Sustainable Communities and Waste

National Environmental Science Program

THE HUMAN VALUES OF DARK SKIES: LIGHT POLLUTION AS AN EMERGING JUSTICE ISSUE

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As part of the Sustainable People–Environment Interactions (IP1) theme of the Sustainable Communities and Waste Hub

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Acknowledgement

The Sustainable Communities and Waste Hub is funded by the Australian Government's National Environmental Science Program. We acknowledge the Traditional Owners of Country throughout Australia and their continuing connection to land, sea, and community. We pay our respects to Traditional Owners, their cultures, and their Elders past, present and emerging. Our Indigenous research partners and partnerships are a valued and respected component of National Environmental Science Program research.

Acknowledgement of Country (Tasmania)

We acknowledge the palawa/pakana peoples, the traditional owners and custodians of lutruwita/Tasmania and the land upon which the University of Tasmania was built. We acknowledge the contemporary Tasmanian Aboriginal community, who have survived invasion and dispossession, and continue to maintain their identity, culture, and Indigenous rights. We also recognise the value of continuing Aboriginal knowledge and cultural practice, in particular the practices of caring for Country and Aboriginal land management, and support the sovereignty of the Tasmanian Aboriginal community over land and sea. We pay our respects to Elders past, present and emerging, to those who never made Elder status, and to the Spirit of this remarkable land.

Citation

Flies, Emily; Allegretto, Gabriella; Kendal, Dave; Somerville, Adele; Anderson, Sharolyn; Ogg, Marnie; et al. (2023). The human values of dark skies: Light pollution as an emerging justice issue. University Of Tasmania. Report: Sustainable Communities and Waste Hub: Sustainable People Environment Interactions (IP1). https://doi.org/10.25959/24797043

What is light pollution?

The excessive and widespread use of artificial light at night (ALAN) has made light pollution one of the fastest growing environmental pollutants. While there is no unified definition of light pollution in the academic literature (Hobkirk, 2020), for the purposes of this report we define light pollution as any excessive use of ALAN that is impacting the outdoor environment; this can include outdoor ALAN or indoor light that spills over into the outdoors. Light pollution causes harm to humans and wildlife, and in economic terms, can be viewed as a negative outcome of the modernisation of society (Argys et al., 2021).

Based on conservatives estimates, artificial sky glow caused by ALAN has increased globally by as much as 400% over a 25-year period (from 1997 to 2017) (Sánchez de Miguel et al., 2021). This is due to several processes, including global urbanisation, electrification, and the shift from outdoor gas-discharged lighting technologies (e.g. high-pressure sodium vapour lights) to solid-state light-emitting diodes (LED). Most LEDs are rich in short wavelength blue light, which disperses more broadly in the atmosphere and deeper in the water column than other colours (Davies et al., 2014), polluting both life on land and under water.

Light pollution is a global driver of biodiversity loss (Commonwealth of Australia, 2020) and has detrimental impacts on human health (American Medical Association, 2016). Without intervention, the spatial extent and intensity of light pollution will continue to increase (especially in developing countries) throughout the 21st century; therefore, light pollution is of global concern and an important area for future global change research (Davies & Smyth, 2018).

The dark sky conservation movement

Light pollution is intertwined with another important concept – the loss of access to the night sky. Like air, water, soil, and other acknowledged polluted resources, our night skies (the natural night skies) are being polluted. Outdoor sources of ALAN reduce the visibility of the night sky. For example, only two thirds of the global population are able to see the Milky Way (Falchi et al., 2016) due to artificial skyglow created by ALAN. The consideration of exposure to light pollution often misses the important point that light pollution limits the visibility of celestial bodies in the night sky for humans and animals. Some animals such as nocturnal insects and migrating birds use the night sky for navigation, while naturally dark skies are critical to hatchling sea turtle sea-finding and offshore migration. There is an emerging body of academic research that explores the importance of dark skies for humans, for cultural astronomy (Gantevoort, 2015; Gullberg et al., 2020; Lee, 2016) and tourism (Hobkirk, 2019), showing that dark skies are culturally, spiritually and economically important to individuals and communities. This research on biodiversity and human impacts of loss of access to dark skies is coupled with a growing movement to preserve and restore the dark skies, as seen by dark sky conservation programs from organisations such as the *International Dark-Sky Association* (IDA), the *Royal Astronomical Society of Canada* (RASC), the *Australasian Dark Sky Alliance* (ADSA) and the *Starlight Foundation*.

Human values for dark skies

Humans throughout history have been captivated by dark skies and the stars and planets visible in them. These features are woven into many Indigenous creation stories; the Dark Emu in some Australian Aboriginal and Torres Strait Islander cultures is one example. In Christianity, the Star of Bethlehem helped herald the birth of Christ. Astronomy has been important in Chinese and Indian culture for thousands of years. Early sailors used the night sky for navigation and often had a professional astronomer onboard, while the colonisation of the Pacific by the Polynesians was only possible due to their intimate relationship and understanding of the celestial sky.

Western science has built on Greek astronomer Ptolemy's documentation of the existence and brightness of 48 constellations and 1022 stars in the second century CE. Islamic astronomy refined the work of Ptolemy and heavily influenced early European astronomy. Today, the influence of the night sky on humans has been studied in subfields of cultural astronomy such as archaeoastronomy (which explores historical cultural perceptions of astronomical phenomena) and ethnoastronomy (which explores current perceptions of the night sky and practices relating to astronomical phenomena, mostly among modern Indigenous communities) (Ruggles, 2014). Dark skies continue to hold cultural, spiritual, historical, recreational and scientific values for many cultures (Gallaway, 2010); these relationships are impacted and threatened by light pollution.

Cultural and spiritual values

Indigenous communities have been observing the night sky for tens of thousands of years – up to 65,000 years in the case of Indigenous Australians (Australian Indigenous Astronomy, 2021). Stars (and the dark spaces between them) provided guidance for navigation, food availability and predicting weather conditions, as well as informing ethics, laws, moral values and social structure (Gantevoort, 2015). Additionally, cross-cultural studies in ethnoastronomy have shown that the same constellations (and features within the constellations) can have unique meanings for different Indigenous and non-Indigenous communities around the world. For example, the dark areas within the Milky Way represent different animals of significance or natural features in different Indigenous cultures in the southern hemisphere (Gullberg et al., 2020). This highlights how the continued visibility of the night sky is important for cultural continuity for Indigenous communities (Hamacher et al., 2020).

Tourism, economic and recreational values

An interest in engaging with dark skies has been demonstrated by the rise in popularity of astrotourism and dark sky tourism. Astrotourism has been described as a type of ecotourism that involves travelling to destinations for astronomical experiences (Hobkirk, 2019), whereas dark sky tourism also incorporates other experiences such as nocturnal wildlife viewing, visiting certified dark sky places, astrophotography, and storytelling (Dalgleish & Bjelajac, 2022).

Astrotourism and dark sky tourism have the potential to be a nature- and place-based sustainable form of tourism. The rise in popularity of astrotourism has led to an increase in resources for tourists, such as the Lonely Planet guide titled *Dark Skies: A Practical Guide to Astrotourism* (Stimac, 2019). Additionally, astrotourism and dark sky tourism can have many economic benefits. For example, it is estimated that in the Colorado Plateau (U.S.) alone dark sky tourism will create over 10,000 jobs each year, with tourists spending 5.8 billion dollars over 10 years (Mitchell & Gallaway, 2019). In Australia, more than a third of international and Australian tourists are interested in viewing the Aurora Australis (Southern Lights), particularly in combination with other dark sky experiences, wildlife sighting and other seasonal natural phenomena (Tourism Australia, 2022). Dark sky tourism (and astrotourism) can be beneficial for rural economies by facilitating sustainable rural development as seen in South Africa (Jacobs et al., 2020). Dark sky tourism (and astrotourism) can also have many socio-cultural benefits, such as preserving Indigenous star lore and providing job opportunities (and further education and training) for marginalised communities (Dalgleish & Bjelajac, 2022).

Scientific value

Dark skies also hold scientific value; the science of astronomy has increased our understanding of our universe and our place within it and is one way that people connect with and value dark skies. The work of early astronomers such as Copernicus and Galileo in identifying that our solar system is heliocentric were crucial to the Scientific Revolution and development of the scientific method. Astronomy continues to play a leading role in scientific advances and modern scientific imagination

by underpinning space travel and deep space exploration, and the development of big data analytics and artificial intelligence. Naturally dark night skies are critical to the security of the earth, space flight and orbiting satellites. A global network of Surveillance Telescopes tracks asteroids in addition to human derived space debris, including 23,000 pieces larger than a softball and half a million pieces the size of a marble. The dark skies north of the Cape Range in Western Australia are critical to the ability of the Department of Defence, Space Surveillance Telescope to detect and track this debris.

Light pollution as an emerging environmental justice issue

Light pollution has recently been proposed as an environmental justice issue. Researchers have found that exposure to light pollution is disproportionately high for racial/ethnic minorities in the U.S. (Nadybal et al., 2020). This has led to other professional organisations, such as the Illuminating Engineering Society (IES) – the recognised authority on lighting education and standards – echoing this message that light pollution is an environmental justice issue (Bartholomew & Loeffler, 2021).

What is environmental justice?

There is no single definition of environmental justice (Agyeman et al., 2016) because environmental justice concepts can capture a broad range of relationships between people (typically related to cultural background, socioeconomic status and gender) and the environment, often with differing philosophical foundations and requiring different policy solutions (Coolsaet et al., 2021). Some of the dominant theories and concepts of environmental justice include (Coolsaet et al., 2021):

- distribution justice (the socially just distribution of environmental ills and goods)
- participation and procedural justice (e.g. autonomy and decision-making power in environmental management)
- recognitional justice (the recognition of differences between e.g. Indigenous and marginalised groups and dominant society and the elimination of disrespect and humiliation).

Environmental ills and goods follow predictable patterns of distribution and access. In the USA, race and income continue to be strong predictors of environmental burdens experienced by communities (Coolsaet et al., 2021). For example, it has been repeatedly demonstrated that exposure to environmental ills such as noise pollution (Dreger et al., 2019) and air pollution (O'Neill et al., 2003)) is concentrated in communities with socioeconomic disadvantage and/or ethnic minorities. Communities with lower socioeconomic status and/or a greater proportion of minority racial/ethnic groups also often have less access to environmental amenities (goods; e.g. green spaces (Gerrish & Watkins, 2018; Schüle et al., 2019; Watkins & Gerrish, 2018)). In Australia, similar patterns have been observed in communities with diverse cultural backgrounds, and high proportions of Aboriginal and Torres Strait Islander people. Similarly, access to environmental goods favours advantaged groups such as the wealthy and those of the majority race/ethnicity.

In the context of this report, light pollution is conceptualised as an environmental ill and dark skies as an environmental good.

Key findings on light pollution as an environmental justice issue

One of the first academic studies exploring light pollution as a distributional environmental justice issue examined the relationship between light pollution exposure (an environmental ill), racial/ethnic minorities and socioeconomic variables in the U.S (Nadybal et al., 2020). The findings from this study showed that Americans with Asian, Hispanic, Black and Native Hawaiian/Pacific Islander heritage were exposed to approximately two times the amount of light pollution (measured as mean radiance from outdoor ALAN at a census tract level) compared to White Americans (based on population-weighted means for racial/ethnic groups).

Another significant finding from this was the non-linear relationship between median family income and exposure to light pollution – where census tracts with a high proportion of homes classified as *medium* median family income were exposed to the highest level of light pollution (Nadybal et al., 2020). This was likely due to census tracts with high-income households being more likely to have influence in their community and being able to afford modifications to urban lighting (such as shielding, changing the amount of light emitted in the blue end of the spectrum and dimming) (Falchi et al., 2011). Also, families with a higher median family income were more likely to be homeowners and would therefore be more likely to make changes to lighting on their property, whereas census tracts with low-income households had lower electricity consumption, due to less infrastructure for lighting (but this trend is predicted to shift in the future with residents in low-median family income households experiencing increasing light pollution exposure) (Nadybal et al., 2020). Further research is also needed to determine if light pollution exposure could reinforce other systems of oppression in the U.S., potentially resulting in an unequal health burden, and to explore the synergistic effects of all environmental injustices in the U.S. from a social and health aspect.

Potential underlying mechanisms

Nadybal et al. (2020) have proposed several mechanisms underlying the inequitable distribution of light pollution exposure in the U.S. These include the historical weaponisation of light in low socioeconomic status areas for policing and surveillance (Browne, 2015), as well as undesirable land use activities (which create light pollution) typically being located in low socioeconomic areas with ethnic minorities (Pais et al., 2013). These factors could also be further compounded by ethnic/racial minorities in the U.S. being exposed to higher levels of air pollution (Crowder & Downey, 2010), which increases the risk of light pollution due to light scatter from particles in the atmosphere – a good example of the concept of intersectionality where multiple systems of oppression reinforce environmental injustices.

While some of the underlying mechanisms in the U.S. have been identified, further research is needed to identify the mechanisms operating in other countries, including Australia. It is also important to acknowledge that lighting infrastructure may be perceived differently in different countries. For example, lighting is used as a proxy for human development in some developing countries because numerous low socioeconomic communities lack reliable lighting infrastructure (Bruederle & Hodler, 2018). This poses a different social justice issue around disadvantage from lack of light *provision*, contrasting with the idea that dark skies are an environmental amenity (Morris, 2002). The relationship between exposure to light pollution and socioeconomic and cultural diversity variables is likely to be context dependent, as different countries and communities are at different stages of economic development, have different historical legacies of urban design and may have different pre-existing environmental justice issues that may compound the impacts of light pollution.

Knowledge gaps and future directions

The academic literature has considered light pollution as an environmental justice issue in terms of racial/ethnic minorities being disproportionately exposed to an environmental ill/pollutant. However, given the benefits of dark skies for cultural continuity, astronomical observations, tourism and rural economic development, light pollution also reduces the accessibility of dark skies, an environmental amenity (good) (Nadybal et al., 2020). Therefore, inequitable access to dark skies is a separate, but strongly related, environmental justice issue. Research on how the reduced visibility of dark skies (due to light pollution) impacts communities has only recently been investigated in the academic literature. Working from an Indigenous Australian perspective, a recent article described light pollution as a form of cultural genocide, as light pollution is seen as a form of Indigenous knowledge erasure (Hamacher et al., 2020). This study will hopefully inspire further research to understand how the reduced visibility of dark skies affects different communities.

Research is also needed to determine if there is a relationship between light pollution exposure and socio-cultural variables at a global level. If there is a relationship, then further interdisciplinary work is needed to understand the drivers of these disparities in light pollution exposure between academic disciplines (e.g. behavioural psychology and human geography), policy makers and lighting professionals. These drivers likely include social factors, such as individuals' perceptions around darkness, light and safety, as well as lack of awareness around the harms of light pollution, and potentially limited legislation around ALAN.

Responding to Light Pollution

Compared with other environmental pollutants, such as air and water pollution, light pollution has not been a high priority policy issue (Hölker et al., 2010) and is not monitored and restricted as closely as many other pollutants (Zissis, 2020). The primary focus of artificial lighting policies has been on energy efficiency and greenhouse gas emissions, with a secondary focus on safety for humans (Hölker et al., 2010). There is a need for lighting policies to address how outdoor lighting can contribute to light pollution that impacts human health and wellbeing and wildlife (Hölker et al., 2010), and to find ways of mitigating these factors. Additionally, there is no international consensus, legislation or standards on several important aspects of lighting that are strongly related to light pollution, such as brightness, direction of lighting and proportion of short wavelength blue light of outdoor lighting – in both the private and public domains. In recognition of impacts of light pollution, legal limits for the amount of blue light in artificial light sources has been considered in the U.K. (All-Party Parliamentary Group for Dark Skies, 2020). There does not appear to be a policy synthesis on how artificial lighting policy contributes to light pollution and impacts human health and wellbeing, but there has been a recent synthesis of management actions to reduce the impacts of artificial light at night on wildlife (Commonwealth of Australia, 2020).

Formation of a nationally supported Dark Sky Network (ADSA 2022), with collaborations between researchers from different disciplines, policy makers, lighting professionals and interested local individuals and communities would provide a two-pronged approach to managing ALAN, by assisting the creation of policy to reduce light pollution and addressing human behavioural habituation to light and night. An international lighting vocabulary document has recently been published (Commission Internationale de l'Eclairage, 2020) which will hopefully promote and facilitate these international discussions around policy between disciplines, industries and countries. It is also important to consider public awareness of light pollution and individual perceptions around lighting as these may influence the likelihood of a shift in policy and practice around lighting and the willingness for the public to adopt changes when it comes to lighting (Hölker et al., 2010).

Regulation of light as a pollutant

Noise and light pollution are two rapidly expanding forms of environmental pollutants that result from poor urban planning. Johnson and Lichtveld (2022) have recognised that both impact on human and ecological health and concluded they meet the definition of pollutants. In the U.S., the Noise Control Act (NCA) of 1972 established a national policy to support environments free from excess noise pollution. This act outlines limits to the sound output of air compressors, motorcycles, medium and heavy trucks, and truck-mounted waste compactors that can make a substantial difference to registered levels of noise (Hammer, 2014).

In Australia, the Australasian Dark Sky Alliance (Night Environment Conservation | ADSA (australasiandarkskyalliance.org)) recommends that light pollution could be reduced by implementing the baseline principles outlined in the NSW Environmental Protection Authority's regulations for noise control. These controls operate in partnership with local government, Police, Main Roads, Maritime Services and the community, and target quantitative and qualitative metrics specific to the noise source and the receiving environment. Following this model, light pollution controls could be multijurisdictional, assessed and enforced on a case-by-case basis with defined

standards for lighting management (e.g. intensity, colour temperature, aiming, time of use, smart controls etc) (see Table 1).

Table 1 – Example of proposed approaches for light pollution regulation (ADSA, 2022)

Environment	Issue	Governing body	Metric
Private residency	Light Trespass	Police, local council	Light intensity, curfew, adaptive controls
Listed species habitat, e.g. marine turtles, marine birds, pygmy possums	Species impact	International treaties (e.g. Convention on International Trade in Endangered Species), Commonwealth government (Environment Protection and Biodiversity Conservation Act 1999), State government conservation acts	Horizon imaging, blue light content, species behaviours
Sports stadium	Light Trespass, Glare	State government	Above the horizontal plane, intensity, curfew
Street lighting	Light Trespass, Glare	Local government, State government roads departments	Above the horizon plane, intensity, colour (wavelength distribution)

Behavioural adaptation through education

Whilst enforceable policies to reduce light pollution are important, the success of top-down approaches may be limited by human behaviours that enjoy and appreciate the benefits of light at night with no understanding or unawareness of its negative aspects. The Australasian Dark Sky Alliance recommends the development of government regulations on light pollution in conjunction with a public education program to increase public awareness of the issue.

Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) are protected under national environment law, the Environment Protection and Biodiversity Conservation (EPBC) Act 1999. MNES include listed threatened species and communities, listed migratory species, Ramsar wetlands, Commonwealth marine environment, World Heritage properties, National Heritage places and the Great Barrier Reef Marine Park. These ecologically, culturally, and economically valuable areas have been rigorously

assessed as 'important, notable or of consequence'. Any action that has the potential to impact on a MNES must be referred to the Commonwealth Government for assessment and approval.

Listed threatened and migratory species and ecological communities assessed under the EPBC Act may have specific Conservation Advice or Recovery Plans which the Environment Minister must legally comply with when assessing a proposal. Light pollution has been recognised in the 2017 *Recovery Plan for Marine Turtles in Australia*, which lists light pollution as a key threat and has an action stating that 'artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats (p. 56). Consequently, all projects referred under the EPBC Act that have may impact on marine turtles are potentially required to show how light pollution will not significantly impact on the populations. As more scientific information becomes available, Conservation Advice and Recovery Plans could be updated with specific actions to minimise the effects of light pollution on listed species and ecological communities.

An additional outcome of the 2017 *Recovery Plan for Marine Turtles in Australia* was the publication of the *National Light Pollution Guidelines for Wildlife including marine turtles, migratory shorebirds and seabirds* in 2020. While these guidelines have no regulatory authority, any projects referred to the Commonwealth government under the EPBC Act are now potentially required to show how the project is 'consistent with the recommendations of the Guidelines', that is, they must identify and assess the risks caused by artificial light at night on listed species and demonstrate how light pollution will be measured, managed and mitigated. The principles of these guidelines are increasingly being applied to both listed and non-listed marine and terrestrial species under the EPBC Act. By extension, the principles are also being applied to the conservation of the night sky, which is increasingly being recognised as a sensitive receptor with an intrinsic value.

At the state level, West Australian government environmental agencies are applying the requirement to address and manage light pollution as a condition of regulatory approval of local developments. This model could be expanded to other state governments.

Finally, recognition of light as pollution could also be accomplished by listing it as a Key Threatening Process (KTP) under the EPBC Act. Although KTPs have little regulatory weight other than on Commonwealth land, there may be benefits in pursuing light pollution as a KTP to bring together relevant material and provide guidance to national and state regulators. Current reviews of the EPBC Act point towards greater use of regional and bioregional planning (which to date have largely been limited to marine areas). As more spatial information becomes available on dark skies and light pollution, these issues could be included in regional biodiversity planning processes.

International Reporting

Astronomy has been demonstrated to assist communities in reaching their UN Sustainable Development Goals (SDG) through human capacity building (Dalgleish, 2020). For example, in South Africa the South Africa Radio Astronomy Observatory (SARAO) developed an initiative in 2005 to provide school education, professional training and jobs in astronomy (and related industries) for local residents. Providing quality education (SDG 4) has led to increased job opportunities, international partnerships (SDG 17) and economic growth (SDG 8), which has allowed for the improvement of infrastructure for local communities (SDG 9) (Dalgleish, 2020). Further work could identify how dark skies and addressing light pollution can contribute to Australia meeting a range of SDG goals.

Conclusion

Light pollution is increasing rapidly at a global level – threatening access to dark skies. Access to dark skies is important to humanity; it provides cultural, spiritual, recreational, economic and scientific

values. Without policy intervention, increasing exposure to light pollution and reducing access to dark skies are likely to exacerbate existing environmental justice issues.

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