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Forum

Investigating the impacts of artificial light via blackouts

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Natural experiments provide remarkable opportunities to test the large-scale effects of human activities. Widespread energy blackouts offer such an 'experiment' to test the impacts of artificial light at night (ALAN) on wildlife. We use the situation in South Africa, where regular scheduled blackouts are being implemented, to highlight this opportunity.

Understanding impacts of ALAN on animal behaviours

ALAN originates from man-made light sources such as streetlights and buildings, and it is increasing globally [1]. This sensory pollutant has been linked to a range of negative effects on wildlife and the environment, including the disruption of a range of animal behaviours such as movements, timing of activity, feeding behaviours, and species interactions [2–4].

Exploring the impacts of ALAN on the behaviours of free-ranging animals is challenging. Most research has been correlative, examining responses across ALAN gradients [5], but this approach often fails to distinguish ALAN effects from other urban pressures such as noise pollution [4]. Although some ALAN exposure experiments have occurred, these have either been small-scale (e.g., adding lights to nest boxes [6,7]), or (by necessity) have limited replicates or only illuminated small areas [8,9].

We highlight that energy blackouts, where electricity supply fails or is turned off, provides an exciting opportunity to better understand how species respond to the presence and absence of ALAN in a direct manner. Blackouts are increasingly common in many parts of the world, and in South Africa load-shedding (with scheduled blackout locations and times) has been introduced as a means of managing these blackouts, providing an ideal opportunity for research on the impacts of ALAN.

South African load-shedding: what is it and how does it operate?

In South Africa, Eskom (the national power utility) is currently unable to fully meet the demand for electricity, resulting in scheduled blackouts throughout the country. Unlike random outages that occur elsewhere, these load-shedding episodes are pre-planned for specific zones. Zone size varies with population density but is generally many square kilometres (Figure 1). Eskom provides schedules in advance for these blackouts, which last approximately 2–4 h, occurring once to three times daily based on Eskom's set 'stage'. Each stage indicates 1 GW of energy reduction across the country. For instance, stage 1 cuts 1 GW, while stage 6 cuts 6 GW and is equivalent to ca. 10% of South Africa's overall grid capacity of 60 GW.

The frequency of these blackouts in South Africa has risen in recent years [10]. In 2021, there were 75 days of load-shedding, rising to 205 days in 2022, and in 2023 there were only 30 days without load-shedding. Load-shedding intensity (i.e., stage levels) have also escalated over this period[i]. Despite mitigation efforts, forecasts suggest that these blackouts will persist for many years [10].

Blackouts cause a clear and obvious reduction in ALAN (Figure 1). The impact of load-shedding on ALAN is quantifiable from remotely sensed data, with night-time radiance in South African cities decreasing in recent years from a monthly average of 15.6 (nanowatts/steradian/cm^2) in 2014–2018 to a monthly average of 12.6 (nanowatts/sr/cm^2) during 2022–2023 as load-shedding has increased (Figure 2). During a typical South African winter night, load-shedding lasting 2–4 h would cover a loss of ALAN across 17% to 33% of the night.

Blackouts and load-shedding in South Africa: opportunities for research

We propose that the international research community leverage South Africa's natural experiment of load-shedding to enhance our global knowledge of the effects of light pollution on animal behaviour. These scheduled outages across vast urban zones allow for comparative studies on animals' reactions to artificial light (non-load-shed areas) versus its absence (load-shed areas) within the same landscape and timeframe. This scenario provides a global first: an opportunity for a large-scale, controlled experiment to investigate ALAN's impacts on animal behaviours.

Load-shedding presents several unique strengths for research. Implemented nationwide, this practice provides numerous replicates over a vast, biodiverse area (1.22 million km^2). This enables studies of ALAN responses across varied climates. For instance, cities like Durban have a tropical climate, others (like Cape Town) are Mediterranean. Urban areas in South Africa also span a diverse range of biomes and habitats, including forested, grassland and fynbos areas, freshwater habitats, and coastal marine areas, providing opportunities to examine the impacts of ALAN across a suite of different taxa encompassing a broad phylogenetic spectrum. The size of load-shedding zones typically encompasses the home range of most species, ensuring that for some individuals their

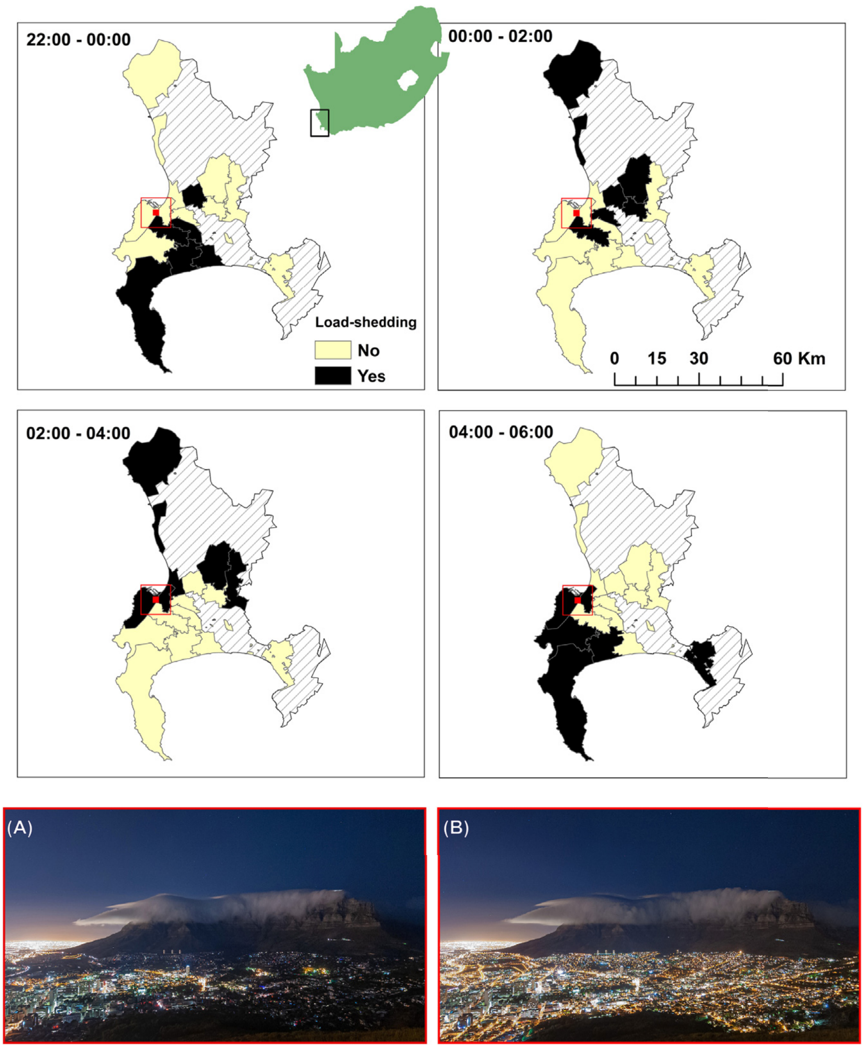

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Figure 1. Load-shedding zones for areas supplied by the City of Cape Town, illustrating the size of the areas and the manner in which power cuts (lasting 2–4 h) are implemented. Zones in black are being load-shed, and those in yellow are not. The hashed areas have power supplied by a provider other than the City of Cape Town. A zone's size is based primarily on population density, with more populated areas having smaller zones. Load-shedding causes meaningful and obvious changes in artificial light at night (ALAN) across large areas of a city, as shown by these photos of Cape Town taken a few minutes before, with load-shedding implemented in most of the Cape Town Central Business District (A) and then after load-shedding has ended (B). The red square on the map indicates the general regions seen in the images, which are taken from a YouTube video[iii] with permission from Eric Nathan© (2023).

entire habitat goes dark during times of load-shedding.

Of course, this natural experiment has its own limitations. The power cuts last only a few hours nightly, making them less suitable for studying longer-term ALAN impacts such as population-level effects. Even during nights with load-shedding, some ALAN remains, albeit in varying and diminished quantities. Furthermore, increases in the use of alternative energy sources (such as batteries and inverters) could result in ALAN increasing during load-shedding over time, and also argues for some on-site light measurements within study areas. Additionally, because load-shedding has occurred regularly now for several years in South Africa, it could mean that species may have already responded to it, for example by modifying their distribution or other behaviours; this lack of baseline measurements of animal behaviours prior to any load-shedding may thus be an additional limitation. Lastly, although no information currently exists, it is possible that other human activities are also reduced during load-shedding. If so, human activity – and thus human disturbance – may be somewhat confounded with load-shedding, creating challenges to disentangle the effect of ALAN from other forms of disturbance. Another important constraint with this system is the insecurity associated with field work at night in South Africa, especially in urban areas where crime rates are high. However, many of these risks can be circumvented by using remote technology to monitor behaviours, such as deploying GPS tracking devices, camera traps, or remote acoustic monitors.

Given these advantages and limitations, we suggest that load-shedding is best suited for examining ALAN's impact on shorter-term behavioural responses, such as movement, foraging patterns and success, species displays, or species interactions. Several of these responses can be explored using GPS tracking devices. Additionally, variation in load-shedding schedules (e.g., 0, 2, or 4 h load-shedding across any one night) could provide for a dose–response analysis, which can expand the types of responses that can be explored, such as examining stress markers or sleep levels under varying degrees of nightly ALAN exposure. Similarly, different areas of cities might be dominated by different light sources (e.g., warm tungsten lamps versus cold, blue-rich LED lights), which may provide opportunities to test for behavioural responses to different light spectra [11].

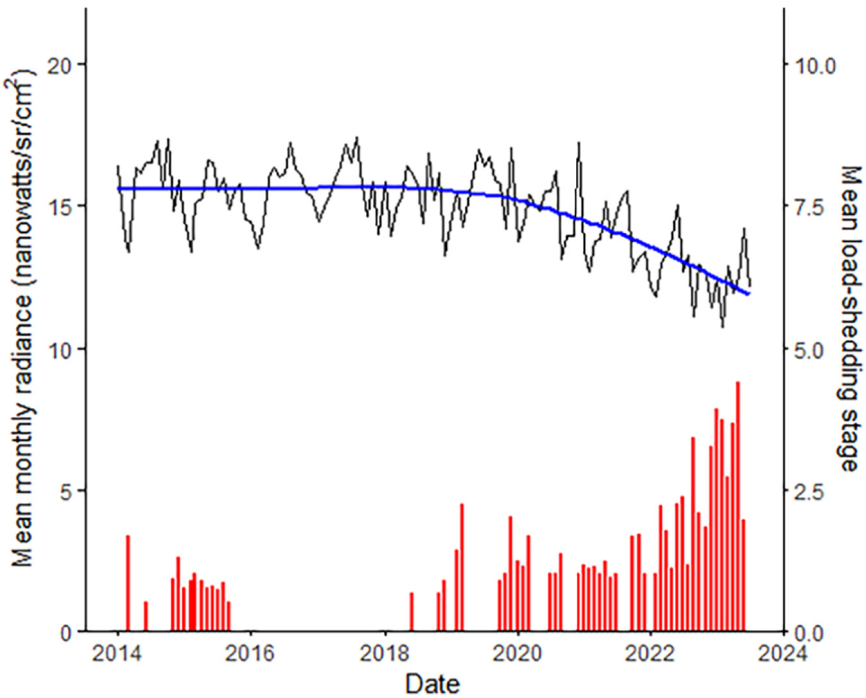

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Figure 2. Declines in average monthly radiance levels (nanowatts/sr/cm2) across Johannesburg, South Africa (black line) – blue line: locally weighted scatterplot smoothing (LOESS) trendline – following an increase in average monthly load-shedding stages in recent years (red bars). Monthly average radiance data were extracted from composite images of night-time data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB), and data on load-shedding stages is publicly available and provides national scale data on the load-shedding status as they are updated. These load-shedding data were averaged daily and then used to calculate the mean monthly load-shedding stage[iv].

Research initiative to exploit this research opportunity

Our goal here is to alert the global research community to this unique opportunity. South Africa's situation is one example of well-documented load-shedding, but several global cities, especially in developing economies, may offer similar opportunities [12]. Ongoing changes in global climate and extreme weather are leading to increased energy demand and consequently, more frequent load-shedding events by energy providers. This trend may result in comparable research opportunities in various countries in the future.

While we invite researchers worldwide to utilise the situation in South Africa, we advocate for a 'global science' approach, as outlined by Asase *et al.* [13], promoting collaboration between researchers from developed and developing nations, rather than the historically exploitative parachute approach. Coetzee *et al*. [14] have previously highlighted the paucity of studies of ALAN in Africa, and this opportunity also presents a chance to directly address this knowledge gap.

A global research fund could facilitate international collaborative research, allowing experts in ALAN research, predominantly from the global north (where most research to date has occurred [14]), to collaborate with local South African researchers, leveraging their invaluable taxon- and locale-specific knowledge. Such collaboration could yield novel ecosystem-level insights into ALAN impacts by enabling studies across different taxa within the same system (e.g., within predator–prey networks). We advocate for the establishment of an 'ALAN load-shedding initiative', mirroring efforts initiated to study the ecological effects of COVID-19[ii].

Declaration of interests

No interests are declared.

Resources

[i]https://loadshed.theoutlier.co.za/

[ii]www.bio-logging.net/

[iii]https://youtu.be/BK0zOMFLnQs

[iv]https://docs.google.com/spreadsheets/d/1ZpX_twP8sFBOAU6t–vvh1pWMYSvs60UXINuD5n-K08/edit#gid=863218371

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