Potential Impacts of increasing floodlight level at Harold Rossiter Park and Kensington Bushland – Preliminary Literature Review.

A report for the Town of Victoria Park – Perth, Western Australia

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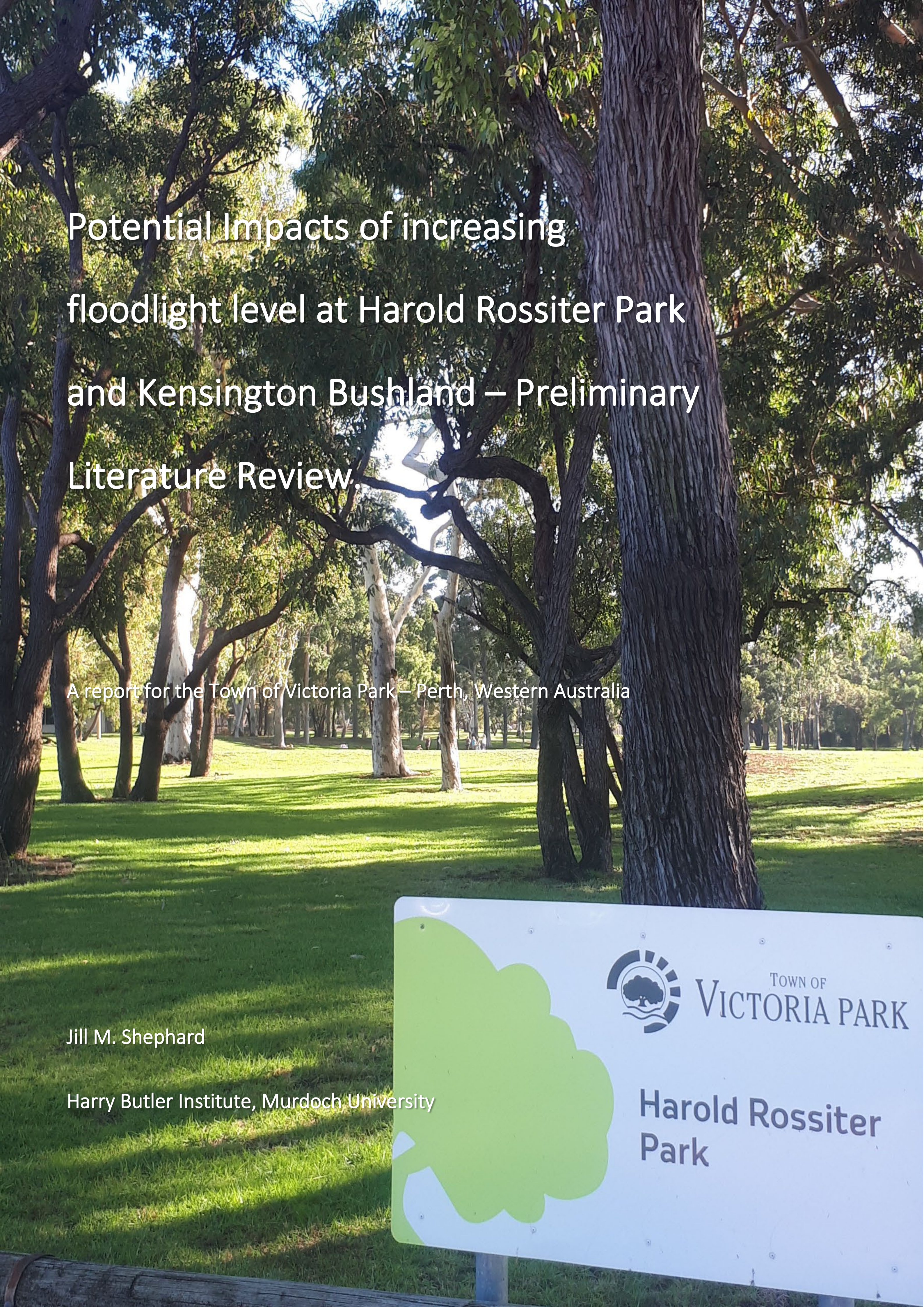

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Cover photograph by Jill Shephard

Red-tailed Black Cockatoos flying over Harold Rossiter Park (Image: Keith Lightbody)

Contents

Facts and Definitions

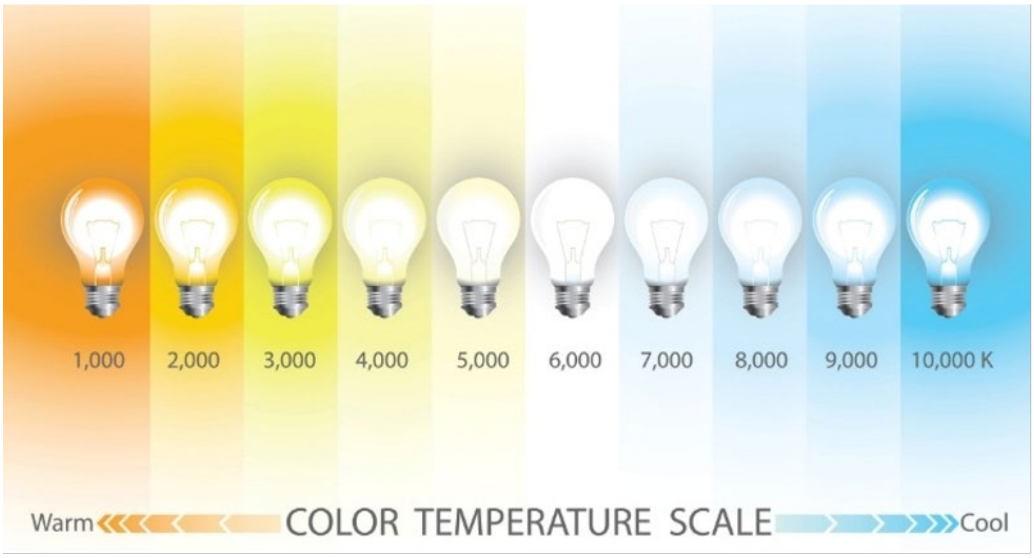
ALAN	Artificial Light at Night
Ecologically relevant light intensity	>1.5 lux (Moaraf 2021)
Moonlight	0.05 – 0.2 lux (Kyba et al. 2017)
LED Lights	Light emitting diodes
LED invented	1962
First use of LEDs in floodlighting	1990's onwards
CRI	Colour rendering index - the higher the value, the more realistic the colour reproduction. Measured between 0 - 100 (this is the equivalent spectrum to daylight).
CIE RA	Index used on commercial products - equivalent to CRI. Highest possible value is 100 (this is the equivalent spectrum to daylight).
CAM	Colour Appearance Model - Another standard used for colour rendering ability
IES TM-30	New standard replacing CIE (since 2021) - The colour rendering of a light source refers to its ability to reveal the colours of various objects faithfully in comparison with an ideal or natural light source.
Colour Temperature	Characteristic of visible light when compared to a 'black body' emitter
CCT	Correlated Colour Temperature - for lights that cannot be compared against a 'black body' emitter - fluorescent and LED lights fit this category. i.e., Light is emitted through a mechanism other than thermal radiation.
CCT ~ 2000K	warm light (red, yellow light). K = kelvin (base SI unit for temperature).
CCT 5000K+	cool light (typically white to light blue)
Foot-Candle	Describes the amount of light reaching a specified surface area as opposed to the total amount of light coming from a source (luminous flux).
Foot-Candle - measurement (imperial system)	Foot-candles are measured in lumens per square foot as opposed to simply lumens (as in the case of luminous flux). It therefor accounts for the amount of light actually illuminating the desired surface area. Also accounts for the amount of light lost due to inefficiencies in absorption, reflection, and dissipation. **Illumination is the most important measurement.** (1 foot-candle = 10.76lux)
Lumen (metric system)	Equals 1 foot-candle/foot^2 - the amount of light that would shine through 1 square foot (0.09m).
Lumen (metric system)	Measurement per square metre - a **lux**. Therefor 1 Lumen illuminates 1m^2
1 Lux	1 lumen per m^2
IP65	Weatherproof Rating. IP65 = Water Resistant but not waterproof.
Luminous Flux	A measure of light output but not of how focussed the light is. Without appropriate focus the light is wasted and therefore inefficient.

Additional Resources

Interpreting light Quality	https://www.stouchlighting.com/blog/led_light_cri_cct_foot-candle
Foot-candles versus lumens versus lux	https://www.standardpro.com/how-to-measure-light/#:~:text=A%20foot%2Dcandle%20equals%20one,10%20lux%20or%2010.57%20lux.
CRI versus Colour Temperature	https://www.ledsmaster.com/color-rendering-index-cri-versus-color-temperature-what-are-they.html

Specifications of Lights in this project

LED Light Type	Specification	Description	Document
Community Floodlight	4000K 100W IP65 1100 lumen	Considered as 'Neutral White' - produces a bright white or cool toned kind of colour which gives a warm effect as well as bright enough to work beneath. **Illumination at ground level: not clear in specs**	(2824 E5.pdf)
Sports Floodlight	5700K 600W 77145 lumen	Bright white with a blue tint. Cold colour. **Illumination at ground level: av.120 lux (range: 76-174 lux)**	(2824 E5.pdf)



Source: lighting access.com

How to use this report

This report is a preliminary literature review and summarises the main findings relevant to the potential impact of a floodlight upgrade surrounding the soccer fields at Harold Rossiter Park on wildlife, particularly black cockatoos.

The written report is presented with a searchable spreadsheet that can be interrogated for detailed study findings and species and taxon-specific impacts of artificial lighting on wildlife. Each row of the spreadsheet is linked to the original published study using a reference number and the accompanying studies are collated as a pdf library supplied with this report and searchable by reference number.

Terms of reference for the literature review

The Town of Victoria Park (ToVP) plans to upgrade flood lighting to the soccer fields at Harold Rossiter Park which are adjacent to Kensington Bushland. The soccer fields and associated cricket field at Harold Rossiter Park are fringed with established trees (Fig. 1). Concern has been expressed in the local community about the impact increased floodlighting may have on wildlife and specifically on Carnaby's cockatoos (*Zanda latirostris*) and forest red-tailed black cockatoos (*Calyptorhynchus banksii naso*) that roost or forage in the park and the surrounding area. In addition, the ToVP has installed several bird watering stations that have been customised to accommodate cockatoos perching to drink at the site and these are known to be well used (Fig. 1f).

Fig. 1 a-e) Large established trees fringing either soccer field 1 or 2 at Harold Rossiter Park; f) Bird watering station at the park; g) Soccer field 1 in the foreground with Kensington Bushland behind.

Aims of the Literature Review

- Investigate and summarise published impacts that artificial light and specifically ALAN (Artificial Light At Night) has on terrestrial wildlife.
- Investigate and summarise mitigation measures suggested in the literature.
- Provide comment on potential impacts of ALAN to black cockatoo species and appropriate mitigation measures.

Method

Literature Review

A systematic key word search was used in the electronic database Web of Science Core Collection (WOS) from 2010 to the present (April 2022). Traditionally this would be done across multiple databases but the short turn-around in this study precluded this. Based on preliminary searches the WOS results were refined by the following categories: Ecology, Environmental Science, Biodiversity Conservation, Ornithology, Zoology, Urban Studies, and Regional Urban Planning. The following keywords were used either singularly or together: bird(s), wildlife, impact(s), artificial light, sports ground, safety benefits, stadium lighting, light pollution, mitigation, moonlight, ALAN (artificial light at night). The broadest search 'ALAN *and* mitigation' produced 789 hits. This was refined using the above key terms and the resulting studies (N = 83) added to a spreadsheet summarising the findings by: animal, habitat, lighting type, secondary stressor (e.g. road traffic), light application (e.g. street light), ecological application (e.g. ALAN), study type (e.g. experimental, review and so on), whether or not the study used multiple light intensities, Country | Region, overall impact, whether mitigation measures were discussed, whether the study was linked to policy statements including suggested policy requirements or revisions of existing policy. The abstract of each paper and the authors keywords are also included. Papers restricted to marine environments were excluded. Two review studies cited in papers from the main search were added to the spreadsheet from pre-2010 as they handled the impacts of 'light polarisation from the interaction of light with man-made objects', and the distinction between 'ecological light pollution and astronomical light pollution' which were topics not explicitly covered in the main search. One thesis was added to the spreadsheet which deals specifically with nocturnal roost trees and roost sites of Carnaby's Black Cockatoo on the Swan Coastal Plain (Le Roux 2017).

Relevant pdfs were downloaded and collated. This pdf resource and the Excel spreadsheet are provided with this report and are linked by a reference number; column 'E.ID' in the spreadsheet.

Results and Discussion

The number of published peer reviewed papers on impacts of artificial light on animal and human populations increased dramatically between 2018 and 2021 (Fig. 2a). Proportionally the number of studies addressing the impact on bird populations make up half of all studies (Fig 2b) and if combined with bat and insect species covers 63% of all studies. The number of studies in Australia was low (4%) compared to the European Union or the Americas.

60% of studies were in either terrestrial or more specifically urban landscapes. A small percentage of studies (8%) conducted in agricultural or coastal landscapes were retained as they covered topics such as industrial light spill. Generally, all studies related to light pollution or ALAN and a small number addressed the role of light in foraging efficiency or predation risk.

While 11% of all studies were inconclusive regarding impact and 6% reported positive impacts in species relying on visual foraging strategies, 80% of studies reported negative consequences for wildlife and are summarised below.

Ground Mammals – Exposure to increased night illumination, whether from full moon events or with low (0.8 lux LED, 7250 K) to high (LED 300 - 760 lux) ALAN increased predation risk for most mammals and so decreased activity in night foraging species (Hoffmann 2018, Prugh 2014, Shier 2020). This to some extent can be mitigated by retaining sufficient habitat cover (Prugh 2014).

Insects – Among insect species there were noted changes to foraging activity and mobility. In most cases lights, even at low lux levels (15 lux) effected behaviour and in most cases, lights acted as ecological traps leading to changes in species assemblages in some studies (Eccard 2018) and increased mortality due to an increase in the number of predators

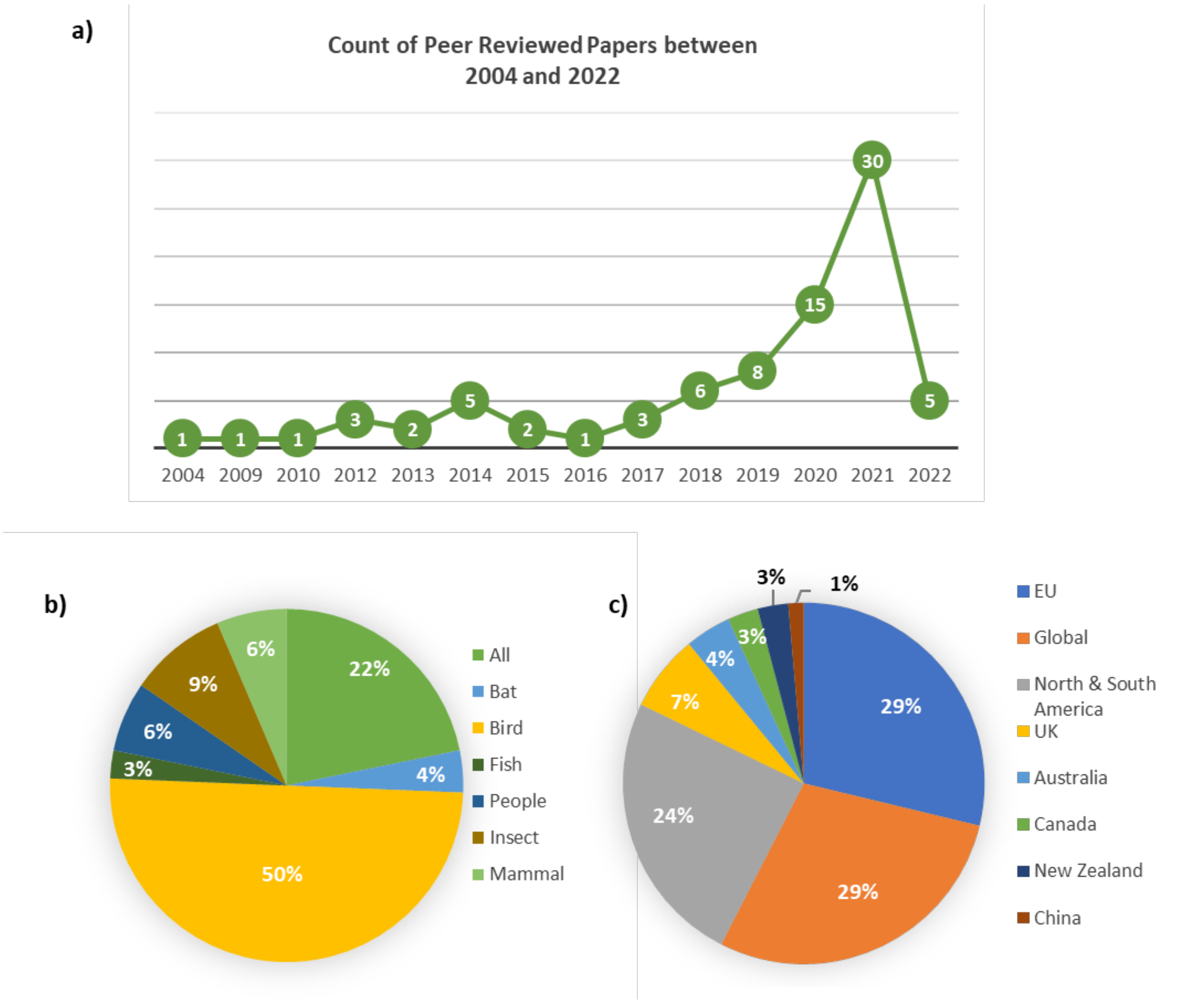


Fig. 2 a) The dramatic increase in peer-reviewed papers in this study between 2018 and 2021 addressing the role and impact of artificial light on wildlife including people. The count was until April 2022. The true count for 2022 will likely be much higher based on the trends in the preceding years; b) Although there was a good representation of papers across taxa, birds made up 50% of all papers; c) Australia produced relatively few papers (4%) on the impact of artificial light on wildlife populations during this time period.

attracted (Davies 2012), as well as changes to development and other life history traits in moths (Van Geffen 2014). Light colour temperatures were important and low lux level (e.g. 0.4 – 8 lux) 'white' LED lights with a colour temperature of 7250 K had equivalent effects to higher lux levels. It was noted that ground-dwelling and airborne assemblages respond to the presence, intensity and spectrum of ALAN in different ways (Lockett 2021), irrespective of this common mitigation recommendations included: directing artificial light to the target area only (Schroer 2021), different coloured lights (lower temperature) should be considered where practicable, short 'on' times or automated switch-offs should be used (Eccard 2018, Lockett 2021), however, Lockett (2021) cautioned that reducing light temperatures to 4000 K would do little to ameliorate the impact of ALAN on invertebrate assemblages. Van Geffen

(2014) who experimented with white, green and red light suggest that red light may mitigate negative effects on at least moth species.

Bats – Activity changes were induced in bats even at low light levels (3.2 lux) resulting in changed foraging strategies (Stone 2012). In a captive population foraging reduced and, in some cases, ceased (Lewanzik 2014). Appropriate mitigation measures included limiting the use of artificial light in space, time and intensity and planning for the incorporation of ‘darkness corridors’ to encourage normal movement and retain landscape connectivity (Lewanzik 2014).

Birds – Among insectivorous species it was found that increased prey availability under green and white artificial light at night actually benefitted birds by reducing overall foraging effort (Welbers 2017), and low light levels of between 1.6 - 7 lux were inconclusive but in these studies sample sizes were low or the study species were migratory (e.g. La Sorte et al. 2022, Sanchez-Gonzalez 2021). Of the remaining 26 studies, most of which investigated LED lighting specifically rather than fluorescent or ALAN generally, reported negative impacts. These related to activity changes such as delayed sleep onset and more nocturnal awakenings (Ren 2021), increased vigilance (Yorzinski 2015) and increased night vocalisation (Dickerson 2022), and fitness costs such as increased energy expenditure or immunocompromisation (Dominoni 2021, van Dis 2021, Ziegler 2021). At the extreme end of impacts, some species abandoned nests and among migratory species, birds could be disoriented (Van Doren 2017), suffer delayed onset of migration movement with survival consequences at the arrival point, and increased mortality risk (Assadi 2021, Loss 2019). Notably these impacts were reported at light levels between 0.3 - 25 lux. Suggested mitigation was similar to measures mentioned above for bats, however, much greater emphasis was placed on light temperature with most studies suggesting lighting in the orange or red spectrum at temperatures of ≤ 3000 K (e.g. Alaasam 2018). One study suggested that simply pointing lights ‘downwards’ was not enough to eliminate attraction and flight path modification in migrating species (Cabrera-Cruz 2021).

Black cockatoos at Harold Rossiter Park and Kensington Bushland

Both Carnaby's cockatoos and forest red-tailed black cockatoos are known to use Harold Rossiter Park and/or Kensington Bushland. The bushland is mostly banksia woodland and is a valuable foraging resource for Carnaby's cockatoos.

Birdlife Australia Great Cocky Count (GCC) data have been collected at two sites (VICKENRO01 and VICKENRO02) that border the park and bushland consistently since 2010 for Carnaby's cockatoos and since 2014 for forest red-tailed black cockatoos (FRTBC). Based on these data the area has had significantly greater FRTBC activity, and between 2014 – 2021 an average of 80 (range 0 – 287) birds were counted at the two roosts (Pers. Comm. Birdlife Western Australia May 2022). By comparison since 2010 only two Carnaby's cockatoos have been counted at VICKENRO01 emphasising that the site is an important forage rather than roost site for Carnaby's. In the 2022 GCC (3/4/2022) only 16 FRTBC were counted at VICKENRO01, however FRTBC numbers were lower than usual across all Swan Coastal Plain GCC sites (Pers. Comm. Birdlife Western Australia May 2022). The GCC only occurs on one night a year (e.g. this year, 2022, it was the 3rd April) and so will not capture seasonal differences in the presence or abundance of either species.

Data from the Black Cockatoo Conservation Management Project at Murdoch University report having counted approximately 120 FRTBC roosting at Harold Rossiter Park in July 2016, however an October 2018 count by Birdlife Western Australia recorded a zero count. This suggested seasonality is also reported by Shephard and Warren (2019) who using GPS tags to track flocks of FRTBC on the Swan Coastal Plain, captured the movement of tagged birds from the Kensington area to the Darling Scarp during long distance spring movements between September to November. At the 2016 count and subsequent flock follows to the area by members of the Black Cockatoo Conservation Management Project, most FRTBC were roosting in tall trees surrounding the cricket oval and to a lesser extent in the trees surrounding the soccer fields. Given the size of the trees fringing the playing fields it is likely that the birds will roost in all these trees at different times. Of 10 key night roosts for FRTBC identified using GPS track data on the Swan Coastal Plain by Shephard and Warren (2019) roost trees were dominated by marri (*Corymbia calophylla*) and other tall species such as jarrah (*Eucalyptus marginata*) and spotted gum (*Corymbia maculata*). In all cases trees were mature and ranged in height from 10 – 20m and were located in urban or peri-urban areas. While few Carnaby's cockatoos were counted at the Harold Rossiter site during the GCC nights, the size of the trees at the park are consistent with the findings of Le Roux (2017) who measured roost tree characteristics from 95 trees at 10 known Carnaby's cockatoo roost sites on the Swan Coastal Plain. With the exception of two pine trees (*Pinus pinaster*) all other trees were either West Australian or Australian natives with a mean height of 26m and DBH of 0.98m. In the Le Roux (2017) study nearly 38% of all trees were in parklands in close proximity to urban lighting including both street and sports ground lighting. The Kensington bushland being predominantly *banksia* spp. does not present as typical night roost habitat for either species.

Generalised impact of ALAN on black cockatoo species

Without experimental studies measuring the impact of current and future lighting on black cockatoo species it is only possible to hypothesise generalised impacts based on prior studies from other bird species. With a projected lighting level of between 50 to 120 lux depending on whether the soccer field lighting upgrades are used for training or competition nights, many of the impacts listed above will be relevant to black cockatoo species. Neither species is known to breed at this site, and while there are records of both species breeding in artificial hollows at some sites on the Swan Coastal Plain, Carnaby's generally breed at sites throughout the wheatbelt and FRTBC in forested areas or in trees old enough to support suitable hollows (Johnstone and Kirkby 2010). Accordingly, impacts above relating to breeding or migration can probably be discounted. However, activity changes such as delayed sleep onset, increased nocturnal awakenings, increased vigilance, and increased night vocalisation might be expected (Dickerson 2022, Ren 2021, Yorzinski 2015). These will incur fitness costs due to increased energy expenditure but determining immunocompromisation or other stress related effects would require formal epidemiological studies.

Mitigation measures to retain roost quality

It is unclear if the additional lighting will reduce the quality of the roost, however, a structured monitoring program with surveys conducted across months including before and after the FRTBC spring ranging movement to the Darling Scarp might inform this. It would be preferable to begin monitoring before installation of the new lights begins and continue it for one to two years, or longer if possible.

To achieve the parameters required for competition level lighting it seems unlikely that the lux level and colour temperature of the lights could be changed, however, perhaps this could be addressed with the community flood lights with lower lux levels or colour temperatures considered with lighting in the orange or red spectrum at temperatures of $\leq$ 3000 K as suggested by Alaasam (2018), given that public safety requirements are met.

Reducing light spill and directing lights to the target area appear to be a minimum but required mitigation in most studies, but it is not clear from the lighting specifications for this upgrade what the expected rate of decay of the light pollution is at various distances behind the light poles. The '2824 Harold Rossiter – lighting layout 100lux' document suggests the immediate decay rate behind the light poles is 75 lux which far exceeds most of the reported light levels in the reviewed studies and the ecologically relevant light threshold of 1.5 lux (Moaraf 2021). It would be useful to know the light decay level at 10m, 20m or 50m behind the poles and more specifically what will it be at known roost trees?

Finally, Raap (2018) caution against generalisation of the effects of ALAN as impacts can be species, sex and season dependant. Beyond the suggested mitigation measures listed here the actual impact will only be realised using a longitudinal monitoring programme.

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Appendices

Appendix 1

Literature Review Spreadsheet - “ToVP_LitReview_SHEPHARD2022_MacroEn.xlsx”

Appendix 2

All papers from the spreadsheet with suffix number matching Column 'E.ID'.

4572 - Stone, E. L. J., Gareth Harris, Stephen. 2012. Conserving energy at a cost to biodiversity? Impacts of LED lighting on bats. Global Change Biology **18**:2458-2465.

4971 - Dwyer, R. G. B., Stuart Campbell, Hamish A. Bryant, David M. 2013. Shedding light on light: benefits of anthropogenic illumination to a nocturnally foraging shorebird. Journal of Animal Ecology **82**:478-485.

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Appendix 3

Zip file of all pdfs.