light-polluted skies (Rodrigo et al, 2021). According to the "World Atlas of Artificial Night Sky Brightness" in 2016 at least 80% of the world's population live under the sky glow (Falchi et al, 2016). It's shocking to know that 99% of the population in Europe and the United States can't experience a natural night (Rodrigo et al, 2021). This brings long-lasting consequences not only to humans but also to animals and ecosystems, making overlighting a severe global concern.

Artificial light at night is one of many ecological disturbances that affects animal behaviour. Light is an important environmental cue regulating activity patterns, mating, migration, navigation, predator avoidance, and foraging behaviour. Many species have evolved and adapted to predictable cycles of daylight, moonlight, starlight, and darkness. Artificial lighting disrupts these natural rhythms and can fundamentally alter ecological interactions and ecosystem functioning. (Gaston et al 2014; Sanders et al. 2021). Natural darkness is itself an important ecological resource. Many prey species rely on darkness to reduce visibility to predators and decrease predation risk. At the same time, nocturnal predators are adapted to low-light conditions through enhanced vision, hearing, or echolocation. Artificial light can therefore disrupt predator–prey dynamics by changing the balance between predator efficiency and prey avoidance. (Seymoure et al., 2023)

Artificial lighting can increase hunting success for visually oriented predators because prey becomes easier to find. For example, owls, bats, and other predators may benefit from streetlights where insects gather. Insects attracted to artificial lights may spend large amounts of time circling lamps, wasting energy and becoming highly vulnerable to predation. This can create traps where prey is drawn into environments with higher mortality risk. At the same time, some prey species, for example some nocturnal rodents, respond by reducing foraging activity or avoiding illuminated areas entirely. These are examples of how artificial lighting can alter both the behaviour and spatial distribution of nocturnal animals, which further affect reproductive success. (Gaston et al. 2014; Sanders et al., 2021)

Artificial light at night also interferes with orientation and migration. Many animals use moonlight and starlight for navigation, especially migratory birds, insects, and sea turtles. In urban areas, artificial lighting

can disorient migrating birds, increasing the risk of exhaustion and collisions with buildings. Sea turtle hatchlings, which naturally orient toward moonlight reflected on the ocean surface, may instead move inland toward artificial light sources, increasing mortality. (Seymoure et al., 2023; Sanders et al., 2021) In addition, ALAN can interfere with animal communication. Fireflies rely on species-specific bioluminescent mating signals, and artificial lighting reduces signal visibility and decreases mating success. Artificial light can also alter seasonal behaviour. Many animals use changes in day length and darkness as cues regulating reproduction, migration, and dormancy. Exposure to artificial light at night may therefore desynchronize biological rhythms from environmental conditions, leading to mismatches between behaviour and resource availability. (Gaston et al., 2014)

Beyond the ecological impact, light pollution also has a direct effect on human health and well-being. All these negative effects on animals also have adverse effects on humans, as we rely on a functioning ecosystem and biodiversity. In addition to this, we are also directly affected by artificial light. Artificial light causes sleep disturbances that can lead to multiple health issues. Our body also needs light and dark phases to have a functioning circadian rhythm (Chepesiuk, 2009). Hormones (e.g. Melatonin) signal when we are sleepy or awake and artificial light interferes with this rhythm, as our body still thinks that it is daytime, even when the sun has set (Hassan, 2024). This disruption of the circadian rhythm especially affects our mood and can lead to a higher irritability as well as reduced cognitive performances.

The sleep quality is poorer, as we wake up more often and have trouble to fall asleep again. Especially deep sleep and REM (rapid eye movement) phases are shortened by artificial light; as the REM phase is especially important for cognitive functions and emotional regulations, a high light exposure affects these functions, leading to mental health issues, such as depression or anxiety (Hassan, 2024). In terms of cognitive functions, attention span and memory (short term and long term) can be affected. Moreover, cognitive processes like decision making, organization, and problem solving can be negatively affected by sleep deprivation caused by light pollution (Hassan, 2024). Children are especially vulnerable to artificial light-associated sleep disorders and older adults struggle more with increased cognitive decline. Studies indicate that students with a high artificial light exposure may have a poorer academic performance and struggle more in school (Chan, 2026). If the human body is exposed to artificial light for a long time, the disruption of the circadian clock can also have physiological consequences, such as heart diseases, diabetes or obesity. This is because sleep deprivation can lead to increased appetite by disrupting hormones (leptin and ghrelin), and it increases stress levels, thus leading to higher blood pressure and an increased risk for cardiovascular diseases (Hassan, 2024). Melatonin is also an important regulator for cardiovascular functions and its suppressed production at night by artificial light leads to a higher heart disease risk (Hassan, 2024).

Artificial lighting is an integral part of daily life and plays a crucial role in the functioning of modern societies. A return to a world without artificial lighting is neither feasible nor desirable. However, it is possible to minimize the negative effects of light pollution on ecological systems and human health. Many mitigation strategies are technical in nature and focus on how lighting is implemented. Three main factors can be addressed to reduce negative effects: the amount of light, the color of light, and the direction of lighting (Gaston et al., 2012). The amount of light is the most straightforward factor—light should be used only where and when it is needed, and at the minimum intensity required to fulfill its purpose. Tools such as timers, sensors, and dimmers can help achieve this, particularly in outdoor environments such as roads and parking areas. The color of light is another important consideration. Many of the adverse effects of light pollution are associated with short-wavelength (blue) light. In many cases, warmer lighting can serve the same function as cooler light. Therefore, it is beneficial to consider the color temperature of lighting and, where possible, opt for warmer tones. Finally, the direction of lighting is a critical factor. This is particularly relevant for preserving night sky visibility, but it also has ecological implications. In many situations, the area requiring illumination is limited and well-defined, such as roads or private properties. In such cases, lighting can be designed and shielded to ensure that light is directed only toward the intended area, thereby reducing unnecessary light spill.
“The solutions are simple, in principle, experts agree—dim some lights; point them toward the ground, not the sky; or opt for longer-wavelength, redder bulbs. Yet, finding ways to implement those fixes is a challenge dogging dark-sky advocates and lighting professionals alike.” (McDermott, 2023) Designing effective policy

frameworks to address light pollution remains a central challenge. In many cases, there is no single governing body responsible for regulating all relevant sectors, which significantly complicates the implementation of coherent measures. Nevertheless, several promising concepts exist that could achieve large-scale positive effects. One of the most prominent approaches is the definition of lighting zones, in which areas are classified according to their ecological sensitivity to artificial light. This allows for the establishment of differentiated emission limits based on environmental context (Jägerbrand & Bouroussis, 2021). Another useful strategy is purpose-based regulation, where specific limits are defined for particular applications, such as parking areas or entrance lighting. In general, light pollution is an issue that can often be mitigated without substantial costs or major reductions in quality of life. For this reason, raising public awareness and promoting best practices can also be considered an effective policy approach.

In conclusion, we can clearly say that the increasing amount of light pollution, although artificial light is important for modern society, has many negative effects on several different levels. Animals (including humans) suffer from the disruption of the circadian cycle and experience a reduction in their fitness (cognitive capacities, mating, migrating etc.). Yet light pollution is usually an overlooked problem, as people do not talk about it as much as about other environmental issues and it is therefore not necessarily perceived as a big problem. It is therefore important that we keep in mind the wide-ranging negative consequences light pollution has on animals and humans, especially since there are practical and affordable solutions to this problem. As the non-stop growing urbanization and artificial lighting continue to expand, light pollution will become increasingly important to address to protect ecosystems, animals and human well-being.

Statement on AI Use

AI-based tools were used during the preparation of this paper for translation, spelling and grammar checking. All content, ideas, analyses, and conclusions are our own.

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