Wildlife Sensitive Lighting

Tools for local and state government

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Acknowledgment of country

We acknowledge the Traditional Owners of the land where this work was carried out, the Wurundjeri and Boon wurrung people of the Kulin Nations, and their deep connection to this land. We pay our respects to their Elders past and present.

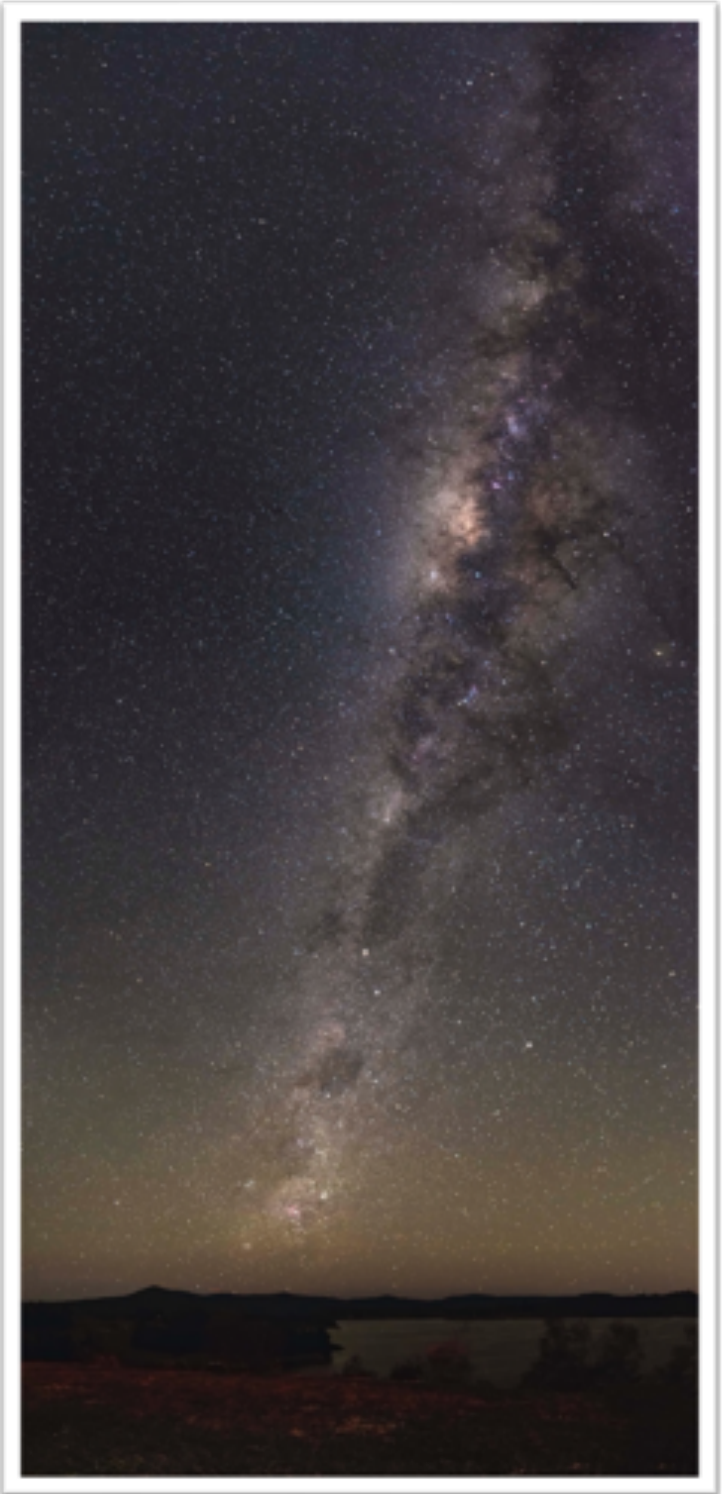


Image: Rob Musson

Glossary

Term	Meaning
Artificial light at night / ALAN	Refers to human-generated (typically electric) light applied at night-time
Correlated Colour Temperature / CCT	Refers to the ‘warmth’ or ‘coolness’ of lighting. CCT is measured in degrees Kelvin (K): lights with low CCT contain more warm tones (yellow-amber-red); Lights with high CCT have more cool tones (blue-white).
Colour Rending Index / CRI	A measure of how well a given light source reveals colours compared to a standard light source (the most common standard used is natural daylight). Lighting that renders colour perfectly has a CRI of 100. Australian Standards require that public lighting has a CRI of at least 70.
Lumens / Lux	Lumens and lux both measure the brightness or intensity of lighting as perceived by the human eye (1 lux = 1 lumen per square metre). The amount of light emitted by a fixture (‘luminous flux’) is measured in lumens; the amount of light striking a surface (‘illuminance’) is measured in lux.
Shared path	Also referred to as a shared use path – this is a path intended to be used by both pedestrian and cycle traffic. Shared use paths are often high quality, sealed paths suitable for a wide variety of uses, including bikes, prams, wheelchairs, and other mobility aids.
Wildlife sensitive lighting	This refers to lighting designed to reduce the effects of ALAN on ecosystems, wild animals, plants and other organisms. However, even wildlife sensitive lighting will have some detrimental effects on wildlife, and natural darkness at night is ecologically optimal.

Executive Summary

Artificial lighting provides an important public good but can also be a powerful ecological pollutant. The negative effects of light pollution on wildlife (and humans) are now widely recognised, and wildlife sensitive lighting products are increasingly available. Despite this, the uptake of wildlife sensitive lighting strategies and our understanding of when and where to apply them has been patchy and is often *ad hoc*.

This project aimed to provide time-poor lighting managers and decision-makers with **better tools for making wildlife sensitive lighting decisions**. These tools (Appendices B-E) are found at the end of the report:

Appendix B – Resource guide

Appendix C – Decision guide

Appendix D – Wildlife sensitive lighting specification

Appendix E – Wildlife sensitive lighting case studies.

In the process, we spoke with a range of lighting users, managers and decision-makers from local and state government who provided valuable insights into current obstacles to, and opportunities to increase, the adoption of wildlife sensitive lighting.

Obstacles to the adoption of wildlife-sensitive lighting include:

- Lack of information about the ecological effects of artificial light and wildlife sensitive lighting strategies
- Lack of consideration of the needs of wildlife in Australian Standards and organisations' lighting design guides, lighting briefs and policies
- Absence of wildlife-sensitive lighting options on standard lighting palettes offered by power networks
- Additional expense and hurdles (real and perceived) involved in using wildlife sensitive lighting design.

Opportunities to increase the adoption of wildlife sensitive lighting include:

- Promote the use of wildlife-sensitive lighting within organisations (including through adoption of the tools produced here)
- Impose wildlife-sensitive lighting requirements inside organisations and on third parties (contractors, lighting designers, developers)
- Increase use of existing (but currently under-utilised) mechanisms in Australian Standards and Department of Transport lighting design guides to make lighting more wildlife-sensitive
- Working with energy networks and lighting manufacturers and distributors to add wildlife-sensitive options to lighting palettes
- Emphasizing common ground between human and wildlife benefits of reduced lighting
- Promoting wildlife sensitive lighting in the community.

1. Introduction

The use of artificial light at night during hours of darkness enhances the visual environment for humans; increases perceptions of safety and personal security and, as a consequence, facilitates human activities including commuting, sport, recreation and exercise. However, the presence of artificial light at night changes the nocturnal environment for all species, not just humans.

Artificial light at night (ALAN) is now recognised (albeit currently not legislated) as a significant environmental pollutant, that affects individual organisms (through its impact on immune function, reproduction, development, behaviour, and feeding) through to entire ecological communities (due to reduced connectivity, disrupted food webs, loss of pollination or other ecosystem function, and reduced biodiversity) (see National Light Pollution Guidelines – reference in Appendix B to this report).

The conflict between the human need for artificial light and wildlife's need for natural darkness demands a holistic lighting strategy that reduces disruption for wildlife, while allowing equitable access to night-time activities (often referred to as 'wildlife sensitive lighting strategies'). Wildlife sensitive lighting technology (including timers, dimmers sensors and amber LEDs) is now mature and increasingly cost-neutral, however uptake remains patchy and often limited to high-profile ecologically-sensitive locations.

Despite considerable research into ALAN and its effects on wildlife and humans (over 4000 research papers alone at the time of writing), there are few practical tools to assist lighting decision-makers who seek to implement wildlife sensitive lighting. The National Light Pollution Guidelines provide an invaluable and comprehensive resource, but feedback from local government suggests that their very detail can be overwhelming, particularly for those for whom lighting is just one of many competing considerations.

Image: Jonny Clow

2. Objectives

The purpose of this report is to provide public lighting decision-makers in local and state government with a tool kit for making lighting design more sensitive to the ecological needs of wildlife, and increasing the use of wildlife sensitive lighting in public spaces.

In consultation with our eight stakeholders (described below), the toolkit delivered as part of this project comprises five key outputs:

Output 1. This **report** presenting insights gained from meeting with organisations regarding obstacles to and opportunities for increasing the adoption of wildlife-sensitive lighting in public spaces

Output 2. A **resource guide** summarising available sources of information on wildlife-sensitive lighting (including the ecological effects of artificial light at night (ALAN), and the costs and benefits of ALAN for human health and personal security)

Output 3. A **decision guide** to assist lighting decision-makers to balance human need and wildlife-sensitive design in public lighting

Output 4. Targeted **case studies** addressing a broad range of wildlife sensitive lighting strategies in common public lighting scenarios

Output 5. A **template wildlife sensitive lighting specification** that can be included in lighting briefs, requests for tender and other communications with lighting contractors and designers.

Image: European Space Agency

3. Consultation

The authors met with representatives from seven local government areas in Victoria (LGAs: Cardinia Shire Council, City of Boroondara, City of Monash, City of Stonnington, Knox City Council, Whitehorse City Council, Yarra Ranges Shire) and the Victorian Government Department of Transport, to identify:

- existing processes around lighting decisions
- competing considerations around lighting decisions, including human amenity, safety, security and accessibility
- obstacles to the adoption of wildlife sensitive lighting design in public lighting
- opportunities to increase adoption of wildlife sensitive lighting design in public lighting.

The number and role of attendees at each meeting varied by organisation, but across all organisations we have canvassed over fifty persons in roles including:

- public lighting
- traffic, travel and transport
- engineering
- landscape architecture
- strategic planning
- city design
- environmental planning and assessment
- project management and delivery
- bushland and wetland management
- parks and open space planning and management
- assets, facilities and infrastructure planning and management
- construction and capital works
- car parking
- sports and recreation
- arts and culture
- residential development
- community safety
- accessibility
- social inclusion
- energy efficiency
- climate
- biodiversity
- ecologically sustainable design
- urban landscape and trees.

3.1. Awareness of wildlife sensitive lighting

Prior to consultation with stakeholders, we asked all meeting participants to complete a short online survey to help identify prevailing motivations in decision-making around lighting, and knowledge of wildlife sensitive lighting design and the ecological effects of ALAN. The full survey results (n = 18 respondents) are set out in Appendix A.

Key results from the survey include:

- Most respondents felt somewhat informed about the ecological effects of ALAN, but less well-informed about strategies for reducing those effects (i.e. wildlife sensitive lighting strategies)
- Human safety, security, amenity (especially travel and outdoor recreation) and health were the main drivers when making decisions to add, alter or remove public lighting
- Choice of lighting infrastructure was heavily influenced by Australian Standards, organisational policy and practice, and the upfront and ongoing costs of lighting
- Ecological effects of ALAN were rarely a consideration for organisations when making lighting decisions
- In contrast, 50% of respondents sought to minimise ecological effects when making lighting decisions in a private/home context.

The last point may suggest that current local and state government lighting strategies lag behind public opinion and practice when it comes to minimising ecological impacts of artificial light.

3.2. Confidentiality

At the request of some stakeholders, we have not identified the source of any information by individual or by organisation (except the Department of Transport). However, where participants or organisations expressed divergent views this has been noted.

4. Insights into lighting decision-making

4.1. Drivers of increased or decreased use of lighting

Stakeholders identified a number of key drivers of increased outdoor lighting (Table 1). They also identified countervailing pressures against increased lighting and demands for removal of existing lighting (Table 2).

Image: Christian on Unsplash

Table 1: Drivers of increased use of lighting

Driver	Description
Personal security and fear of crime	Frequently cited as drivers of demands for increased lighting in public spaces, particularly transit corridors, car parks and transport hubs (and sometimes residential streets). Conversely, lighting of some public spaces (especially parks, carparks and bus shelters) was perceived as likely to encourage night-time gatherings and generate additional personal security concerns. Demands from traders and police to increase light levels to improve the quality of security camera footage.
Increased demand for access to outdoor exercise, recreation, and low-carbon transport	Increased demand for public spaces (parks and gardens, sports facilities, shared paths) leads to increased hours of usage and demand for lighting. Increased use of shared paths gives rise to increasing bike-pedestrian interactions and demand for better lighting to avoid collisions. Increased use of public space and shared paths has been driven by: • demand for outdoor recreation spaces during Covid lockdowns (this demand is ongoing) • demand for safe recreation spaces for the community • demand for healthy, low-carbon transport options (cycling, walking) influenced by climate change • preference for shared paths by users of wheelchairs and other mobility aids due to high quality sealed surfaces and absence of obstructions commonly found on footpaths (e.g. cars, signs, etc).
Designation of strategic cycling corridors	Major shared paths (including Gardiners Creek Trail and Dandenong Creek Trail) have been designated as strategic cycling corridors by the Victorian Government. These designations recognise the existing use of these trails, by commuting cyclists in particular, and are likely to drive increased demand into the future. Expectations that cyclists can travel at speed along these corridors raises increased safety concerns for other path users, and demands for increased lighting to reduce collisions. In addition, the perceived desirability of consistent lighting along strategic cycling corridors imposes pressure to increase light levels in darker stretches.

Increased demand for sporting facilities	Demand for sporting facilities can increase the spread and intensity of ALAN by: • introducing lighting infrastructure to open spaces (as new facilities are built or upgraded) • extending the hours of operation of existing facilities to meet club allocation demands of new teams • elevating the required illuminance levels to meet sporting code requirements for training or competition.
New road infrastructure	Infrastructure added to improve traffic flow or motorist and pedestrian safety can lead to increased lighting requirements. New roundabouts, pedestrian crossings and footpaths were identified as common drivers of increased lighting (in part because road lighting design standards mandate lighting for these).
New residential, retail and commercial precincts	New developments expand the overall scope of urban ALAN. In urban growth areas and regional areas, developments often replace unlit land with residential streets or commercial structures that are always illuminated to (and often in excess of) Australian Standards. New suburbs are often more highly illuminated than older suburbs due to changes in streetlighting practices (e.g. there has been a shift from placing a luminaire on every second telephone/power pole to every pole). Developer-funded works within these precincts may over-illuminate to match surrounding arterial roads (possibly due to a misperception that this is required by the Department of Transport).
Increased viability of solar-powered lighting	Rapidly decreasing cost and improvements in technology mean that solar-powered lighting fixtures are now a viable (or even preferred) alternative to networked lighting. This has positive and negative ecological implications: • (negative) solar powered lighting facilitates the introduction of ALAN into locations where it would otherwise be uneconomical or impractical, including remote areas of parks and reserves • (positive) limitations of solar power mean that solar lighting is of limited intensity and/or cannot be run at high intensity for the whole night • (positive) solar lighting installations often employ timers and dimmers to reduce lighting duration or intensity after peak hours of use. Accordingly, solar lighting that is (i) properly deployed and (ii) used where networked lighting would otherwise be installed, can result in more wildlife-sensitive lighting conditions.

Table 2: Pressures against current or increased use of lighting,

Driver	Description
Upfront and on-going cost of lighting infrastructure	Cost (including up-front, operating and maintenance costs) was a major factor in resisting the installation of any new lighting. Up-front planning and design costs of new lighting can include the need to assess impacts on tree roots, sight-lines and light spill. User costs of sports floodlighting create a financial incentive to reduce night-time use of facilities and keep lighting to a minimum (e.g. reduced lighting intensity during training sessions).
Resident and community group preference for low lighting or wildlife sensitive lighting	Pressure from residents to reduce (or not introduce) lighting occurs in several peri-urban or bushland areas within LGAs. This may reflect the aesthetic and/or ecological values of residents. Community groups associated with ecologically sensitive areas or environmental issues (e.g. 'friends of' groups, committees of management or parkland advisory committees) can oppose the introduction of lighting around bushland, grassland and wetland reserves.
Impacts of lighting spill and glare on residents	Largely in relation to sporting facilities. Objections from neighbours can affect both the design of lighting and its hours of operation.
Unwanted night-time gatherings in illuminated spaces	Artificially lit spaces including bus shelters, parks, playgrounds and carparks can attract gatherings at night-time, resulting in increased noise for nearby residents and increased personal safety concerns for commuters and passers-by.
Night-time use of unsafe or inappropriate areas	Lighting can mean an area is wrongly perceived as safe or appropriate to use at night. Examples include: • Isolated paths with infrequent exits – these occur along many urban waterways where housing or industrial zones back onto shared paths, and in remote areas of large parks and reserves. These paths may be less safe for users late at night, regardless of lighting. • Bushland and wetland reserves – the ecological value of habitat for wildlife (such as nocturnal birds, bats, arboreal mammals and frogs) may be reduced if these areas are frequently used after dark. Several organisations noted a preference not to light these spaces to avoid encouraging use at night-time.

4.2. Lighting decisions in local government

Lighting practices and processes varied between stakeholder organisations, however several broad themes emerged that affect the capacity of LGAs to implement wildlife sensitive lighting strategies.

Decision-making around lighting is highly decentralised in local government

Lighting decisions are mostly team-based and purpose-specific (for example, decisions around sports floodlighting sit with sports and recreation teams; decisions around lighting in new suburbs sit with residential development or planning teams, and so on).

The extent and currency of council public lighting policies vary widely, but few LGAs have up-to-date, organisation-wide guidelines for how to apply lighting to common scenarios.

The extent to which LGAs can influence public lighting is thus often down to time, budget and the knowledge and motivations of individual officers to broadly communicate and consult across the organisation.

Delineations between human and ecological priorities are unclear

Wildlife sensitive lighting design is often not addressed in lighting policies or standard lighting specifications used by councils (for example, in requests for tender).

Strategies for balancing human and ecological needs tend to be *ad hoc*; non-ecological arguments (especially cost) are often used to avoid introducing lighting into ecologically sensitive areas.

Lack of access to research on the ecological effects of artificial light is a barrier to making more ecologically sound decisions around lighting.

Decisions around lighting are heavily influenced by external parties

During development of residential, commercial or recreational precincts, decisions around lighting are often based on proposals provided by developers or designers. The role of local government, at a minimum, includes ensuring that lighting proposals meet council requirements and Australian Standards, however the extent to which councils move beyond that (e.g. to push for more wildlife-sensitive lighting) depends on the specific organisation, project and officer concerned.

Some council project managers and engineers may be reluctant to push back on proposals or advice from external lighting designers/engineers with more detailed experience in lighting design. Again, this is highly subjective and often comes down to the time, resources and motivations of the council officer or team involved.

The absence of accessible information on wildlife sensitive lighting contributes to this knowledge and power imbalance between council officers and external parties.

Australian Standards and cost are the principal criteria used

Once a decision has been reached to install lighting, choice of lighting infrastructure is principally influenced by cost and compliance with Australian Standards (principally AS/NZS 1158 *Lighting for roads and public spaces*, AS/NZS 4282 *Control of the obtrusive effects of outdoor lighting*, and AS/NZS 2560.2 *Sports lighting: Specific applications*).

Australian Standards are viewed differently across councils. A common perception (shared by many council engineers and reinforced by external consultants) was that all new lighting must comply with standards.

Willingness to depart from standards (to balance the needs of residents, wildlife and late-night users of paths and open spaces) varied between LGAs.

There is some capacity to work within the standards framework to reduce the impact of outdoor lighting levels. For example, categorization of activity levels as ‘low’, ‘medium’ or ‘high’ (which in turn informs lighting intensity requirements) is intended to be subjective and organisation-specific. Some organisations observed a tendency amongst lighting designers to adopt a one-size-fits-all approach with sites being characterised as ‘high’ activity by default. There is thus scope for organisations to push for lower activity categorizations that permit the use of substantially lower light levels under AS/NZS 1158.

Wildlife-sensitive lighting considerations seen as an additional responsibility

Designers, engineers and project managers are likely to resist wildlife sensitive lighting measures unless funds for inclusion have been allocated.

Wildlife sensitive lighting is therefore unlikely to be achieved unless it is included in project designs and costings from the outset.

Lighting choices are restricted by structural and financial issues

Residential streetlights (and some park and carpark lights) are owned and operated by energy network providers ('networks'). Each network has a limited palette of approved luminaires from which LGAs can choose.

LGAs wishing to install non-standard lighting must have the proposed luminaires approved by the network, and must also bear the additional cost of maintaining and replacing non-standard luminaries. This financial burden makes non-standard lighting cost-prohibitive.

Lighting on major roads is owned and operated by the Department of Transport, and choice of lighting is restricted to the Department's lighting palette (which must also be network-approved). LGAs wishing to use non-standard lighting must negotiate this with the Department and networks.

Sports lighting levels are frequently determined by sporting codes. Clubs wishing to host competition matches must have access to facilities illuminated to the relevant codes' standards.

Substantial progress in wildlife sensitive lighting has occurred (sometimes for other reasons)

Most organisations have resisted the introduction of artificial light into high-value habitat areas (including remnant bushland and wetlands).

Curfews on open-space lighting (including sports fields, parks and car parks) are common.

Increasing use of high-quality focussed LED lighting at sporting facilities has reduced light spill into neighbouring habitat (although this can introduce a larger proportion of blue-rich light into the environment if replacing older technology).

The use of timers, sensors and dimmers to reduce lighting intensity during late night and early morning periods is increasingly common.

Many of these responses are at least partly driven by non-ecological concerns, including lighting cost and effects of light spill on residential properties.

4.3. Lighting decisions at Department of Transport

Consistent with its size and overall remit, Department of Transport decision-making around lighting is more formalised and transparent than at the local government level. Key lighting practice guidance is found in:

- Technical Guideline TCG 006: *Guidelines to Street Lighting Design*
- Austroads Guide to Road Design, Part 6B: *Roadside Environment*
- Australian Standard AS/NZS 1158: *Lighting of Roads and Public Spaces*
- Additional guidelines, standards and policy documents are set out in the introduction to TCG 006.

As with local governments, some attributes of Department of Transport lighting practice and policy affect the organisation's capacity to implement wildlife sensitive lighting strategies.

Lighting design is highly prescriptive, usually by reference to Australian Standards

TCG 006 provides specifications for lighting a range of roadway scenarios. Most specifications require lighting in accordance with AS/NZS 1158.

Lighting is mandatory in many of these scenarios, including roundabouts, pedestrian crossings and underpasses and railway crossings.

Departure from Department of Transport guidelines and Australian Standards does occur, but requires substantial documentation and approval from senior management.

Non-standard lighting design may be adopted to reduce light spill

See TCG 006 at section 2.3: the example given is of using lower mountings where residential windows are close to the property line.

Nothing in the guidelines would prevent similar measures being taken to reduce light spill into ecologically sensitive habitat.

Ecologically sustainable development is mandated (but artificial light is not mentioned)

Section 1.5 of the Austroads Guide to Road Design, Part 6B: *Roadside Environment* requires road agencies to undertake infrastructure planning and development in accordance with ESD principles.

Significant issues to be considered include management of vegetation, fauna and noise.

Although ALAN is not specifically referred to, failing to consider the ecological effects of artificial light would be inconsistent with the core objective of "protecting biological diversity and maintaining essential ecological processes and life-support systems".

Wildlife sensitive lighting may also be considered under section 2.2 (Fauna Management).

5. Obstacles to the adoption of wildlife-sensitive lighting

Following consultation with stakeholders we have identified the following as the main obstacles to the adoption of wildlife sensitive lighting strategies.

NOTE: Wildlife sensitive lighting is not concerned with producing optimal night-time light conditions for wildlife (since the only long-term ecologically optimal lighting is natural darkness, with illumination provided only by moon- and starlight). Instead, wildlife sensitive lighting is concerned with producing the best possible lighting conditions for wildlife consistent with reasonable levels of night-time lighting for human activity and safety. Thus, necessary human use of ALAN is not an obstacle per se to wildlife sensitive lighting. However wildlife sensitive lighting design inevitably involves some value judgements around which night-time activities should be illuminated, and regarding the balance between human need and the preservation of natural dark spaces.

5.1. Lack of information

Many participants indicated that they had limited awareness of the ecological effects of ALAN, and strategies for making lighting more sensitive to wildlife. Other participants were aware of these issues but lacked resources (access to scientific research and practical guidance) with which to promote the use of wildlife sensitive lighting within their organisation.

This lack of information flows through to the planning, costing and design of public lighting. The ecological effects of lighting are not routinely assessed as part of environmental impact assessments or similar processes. The absence of ALAN considerations from the early stages of projects usually means that wildlife sensitive lighting is perceived as an unforeseen (and therefore, unfunded) expense if raised at later stages.

5.2. Australian Standards

As discussed above, Australian Standards are highly influential in decisions around the design of public lighting. For the most part, standards do not consider or promote wildlife sensitive lighting design.

- Australian Standard AS/ANZ 1158 *Lighting for roads and public spaces* is not inherently sensitive to the needs of wildlife. It does not provide for maximum limits on lighting intensity or colour temperature:

  > "*Conformance is achieved by being greater than or equal to the applicable table value*"
  > (AS/NZS 1158.3.1 Tables 3.3 to 3.7).

- Further, AS/ANZ 1158 expressly requires lighting to spill into nearby habitat in some circumstances:

  > *"Conformance of 50% of [horizontal illuminance] shall also be demonstrated over an area of 5 m either side of the pathway"*
  > (AS/NZS 1158.3.1 Table 3.4).

- Australian Standard AS/ANZ 4282 *Control of the obtrusive effects of outdoor lighting* (currently under review) contains an 'informative' appendix noting some of the potential effects of ALAN on wildlife. However, the terms of the standard itself do not specifically provide for limitations on light spill into nearby habitat.

However, there are avenues for minimising the impact of public lighting on wildlife while working within the Australian Standards framework (see "Opportunities to increase wildlife-sensitive lighting" below).

5.3. Limited third-party lighting palettes

Victorian energy networks exercise significant power over which luminaires may be installed on streets and roads (and some parks and carparks). Only a limited range of lighting products are approved for installation by the networks. The adoption of non-standard lighting requires a lengthy approval process, and increased cost to LGAs (local roads) or the Department of Transport (arterial roads).

Despite being the end-users of lighting, local governments and the Department of Transport have limited ability to influence the lighting palettes offered by networks. Since the additional cost of non-standard lighting is borne by end-users, networks have no financial incentive to expand their standard lighting palette to include more wildlife-sensitive lighting products.

5.4. Existing lighting design guidance

Design guidance including Department of Transport (VicRoads) and Austroads documents do not expressly provide for consideration of the ecological effects of ALAN and therefore they are not required to be accounted for. More generally, such guidance tends to promote the adoption of increased outdoor light levels (for example by mandating lighting for new road infrastructure).

5.5. Additional hurdles & costs

Developers, project managers and engineers are often looking for the 'path of least resistance' in designing and approving new precincts. In this context wildlife sensitive lighting is perceived to impose an additional hurdle and increased cost and is thus unlikely to be adopted in the absence of a binding requirement.

More generally, some wildlife sensitive lighting strategies are more expensive than traditional outdoor lighting. For example, using lowered poles or bollard lighting reduces the distance between luminaires and increases the number (and thus cost) of luminaires required for a given area. In addition, some organisations have observed an increased rate of vandalism of bollards compared to traditional outdoor lighting, which increases maintenance and replacement costs.

6. Opportunities to increase wildlife-sensitive lighting

Following consultation with stakeholders we have identified the following opportunities for increasing the use of wildlife sensitive lighting strategies within local and state government.

6.1. Promote wildlife sensitive lighting within organisations

This report and the tools provided with it (Appendix B: Resource Guide; Appendix C: Decision Guide; Appendix D: Lighting Specification; Appendix E: Case Studies) are intended to:

- inform users of the impacts of ALAN on wildlife, and strategies for implementing more wildlife-sensitive lighting
- provide an evidence base to increase awareness of wildlife sensitive lighting within organisations
- assist the development of more wildlife sensitive lighting policies (including lighting aspects of policies relating to outdoor design, parks and open spaces, sport, transport, environment and biodiversity, ecologically sustainable development, planning and development, and crime prevention)
- inform the practice of organisations with regard to artificial lighting, including contracting and consultation, capital works, environmental impact assessments, and dealings with networks and Department of Transport .

6.2. Question the need for all new lighting

No lighting at all is always the most wildlife sensitive option. Leaving dark spaces unlit is often the most straightforward and cost-effective path.

6.3. Impose wildlife sensitive lighting obligations internally and on third parties

Contracting, planning and development processes give local and state government agencies significant opportunities to promote awareness and adoption of wildlife sensitive lighting design both internally and amongst third parties.

Consideration should be given to the inclusion of wildlife sensitive lighting requirements in:

- organisations' lighting briefs and contracts
- organisations' planning guidelines
- organisations' costing/pricing processes
- Precinct Structure Plans for new suburbs
- Environmentally Sustainable Design guidelines for developers
- organisations' briefs to ecological consultants
- Department of Transport (VicRoads) and Austroads road design guidelines
- Department of Transport environmental impact checklists.

6.4. Utilising existing mechanisms that permit wildlife sensitive lighting

Several mechanisms in existing lighting guidance appear to facilitate wildlife sensitive lighting but are under-used at present. These include:

- AS/NZS 1158.3.1 paragraph 2.4 (pedestrian lighting) and AS/NZS 1158.1.1 paragraph 2.4.1 (major road lighting) provide that terms used to describe activity levels and fear of crime (such as 'low' 'medium' and 'high') have no fixed meaning, but are to be determined in consultation with the client (LGA or Department of Transport). This consultation does not always occur and there may be a tendency for higher ratings to be adopted by default. Organisations can and should insist on lower ratings where appropriate. This then permits lower intensity lighting to be used while remaining compliant with the standard (see e.g. AS/NZS 1158.3.1 Tables 2.1 to 2.5 and 3.3 to 3.7, and AS/NZS 1158.1.1 Tables 2.1 and 3.1).

- AS/NZS 1158.3.1 paragraph 3.1.3.5 allows authorities (LGA or Department of Transport) to limit light spill to avoid negative impacts on wildlife (the example given is where light is listed as a threat to threatened species or ecological communities; however, this is not the only circumstance where lighting can negatively impact wildlife).
- AS/NZS 1158.1.1 paragraph 2.4.2 and AS/NZS1158.3.1 paragraph 3.1 permit the use of adaptive lighting in major roads, minor roads and pedestrian areas. This would typically take the form of dimming lights to a lower lighting category outside of peak hours, and may also include the use of sensors to temporarily increase light levels when users are present.
- AS/NZS 1158.6 paragraph 5.7 foreshadows the use of lighting for roads and public spaces with colour temperatures as low as 2700K (there is no prohibition on colour temperatures lower than 2700K provided the colour rendering standard (CRI ≥ 70) is satisfied). There are many 2700K/70 CRI products now available that are both compliant with Australian Standards and substantially more wildlife sensitive than the current 4000K lighting typically deployed (see Appendix B).
- A current discussion draft of AS/NZS 4282 (not yet released) provides for 'environmental receivers' (i.e. flora and fauna) to be taken into account when determining the permissible limits of light spill.
- VicRoads Technical Guideline TCG 006 permits lowered mountings and full cut-off luminaires to be employed "where light spillage is likely to be an issue". The example given relates to abutting residential properties, but light spillage is equally an issue for abutting habitat.
- Austroads Guide to Road Design, Part 6B at section 1.5 requires road agencies (including Department of Transport) to undertake planning and development in accordance with ecologically sustainable development (ESD) principles. Amongst other things, the Department's activities should advance (or not adversely impact) the "protection of biological diversity and maintenance of essential ecological processes". ALAN along roads and paths can substantially undermine ecological processes including landscape connectivity, pollen transport, food systems and nutrient cycling, and lead to loss of biodiversity in plants and animals. Application of wildlife sensitive lighting design is thus in accordance with ESD principles and the Austroad Guide to Road Design.

6.5. Expand lighting palettes to include wildlife sensitive lighting options

Wildlife sensitive lighting fixtures (with features such as low colour temperature, timers, dimmers, sensors, and shielding) are increasingly commercially competitive with traditional 4000K streetlights. The absence of these products in approved lighting palettes may be due to:

- lack of commercial incentive for networks to expand their existing palettes
- failure of manufacturers to seek network approval for wildlife sensitive lighting products (possibly because these are still perceived as a niche product)
- lack of perceived demand for wildlife sensitive lighting fixtures.

Councils and the Department of Transport should engage with networks and manufacturers with a view to increasing the adoption of wildlife sensitive lighting products across network areas by identifying:

- the most common scenarios where wildlife sensitive lighting products are required
- appropriate wildlife sensitive lighting products for those scenarios
- likely demand for those products.

Engagement may be usefully facilitated by an external consultant with knowledge of wildlife-sensitive lighting strategies, lighting procurement and development processes.

6.6. Holistic approaches to human and wildlife requirements

In the context of lighting, human and wildlife needs are often presumed to be in conflict, however this is not always the case. The following strategies are likely to benefit both humans and wildlife:

- using darkness as an indicator of spaces that are inappropriate for night-time use (ecologically and safety-wise) increases human safety and protects habitat
- illuminating only one path through parks and gardens concentrates users on a single path (reducing chances of users finding themselves alone) and simultaneously allows lighting to be directed away from more ecologically sensitive routes (e.g. riverside or bushland)
- placing new pedestrian/shared paths close to roads allows users to benefit from lighting while eliminating the need to install additional path lighting (through potentially ecologically sensitive habitat).

In addition, wildlife sensitive lighting strategies are also beneficial for human health, as they reduce the intensity, hours of operation, and colour temperature of outdoor lighting. Low-intensity, low-colour temperature lighting is less likely to disrupt human melatonin cycles, circadian rhythms and sleep. Exposure to high intensity, high-colour temperature lighting has been linked to a number of human health impacts including increases in some types of cancer (see Appendix B: Resource guide for more details).

6.7. Promoting wildlife sensitive lighting in the community

Councils could promote the importance of natural darkness and the need for wildlife sensitive lighting to the community. Community engagement might include:

- signage at sites where wildlife sensitive lighting has been employed, explaining its features and rationale
- signage at sites where lighting has not been installed for ecological reasons, explaining those reasons
- examples of local wildlife that are adversely impacted by ALAN, or that benefit from wildlife sensitive lighting
- drone/satellite images that emphasize the disappearance of dark areas and the urgent need to retain existing dark corridors
- targeted engagement with lighting proponents/users (e.g. sports clubs) around reasons for limiting lighting duration, intensity, or colour temperature near ecologically sensitive areas
- addressing lighting expressly as part of discussions around the introduction of new road infrastructure. Proponents of new footpaths, roundabouts or pedestrian crossings may not appreciate that this infrastructure will result in increased lighting, and may not appreciate the adverse effects of that lighting on wildlife (and residents). Discussions around the placement of infrastructure will also be better informed if lighting and its effects on wildlife are addressed (for example, it may be possible to locate a road or footpath in a way that reduces light spill into ecologically sensitive habitat).

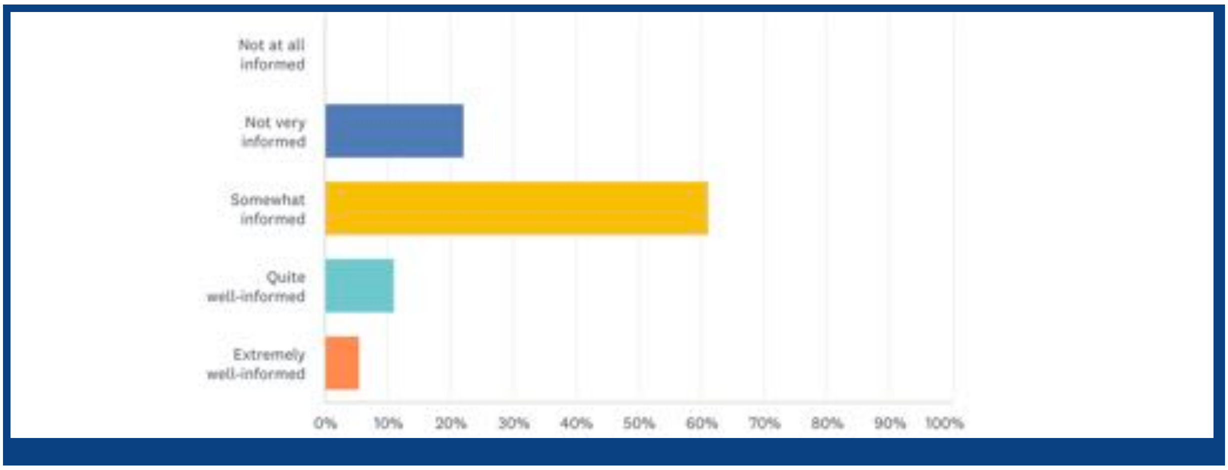
APPENDIX A: Pre-consultation survey

Questions and responses

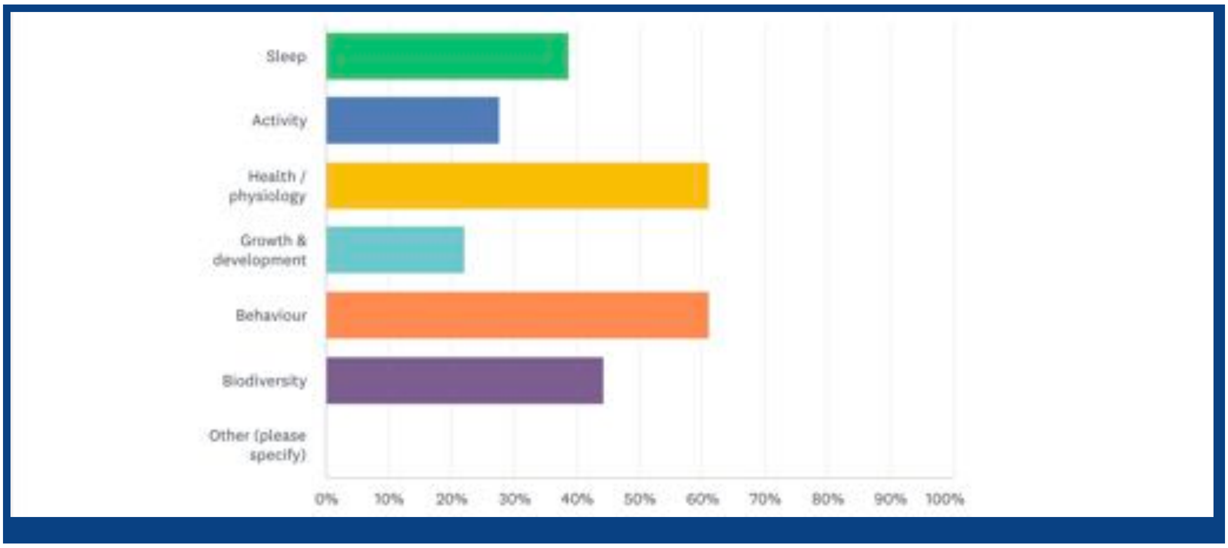
Participants were asked to complete a set of nine substantive questions relating to their knowledge and experience of wildlife sensitive lighting and lighting decision-making. Their responses are set out below. Responses to additional questions relating to the identity, employer and role of the respondent have not been reproduced. Number of respondents for all questions = 18 unless otherwise indicated.

Lead Question: Thinking about your own state of knowledge (prior to reading any of the materials provided to you):

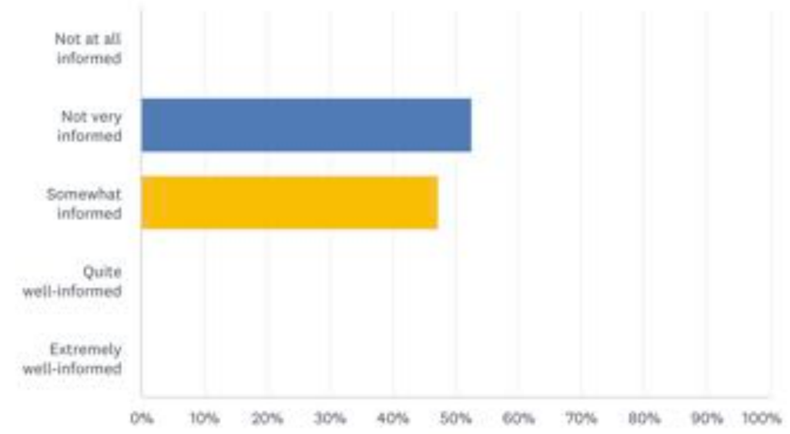
1. Do you feel informed about the effects of artificial light at night (ALAN) on plants, animals and humans?



2. What do you consider to be the most concerning effect(s) of artificial light on plants, animals and humans?



3. Do you feel informed about strategies for reducing the effects of ALAN on plants, animals and humans?



Lead Question: When you/your organisation are considering adding, removing or changing artificial outdoor lighting:

4. Which of the following are your main concerns/objectives?

ANSWER CHOICES		RESPONSES	
Public amenity (creating pleasant, attractive, useful spaces)		61.11%	11
Accessibility & physical safety for pedestrians/cyclists (ability to navigate, move, avoid collisions, trips & falls)		50.00%	9
Road safety (vehicles, pedestrians, cyclists)		27.78%	5
Personal security (crime prevention)		33.33%	6
Public order (discouraging antisocial behaviour)		16.67%	3
Responding to residents' demands		11.11%	2
Responding to business-owners' demands		0.00%	0
Minimising ecological impacts of light		16.67%	3
Minimising human health impacts of light		22.22%	4
Other (please specify)	Responses	44.44%	8
Total Respondents: 18			

Summary of 'other' responses: Energy efficiency; Reducing emissions; Reducing lighting costs; Compliance with Australian Standards; Facilitating increased/improved participation in sport and recreation; Facilitating safe use of and travel to/from recreation reserves; Responding to other stakeholder demands (e.g. sports clubs).

5. Which of the following are the main influences affecting lighting specifications, including choice of mountings, luminaires, shielding, spacing, timing, sensors, light intensity, light colour:

ANSWER CHOICES		RESPONSES	
Resident and business preferences (what looks attractive / in keeping with environment)		0.00%	0
Legislation (State or Federal)		29.41%	5
Australian Standards		76.47%	13
Your organisation's policies and practice		52.94%	9
Your personal past practice		5.88%	1
Consistency with existing lighting infrastructure		23.53%	4
Up-front cost of lighting infrastructure		47.06%	8
Lighting efficiency / running costs		70.59%	12
Maintenance costs		52.94%	9
Ecological impacts		11.76%	2
Human health impacts		23.53%	4
Other (please specify)	Responses	17.65%	3
Total Respondents: 17			

Summary of 'other' responses: Requirements of network operators; Australian Standards' lack of consideration of negative aspects of lighting

6. In your organisation, do outdoor lighting decisions consider the ecological impacts of artificial light:

ANSWER CHOICES	RESPONSES	
Never	6.25%	1
Only when specifically required by legislation or standards	31.25%	5
Whenever light is being applied near natural settings (e.g. bushland, grassland, waterways)	43.75%	7
Whenever light is being applied near natural settings or constructed green spaces (including parks, gardens and ovals)	18.75%	3
Always	0.00%	0
TOTAL		16

7. In your experience, what barriers exist **within your organisation** to greater adoption of ecologically-sensitive lighting strategies:

ANSWER CHOICES		RESPONSES	
Strategies are inconsistent with legislation (State or Federal)		11.76%	2
Strategies are inconsistent with Australian Standards		29.41%	5
Strategies are inconsistent with your organisation's policies and practice		23.53%	4
Strategies are inconsistent with amenity / aesthetic preferences		17.65%	3
Lack of knowledge of the ecological effects of artificial light		70.59%	12
Lack of familiarity with ecologically-sensitive lighting strategies		70.59%	12
Perceived cost		17.65%	3
There are no barriers		0.00%	0
Other (please specify)	Responses	35.29%	6
Total Respondents: 17			

Summary of 'other' responses: Obtrusive lighting is assessed based only on effects on humans and residential boundaries; Ecological impact assessment is project-based; No basis for wildlife sensitive lighting in existing policy/strategy documents; wildlife sensitive lighting inconsistent with specific uses of facilities (sport); Lack of consistency in how biodiversity/ecological impact is considered across organisational boundaries (LGA, Department of Transport, Network operators); wildlife sensitive lighting strategies are inconsistent with perceptions of public safety.

8. In your experience, what barriers exist **within partner organisations** (e.g external consultants or contractors) to greater adoption of ecologically-sensitive lighting strategies: *(select all that apply)*

ANSWER CHOICES		RESPONSES	
Strategies are inconsistent with legislation (State or Federal)		18.75%	3
Strategies are inconsistent with Australian Standards		31.25%	5
Lack of knowledge of the ecological effects of artificial light		56.25%	9
Lack of familiarity with ecologically-sensitive lighting strategies		56.25%	9
There are no barriers		0.00%	0
Other (please specify)	Responses	25.00%	4
Total Respondents: 16			

Summary of 'other' responses: Lack of express requirement for consultants/contractors to consider wildlife sensitive lighting; Lack of willingness to even consider strategies that are outside Australian Standards; Potential increased cost of wildlife sensitive lighting may make tenders uncompetitive.

Lead Question: Thinking about times when you are considering adding, removing or changing artificial outdoor lighting *in a private/home context*:

9. Which of the following are your main concerns/objectives?

ANSWER CHOICES		RESPONSES	
Amenity (creating pleasant, attractive, useful spaces)		72.22%	13
Accessibility & physical safety for you and your visitors (ability to navigate, move, avoid collisions, trips & falls)		88.89%	16
Security / crime prevention		50.00%	9
Minimising ecological impacts of light		50.00%	9
Minimising human health impacts of light		16.67%	3
Lighting equipment cost		55.56%	10
Quality / ease of maintenance		50.00%	9
Other (please specify)	Responses	5.56%	1
Total Respondents: 18			

Summary of 'other' responses: Energy efficiency

APPENDIX B: Resource guide

Wildlife sensitive lighting research, information and products

Wildlife sensitive lighting products

NOTE: No lighting product is intrinsically wildlife-sensitive; the appropriateness of any product depends on the extent to which it facilitates the most favourable lighting conditions possible in a given scenario.

In Australia, the Australasian Dark Sky Alliance's database of ADSA Approved luminaires provides the best guide to current products that are likely to be useful for wildlife-sensitive lighting. This database presently contains 386 different luminaires across 35 product families, including post top, bollard, wall and down lights, from manufacturers including WE-EF, ERCO, EWO and AEC Illumination. The database includes a number of low-colour temperature products (2700K and even 2200K) that comply with the AS/NSZ 1198.6 requirement that lights have a minimum colour rendering index (CRI) of 70. Organisations wishing to explore further any of the products in the database should contact the manufacturers directly.

Download the database of ADSA Approved luminaires here (in Excel):

https://www.australasiandarkskyalliance.org/certified-luminaires

Find out more about the ASDA certification scheme and the meaning of different certification categories here:

https://www.australasiandarkskyalliance.org/adsa-approved

In addition, the WE-EF website contains a lot of useful examples and information regarding its ADSA approved 'night-sensitive lighting', and its adaptive-controlled variable colour-temperature 'wild light' products:

https://www.we-ef.com/aus/environment/night-sensitive-lighting

https://www.we-ef.com/aus/environment/wild-light-lp

Research on the ecological effects of artificial light

National Light Pollution Guidelines for Wildlife

The *National Light Pollution Guidelines for Wildlife* produced by the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) provide a detailed entry point into research on the ecological effects of artificial light at night (ALAN) in the Australian context. Worldwide, the *Guidelines* are a unique set of documents and have been endorsed by 132 countries as parties to the Convention on the Conservation of Migratory Species of Wild Animals.

The *Guidelines* comprise:

1. A main document which summarises research and principles around the effects of ALAN on wildlife
2. Five technical appendices addressing (i) best practice lighting design for wildlife; (ii) how light is perceived by wildlife; (iii) how to measure ALAN; (iv) audits of ALAN and (v) ALAN management
3. Additional appendices summarising research on specific groups of wildlife, and providing additional guidance on best lighting practice in relation to those species.

The *Guidelines* (including all current appendices) can be downloaded here:

https://www.dcceew.gov.au/environment/biodiversity/publications/national-light-pollution-guidelines-wildlife

To date, specific appendices have been produced for marine turtles, seabirds and migratory shorebirds. The fourth appendix will deal with bats and was recently circulated for public consultation (an electronic copy of the consultation draft is provided with this report – please note that this version has not been made fully accessible and will be obsolete once the final appendix is released).

Convention on the Conservation of Migratory Species (CMS) report

The CMS is a United Nations entity which seeks to address human impacts on migratory species, including the effects of ALAN. The report of the CMS's 5th Meeting in 2021 provides a useful summary of global research on the effects of ALAN on birds, insects, bats and other mammals, fish, reptiles and amphibians (see tables 2 to 9). This report provides a useful entry point for research on wildlife not specifically addressed in the existing appendices to the *Guidelines*.

Download the report of the 5th meeting of the CMs here: https://www.cms.int/sites/default/files/document/cms_scc-sc5_inf.7_impact-of-light-pollution-on-migratory-species_e.pdf

EUROBATS

Another useful resource for research on the effects of ALAN on bats and insects is *Publication Series No. 8* issued by the Advisory Committee for the Agreement on the Conservation of Populations of European Bats (EUROBAT):

https://www.eurobats.org/publications/eurobats_publication_series

Research on the human health effects of artificial light

These are some easily-accessible articles outlining effects of artificial light on human health (more detailed scientific papers are summarized below):

Stevens, R (2017) *Harvard study strengthens link between breast cancer risk and light exposure at night*, https://theconversation.com/harvard-study-strengthens-link-between-breast-cancer-risk-and-light-exposure-at-night-75171

Valmadre et al 2013, *How a week of camping resets the body clock*, https://theconversation.com/how-a-week-of-camping-resets-the-body-clock-16557

Stevens, R (2016) *New atlas shows extent of light pollution – what does it mean for our health?* https://theconversation.com/new-atlas-shows-extent-of-light-pollution-what-does-it-mean-for-our-health-60836

Kusmanoff et al 2016, *Getting smarter about city lights is good for us and nature too*, https://theconversation.com/getting-smarter-about-city-lights-is-good-for-us-and-nature-too-69556

Peer-reviewed research

The following is a small sample of recent, publicly available scientific studies on the human health effects of artificial light. Dot points summarise the key finding(s) of each study:

Effects on sleep, circadian rhythms and mental health

Paksarian et al 2020 "Association of Outdoor Artificial Light at Night With Mental Disorders and Sleep Patterns Among US Adolescents" *Journal of the American Medical Association – Psychiatry*, vol 77, doi.org/10.1001/jamapsychiatry.2020.1935

- Study of 10,000 15 year-olds found increased outdoor lighting was strongly associated with nightly loss of sleep and increased prevalence of mood, anxiety and depressive disorders.

Stebelova et al 2020 "Impact of Dim Light at Night on Urinary 6-Sulphatoxymelatonin Concentrations and Sleep in Healthy Humans" *International Journal of Molecular Sciences*, vol 20, doi.org/10.3390/ijms21207736

- Dim night-time lighting (1-5 lux) fragments sleep and reduces melatonin production in young, healthy humans.

Vethe et al 2022 "Evening light environments can be designed to consolidate and increase the duration of REM-sleep", *Scientific Reports*, volume 12, doi.org/10.1038/s41598-022-12408-w

- Eliminating or reducing short-wavelength (blue) light from evening lighting improves the amount and quality of REM sleep and improves circadian rhythms

Effects on heart, weight and diabetes

Benedito-Silva et al 2020 "Association between light exposure and metabolic syndrome in a rural Brazilian town" *PLoS One*, vol 15, doi.org/10.1371/journal.pone.0238772

- Suppression of day/night light differences due to artificial light increased risk of heart disease and diabetes and increased body mass index.

Mason et al 2022 “Light exposure during sleep impairs cardiometabolic function” *Proceedings of the National Academy of Science*, vol 119, doi.org/10.1073/pnas.2113290119

- Night-time exposure to light increases heart rate and insulin resistance

Associations with breast cancer and female infertility

Urbano et al 2021 “Light at night and risk of breast cancer: a systematic review and dose–response meta-analysis” *International Journal of Health Geographics,* vol 20, doi.org/10.1186/s12942-021-00297-7

- Meta-analysis of previous studies published on the effects of artificial light exposure on breast cancer risk
- Overall, found that risk of breast cancer in pre-menopausal women increased by 11% in the group exposed to highest levels of artificial light compared to the lowest exposure group

Fernandez et al 2020 “Night Shift Among Women: Is It Associated With Difficulty Conceiving a First Birth?” *Frontiers in Public Health*, vol 8, doi.org/10.3389/fpubh.2020.595943

- Disruption of circadian rhythms due to night work (including artificial light) makes women <35 years more likely to require fertility treatment and suffer endometriosis.

Research on the effects of artificial light on crime and safety

XYX Lab

The XYX Lab at Monash University has some excellent research exploring how public lighting can (and can’t) improve safety and perceptions of safety, with a focus on women. Relevant projects include:

Lighting Cities: Creating Safer Spaces for Women and Girls

Deferring to more lights and brighter cities does not create safer spaces for women and girls. Lighting design is vital for gender-sensitive cities.

Project webpage: https://www.monash.edu/mada/research/lighting-cities

Conversation article: https://theconversation.com/more-lighting-alone-does-not-create-safer-cities-look-at-what-research-with-young-women-tells-us-113359

Merri Creek, Coburg Safety Audit

Report following survey of 800 women using Merri Creek shared path. Lack of sense of safety was attributed to various factors including isolation and lack of lighting. However, most women indicated that they wouldn’t use the area alone even if more brightly lit.

Project webpage: https://www.monash.edu/mada/research/merri-creek-coburg-safety-audit

Full report:
https://www.monash.edu/__data/assets/pdf_file/0003/2640405/D20_476116__Merri_Creek_Safety_Report_XYX_Lab_-_Final_-_November_2020.pdf

Colour temperature, human vision and safety

Historically, 4000K was considered a desirable colour temperature street lighting, however research suggests that road users prefer lower colour temperature lighting, and that changing or removing streetlighting has surprisingly little effect on road safety or crime rates. The following papers are publicly available:

Jin et al 2015, Research on the Lighting Performance of LED Street Lights With Different Color Temperatures, *IEEE Photonics Journal*, vol 7, doi.org/10.1109/JPHOT.2015.2497578

- 3000K lighting provided better visibility for motorists than 4000K lighting, and additional benefits including reduced dark-adaptation time (when moving from brightly lit highways to darker side-roads) and better penetration in fog, smoke or haze

Davidovic et al 2019, Drivers' Preference for the Color of LED Street Lighting, *IEEE Access*, vol 7, doi.org/10.1109/ACCESS.2019.2920737

- Subjective and objective testing of 3000K and 4000K street lighting found that 3000K provided better overall visibility and achieved better results on most parameters, including detection of pedestrians

Steinbach et al 2015, The effect of reduced street lighting on road casualties and crime in England and Wales: controlled interrupted time series analysis, *Journal of Epidemiology and Community Health*, vol 69, www.jstor.org/stable/44017632

- Removal, dimming or changing the colour of street lighting had no effect on rates of night-time collisions or rates of crime (14 year study across England and Wales).

International Dark Sky Association

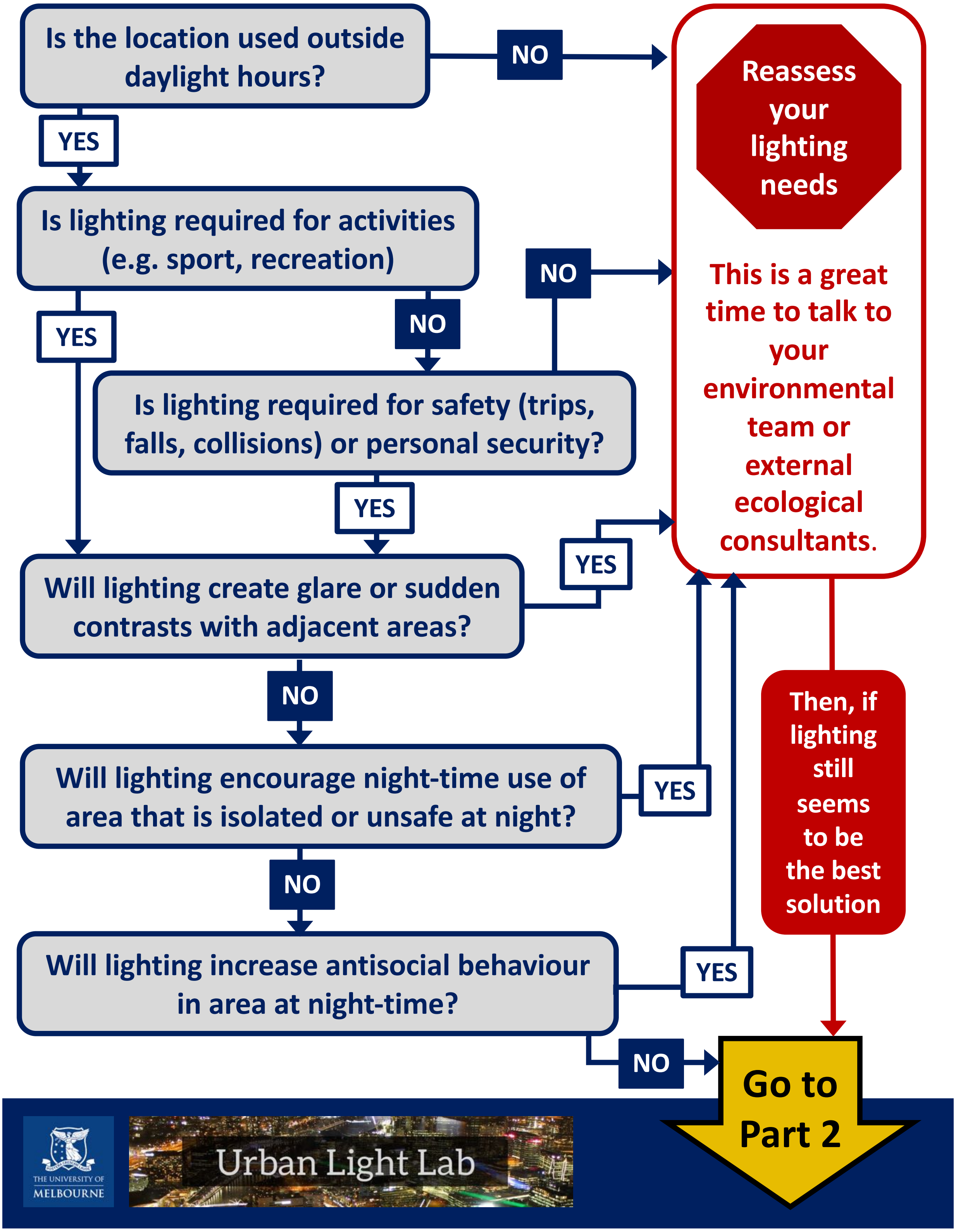
- The International Dark Sky Association provides links to publicly available resources on the relationships between crime, safety and artificial lighting: https://www.darksky.org/light-pollution/lighting-crime-and-safety/

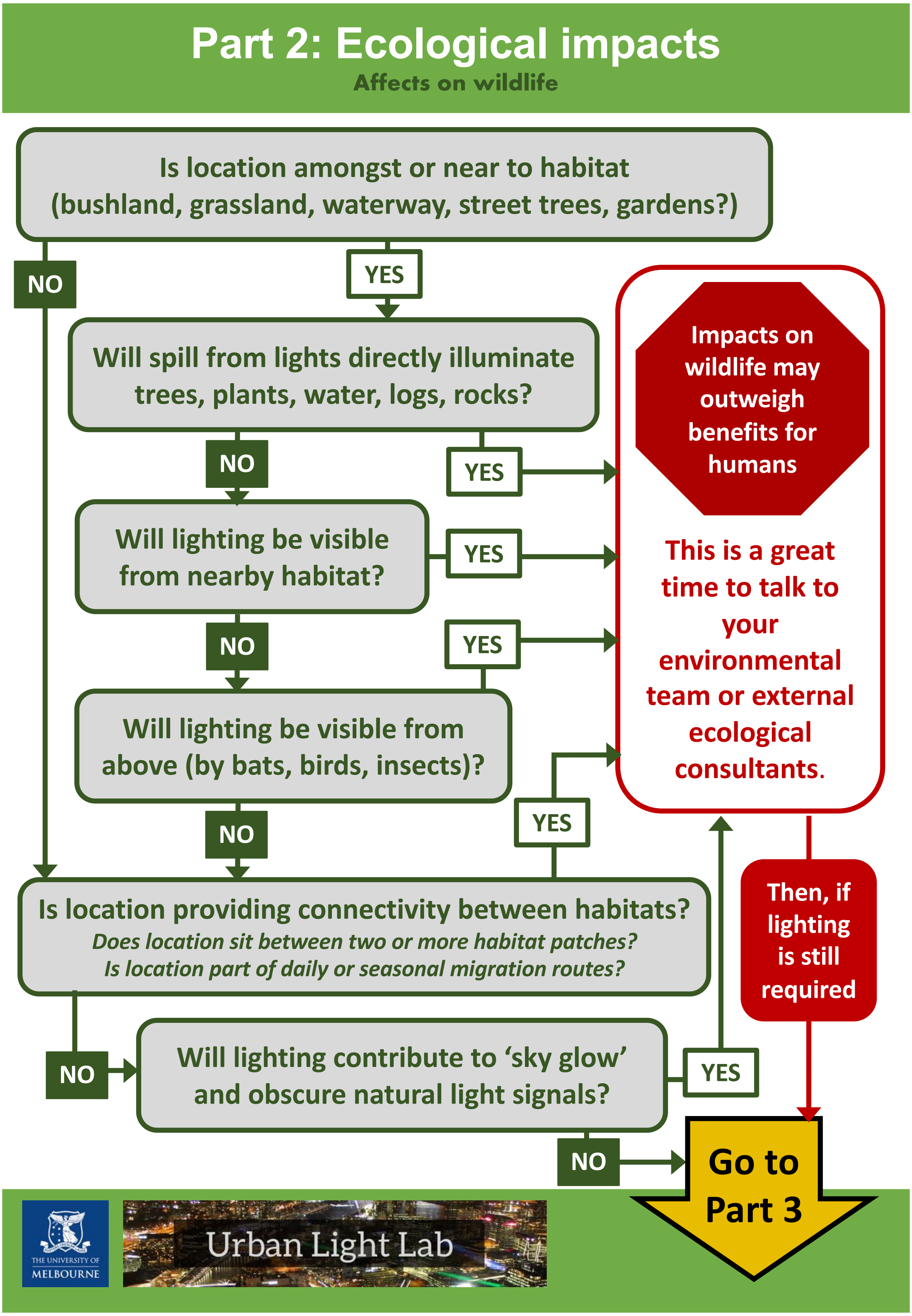
APPENDIX C: Decision guide

Self-guided decision tree for wildlife sensitive lighting

Part 1: Is lighting required?

Safety, amenity and natural darkness




Part 2: Ecological impacts
Affects on wildlife
Is location amongst or near to habitat (bushland, grassland, waterway, street trees, gardens?)
NO
YES
Will spill from lights directly illuminate trees, plants, water, logs, rocks?
NO
YES
Will lighting be visible from nearby habitat?
YES
NO
YES
Will lighting be visible from above (by bats, birds, insects)?
NO
YES
Impacts on wildlife may outweigh benefits for humans
This is a great time to talk to your environmental team or external ecological consultants.
Is location providing connectivity between habitats?
Does location sit between two or more habitat patches?
Is location part of daily or seasonal migration routes?
Then, if lighting is still required
NO
Will lighting contribute to 'sky glow' and obscure natural light signals?
YES
NO
Go to Part 3
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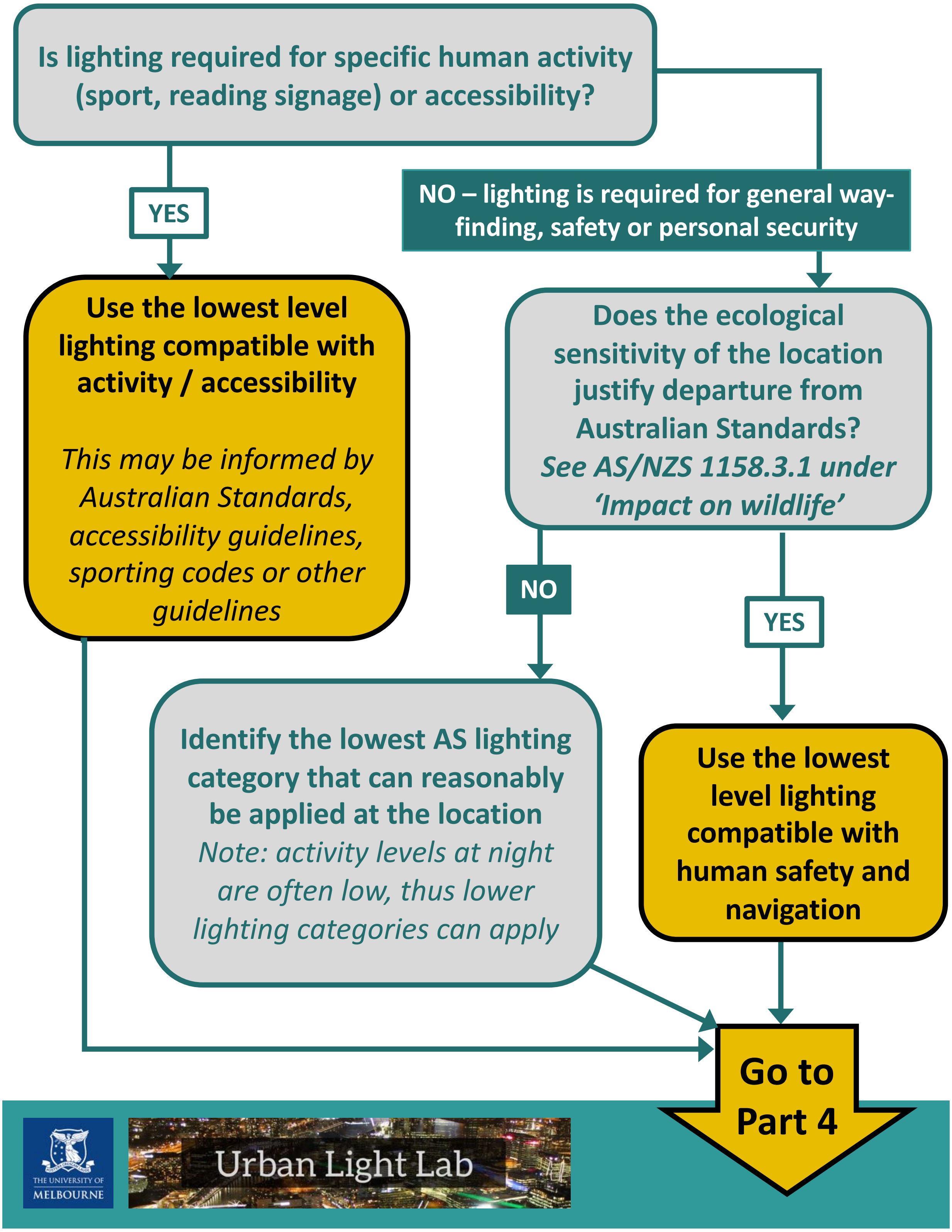
Part 3: Minimize light intensity

Fulfilling human objectives



Part 4: Timing, spectrum & spill

Warmer colours, when and where needed

Is the location used regularly throughout the night (from dusk to dawn)?

NO – area is unused outside of peak hours of activity

Use timers to turn lights off outside peak periods

User-operated demand switches can briefly turn lighting on if needed

YES

NO – area is used intermittently outside of peak hours of activity

Turn off or dim lights outside of peak periods

Motion sensors can increase illumination when required

For ALL lighting fixtures:

- **Use low-colour temperature (amber) lighting to reduce impacts on human health and wildlife.**

  There are now many AS-compliant luminaires with colour temperature (CCT) below 3000K

- **Direct light downwards and only where it is needed; avoid light spill into nearby habitat and tree canopies**

  Use full cut-off luminaires, shields/hoods, lowered fixtures and focussed beams to keep light where it is needed

- **If lighting must be used close to sensitive habitat, reduce light spill further with walls, earthworks or dense plantings**

See Appendix D & E for wildlife sensitive lighting specifications, case studies and strategies. For further information on the ecological effects of light pollution, and best practice lighting, see the National Light Pollution Guidelines for Wildlife at: https://www.dcceew.gov.au/environment/biodiversity/publications/national-light-pollution-guidelines-wildlife

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APPENDIX D: Lighting specification

Wildlife sensitive lighting specification for lighting briefs, RFTs etc

Wildlife sensitive lighting specifications

There are multiple ways to make lighting more wildlife friendly (reduce intensity, colour temperature or height of light fittings; add shielding; adopt curfews and adaptive controls such as timers, dimming and sensors). However, not all options suit all situations. Accordingly, it is not possible to have a one-size-fits-all wildlife-sensitive lighting specification that will suit all circumstances. The following principles should be used as a guide in formulating specifications that meet your organisation's specific needs. **A detailed example of a wildlife sensitive lighting specification is set out at the end of this appendix.**

Be specific

Lighting designers and suppliers may favour solutions that minimise cost (for fear of losing the tender to a cheaper bid). Accordingly, specifications that are vague ('make lights insect-friendly', 'reduce height of poles', 'use low-CCT lighting') are likely to attract proposals that do the bare minimum to accommodate wildlife.

To improve wildlife outcomes, be as specific as you can, and where possible put numbers to your requirements:

> *"All lighting fixtures should be directed away from the waterway"*
>
> *"Lights should be elevated no more than 4.5m above the path"*
>
> *"Lights should have a colour temperature of 2700K or less"*
>
> *"Light spill should be reduced to <1 lux at a distance of 10 metres from the edge of the path"*

To avoid unintended outcomes, specify **all** the lighting characteristics that you would like met and, if necessary, prioritise them based on your scenario. For example:

> *"Preference will be given to proposals that satisfy most or all of the following requirements (more important requirements are listed first):*
>
> - *Illuminance not to exceed AS 1158.3 requirements by more than 50% at any point*
> - *Upward waste light of 0%*
> - *Bollard lighting (<1.2 m height) to be used wherever possible*
> - *If poles required, height not to exceed 3.0 m*
> - *Lights to be dimmable after 10pm, with sensor to return to full brightness when activated*
> - *Colour temperature not to exceed 3000K"*

Colour temperature

Correlated colour temperature (CCT) is commonly used to describe the relative warmth (low colour temperature) or coolness (high colour temperature) of light. It seeks to capture the spectral output of each lighting fixture in a single number. Because of this, it provides only a rough idea of the colour (and thus ecological effect) of a given light – two lights with quite different spectra can have very similar colour temperatures.

To make lights more wildlife-sensitive, we are particularly interested in minimising the output of short wavelength (blue, violet and UV) light. Accordingly, when specifying a colour temperature, you should specify a preference for lights that reduce short wavelength output. For example:

> *"All lights should have a colour temperature ≤3000K. Preference will be given to products that minimise the output of blue, violet and UV light (≤495 nm)"*

Early LED lighting was dominated by 4000K (or higher) products. Lighting fixtures are now frequently offered in 3000K (and increasingly 2700K) versions, both of which can comply with Australian Standards. As a general rule, and wherever possible treat **3000K** as a **maximum** for all outdoor lighting.

Clarify how standards should be complied with

Unless specifically requested, lighting practitioners are unlikely to propose lighting solutions that do not comply with Australian Standards. However, **Australian Standards are only guidelines that have no stated maximum**, and there are sometimes good reasons to depart from a particular standard to improve wildlife outcomes (indeed, the standards themselves allow for this). For example, AS/NZS 1158.3 Table 3.4 requires lighting to be maintained to 50% intensity up to 5 metres either side of a shared path (this is intended to avoid sudden reductions in light levels between a shared path and nearby kerb). However, your organisation can deem this requirement to be unnecessary (for example, due to the needs of wildlife – see clause 3.1.3.5), and should do so wherever shared paths run beside or amongst habitat areas.

If you have specific wildlife needs that may require departure from standards (for example, a population of a rare or threatened species in close proximity to essential lighting), you should make clear that non-compliant proposals will be acceptable. You can also ask the lighting practitioner to identify standards that are not met so that an informed decision can be made. For example:

> *"Proposals should comply with Australian Standards as far as possible, while achieving the above specifications. However, we do not expect proposals to comply with Australian Standards in all aspects, particularly when to do so may negatively affect the environment and wildlife within it. Please identify any aspect of your proposal that is non-compliant."*

Australian Standards specify minimum light levels to be achieved, but *maximum* light limits are only imposed at certain angles (to avoid glare and over-illuminance for humans). There is no other defined maximum on light intensity. In nearly all scenarios, reducing intensity will reduce the impact of lighting on wildlife. Accordingly, lighting proposals should specify that where Australian Standards on lighting intensity are to be met, the standard should not be exceeded beyond a reasonable margin for error (having regard to the fact that points immediately below light fixtures are always likely to exceed the minimum by a substantial margin). For example:

> *"Proposals should comply with Australian Standards, however illuminance levels should not exceed the amount required by Australian Standards by more than 50% at any point"*

Further, Australian Standards require clients to make subjective judgements about activity levels, fear of crime and needs for amenity (typically by assessing these as 'low', 'medium' or 'high'). These assessments in turn determine the light levels to be applied. Unless these matters are addressed in the lighting brief, designers will form their own judgements about the level of light to be applied. Accordingly, these matters should be addressed in the design brief (unless you want them to be assessed by the designer). For example, if perceived risk is low, you could state:

> *"For the purposes of selecting lighting categories, fear of crime and need to enhance amenity at all sites should be considered to be low"*

or

> *"For the purposes of selecting lighting categories:*
>
> - *fear of crime and need to enhance amenity at all sites should be considered low*
> - *vehicle, cyclist and pedestrian activity at all sites should be considered low, except at Example Reserve (vehicle activity = high; pedestrian & cyclist activity = medium)"*

The first example above would still allow the designer to assess whether activity levels at the site are low, medium or high, and select categories accordingly. The second takes this decision out of the designer's hands entirely.

Alternatively, you may simply specify the lighting level to be applied in each instance. For example:

> *"All shared paths are to be lit to subcategory PP5 and all connecting ramps and footbridges to subcategory PE3"*

Be clear about your priorities

Within a single project, wildlife sensitive lighting may be more important (or more achievable) at certain places or at certain times. Strict compliance with Australian Standards may also be more important in some areas (e.g. where pedestrians and vehicles interact, or known crime hot-spots) than in others (e.g. off-road shared paths). These distinctions may not be apparent to lighting designers unless specified in the brief.

Wildlife sensitive lighting design will often require reduced fixture heights and lower light intensities. This often means using an increased number of poles and fixtures. You should be clear that this is acceptable so that it can be included in plans and costed in at the beginning of the design process.

Example of wildlife sensitive lighting specification

The following provides an example of a wildlife sensitive lighting specification for a hypothetical precinct containing a sports ground (used for football and cricket), shared paths and car parks. Note that the specifications and details supplied are examples only – your organisation's needs are likely to differ from project to project. Drafting notes (highlighted) provide guidance as to where project-specific changes will commonly be required.

Lighting must consider the needs of wildlife

Wildlife (including animals and plants) can be harmed by artificial light. All lighting in this project must as far as possible avoid exposing wildlife to artificial light, and adopt wildlife sensitive lighting strategies as set out below.

General principles

Areas not used by humans, or that do not require lighting for safe use, should not be lit

Lighting should only be applied continuously during peak hours of human use [define what these hours are]– at all other times adaptive lighting should be employed to minimise light emissions

Proposals should comply as far as possible with the National Light Pollution Guidelines (download at https://www.dcceew.gov.au/environment/biodiversity/publications/national-light-pollution-guidelines-wildlife) and in particular Appendix A – Best practice lighting design

In areas where vehicles and pedestrians interact (carparks and crossing points) proposals should comply strictly with Australian Standards, while meeting the specifications set out below as much as possible. [Add any other high-risk sites where strict compliance with standards may be appropriate to reduce liability risk for your organisation]

In all other areas, proposals should achieve the specifications set out below, whilst complying with Australian Standards as far as possible. However, we do not expect proposals to comply with Australian Standards in all aspects. Please identify any aspect of your proposal that is non-compliant.

Specifications – All areas

Lighting intensity should be reduced wherever possible. Illuminance levels should not exceed the amount required by AS/NZS 1158 (paths, carparks) or AS/NZS 2560 (sports ground) by more than 50% at any point.

Short wavelength (UV, violet, blue) light is particularly harmful to wildlife. Preference will be given to proposals and products that minimise the output of blue, violet and UV light (≤495 nm).

Specifications - Shared paths

All shared paths should be lit to subcategory PP5 and all connecting ramps and footbridges to subcategory PE3. [These subcategories provide the lowest levels of illumination available for shared paths and connecting elements respectively. PP1 and PE1 provide the highest illumination]

Bollard lighting (<1.2 m height) should be used wherever possible on shared paths [AS/NZS 1158.3 Table 3.4 exempts fixtures <1.5 m in height from compliance with vertical illuminance requirements – it may be worth pointing this out to designers]. If poles are required, their height should not exceed 3.0 m.

Where the shared path runs within 50 metres of a waterway, bushland or other habitat, path lighting should have a maximum colour temperature of 2700K. All other shared path lighting should have a maximum colour temperature of 3000K.

Where the shared path runs through or beside waterways, bushland or other habitat:

- point horizontal illuminance (E_{ph}) requirements either side of the path are deemed unnecessary [see AS/NZS 1158.3, Table 3.4, footnote d]
- In addition, E_{ph} should not exceed 0.5 lux at any distance greater than 1 metre from the edge of the path
- As far as possible, lighting fixtures should be positioned so that any light spill travels away from habitat.

Shared path lighting should be dimmable and equipped with timers and motion sensors. Shared paths should be continuously lit between sunset and 10pm, and from 5am to sunrise. Between 10pm and 5am, shared path lighting should be dimmed to 10% of maximum illuminance, with sensor-activated increases in lighting to 50% of maximum illuminance for 1 minute. [Adjust times and percentage values as appropriate for your project]

Specifications - Car parks

All car parks should be lit to subcategory PC3, with pedestrian crossings lit to subcategory PCX and car spaces designated for people with disabilities to subcategory PCD. [PC3 provides the lowest levels of illumination available for car parks; PC1 provides the highest illumination. There is a single subcategory applicable to crossing points (PCX) and disabled car spaces (PCD)]

Bollard lighting (<1.2 m height) should be used wherever possible on shared paths [AS/NZS 1158.3 Table 3.4 exempts fixtures <1.5 m in height from compliance with vertical illuminance requirements – it may be worth pointing this out to designers]. If poles are required, their height should not exceed 3.0 m.

Where the car park boundary sits within 50 metres of a waterway, bushland or other habitat, car park lighting should have a maximum colour temperature of 2700K. All other car park lighting should have a maximum colour temperature of 3000K.

Where the carpark is immediately adjacent to waterways, bushland or other habitat:

- point horizontal illuminance (E_{ph}) requirements are deemed unnecessary [see AS/NZS 1158.3, Table 3.4, footnote d] except for areas lit to subcategory PCX or PCD
- In addition, E_{ph} should not exceed 0.5 lux at a distance of 1 metre outside the carpark boundary
- As far as possible, lighting fixtures should be positioned so that any light spill travels away from habitat.

Car park lighting should be dimmable and equipped with timers and motion sensors. Car parks should be continuously lit between sunset and 10pm, and from 5am to sunrise. Between 10pm and 5am, cark park lighting should be dimmed to 10% of maximum illuminance, with sensor-activated increases in lighting as follows:

- to 100% of maximum illuminance for 1 minute in areas lit to subcategory PCX
- to 100% of maximum illuminance for 5 minutes in areas lit to subcategory PCD
- to 50% of maximum illuminance for 1 minute in all other areas.

[Adjust times and percentage values as appropriate for your project – car parks at transport hubs may have very different peak hours of operation compared to those at retail precincts or sporting grounds]

Specifications - Sports ground

Lighting shall be adaptable to meet the following sporting code and competition level use cases:

- Football training (semi-professional level)
- Football competition (semi-professional level)
- Cricket competition (class V)

[AS/NZS 2560.2 provides tables of lighting technical parameters (LTPs) for each code, competition level and use. Lighting installed to meet the requirements of high-illumination use cases should be able adaptable to meet lower-intensity use cases. To ensure that excessive lighting is not being applied at any time, nominate at least a maximum and a minimum use case (in this example we have nominated a third, intermediate use case)]

Lighting shall be enabled remotely by council, but lights should not turn on until activated by users on site. All user-activated switches shall be programmable to turn off after a set period.

In addition, a user-operated switch should be provided which turns on lighting at the lowest level for a period of 15 minutes. This switch should not operate between midnight and 5am.

All luminaires shall be shielded to eliminate light spill:

- above the horizontal
- behind the light pole
- beyond the playing surface (and any required run-off area)

Preference will be given to proposals that satisfy the following requirements:

- luminaires are positioned at least 1 metre below the average height of surrounding canopy trees [this may not be practical for larger sports grounds or those surrounded by small trees]
- vertical and horizontal illuminance of surrounding vegetation (including at canopy height) is reduced to <1 lux [light spill is typically assessed at human height (1.5 m above ground) but should also be assessed at heights relevant to birds, arboreal mammals etc]
- colour temperature of all lighting does not exceed 3000K [Sports lighting may not be available at low colour temperatures for all applications – e.g. competition and televised sport may require lighting around 5700K].

APPENDIX E: Case studies

Application of wildlife sensitive lighting in common scenarios

Case Study 1: Shared path

Image: WE-EF Leuchten GmbH

Likely ecological impacts of ALAN from shared paths

For a shared path located beside a waterway or amongst bushland or grassland, potential impacts of artificial light at night (ALAN) include:

- barrier to movement of light-avoiding animals (most possums, bats, gliders and frogs; some birds) and also light-attracted animals (invertebrates and some birds get 'trapped' by lights); habitat is effectively fragmented by lighting
- reduction in size of habitat due to 'edge effects' (habitat near path becomes uninhabitable for light-avoiding species)
- increased mortality of invertebrates (especially flying insects) attracted to lights, with cascading impacts on pollination and insectivorous birds, frogs and mammals
- disrupted sleep for daytime animals
- masking of natural seasonal lighting cues from the sun and moon; this can lead to mistimed reproduction, growth, migration and development
- masking of natural sunrise and sunset cues; this can lead to animals being active at the wrong time of day, which can increase mortality due to exposure to new predators or mismatch with prey availability
- suppression of the daily vertical movement of aquatic invertebrates: these spend the day on the riverbed then rise to the surface at night to feed on microscopic plants and algae. ALAN suppresses this movement and disrupts food chains.

Human interests to consider

- Shared paths may be key commuter routes, providing low-carbon transport, healthy exercise, and high-quality sealed surfaces for wheelchairs and prams. In cooler months, peak commuting times coincide with darkness.

- Shared paths are also an important outdoor recreation resource; many people need to exercise after dark (or before sunrise) due to work, education or caring commitments during daylight.
- Cycle-pedestrian interactions may make collisions likely where visibility is poor (although cyclists should employ front and rear lights)
- Shared paths can be isolated, with infrequent exits due to surrounding bushland, waterways, residences or industrial zones. Lighting alone is unlikely to make an isolated path safe, but may inadvertently indicate to potential users that this is an appropriate space to use at night
- Use of shared path at night may disturb neighbours in abutting properties. Lighting may encourage increased late night or early morning use.
- Lighting of shared path may disturb neighbours in abutting properties, especially if applied at full intensity / all night long.

Best practice outcomes

A best practice shared path lighting project should have most, or preferably all, of the following features:

- No lighting applied except where it will improve a specific, identified human safety outcome
- Lowest possible illuminance levels
- Bollards, handrail lighting or lower light poles to prevent spill of light beyond path and into nearby habitat
- Using full cut-off and shielded luminaires to prevent upward and outward light spill
- Lights facing inward and away from nearby habitat
- Use of adaptive lighting – lights dimmed or turned off outside of peak activity times, with sensor-activation for occasional late-night users
- Use of low colour-temperature luminaires – e.g. 2700-3000K – with minimal UV/violet/blue light content.

Lighting strategies to reduce wildlife impacts from shared paths

Not all strategies will be appropriate in all scenarios, however at least some of the following strategies will be applicable to nearly all shared paths

Strategy	Strengths and weaknesses
No lighting • **remove existing lighting** • **do not install new lighting**	**Strengths:** Natural darkness is ecologically optimal. Wildlife can exhibit natural movement, behaviours and development Absence of light will discourage use of paths late at night – less disruptive for neighbouring residents and will not encourage use of unsafe spaces. **Weaknesses:** Path may be inaccessible/unsafe at night for many users (but lighting can be removed where path is close to existing streetlighting) Effect of glare from bike lights will increase in absence of path lighting
Reduced lighting intensity • **using lower lux fixtures**	**Strengths:** Reduces intensity of light spill and distance over which it is perceived Reduces glare for path users and reflection of light off path Reduces 'edge effect' on neighbouring habitat; larger proportion of habitat remains unaffected Reduces impact on neighbouring residents May reduce electricity consumption. Can be Australian Standards compliant by deeming path activity and fear of crime levels to be low (for example changing a path from category PP3 to PP5) **Weaknesses:** May not provide sufficient light for users on busy sections (where users create additional shadowing)
Lower light fixtures • **short poles** • **bollards** • **handrail lighting**	**Strengths:** Reduces lighting spill into nearby habitat Reduces distance from which light can be seen by birds, bats, flying invertebrates and arboreal mammals Supported by VicRoads Technical Guideline TCG 006 (e.g. where streetlights are source of shared path lighting) Intensity of each luminaire can be reduced **Weaknesses:** May not be fully AS/NZS1158.3.1 compliant (if spill off path is removed entirely) unless wildlife impact provision (paragraph 3.1.3.5) can be invoked May increase ecological impacts on ground-dwelling animals (beetles, wombats, reptiles, birds) More vulnerable to vandalism (paint, structural damage)

Strategy	Strengths and weaknesses
	May require increased number of luminaires (as each has less reach)
Light cut-offs and shielding • **Full cut-offs prevent direct light emissions above the horizontal** • **Additional shielding may be required to prevent light spill**	**Strengths:** Keeps light only where needed – on the path and away from surrounding habitat Can be retrofitted to many existing lights Can be used on standard network and Department of Transport lights (e.g. where streetlights are source of shared path lighting) **Weaknesses:** May not be fully AS/NZS1158.3.1 compliant (if spill off path is removed entirely) unless wildlife impact provision (paragraph 3.1.3.5) can be invoked Sudden change in light levels between path and nearby habitat may increase fear of crime (cannot see person hiding in bushes)
Lower colour temperature • **2700K lighting is sufficient for most outdoor activities including cycling** • **Even lower colour temperatures (< 2200K) should be considered if lighting must be placed close to high value habitats**	**Strengths:** Low colour temperature light contains more long-wavelength (amber, red) light, which is invisible to many animals. Low colour temperature light thus appears much less intense to many animals. Low colour temperature light contains less short wavelength (blue) light, so is less able to disrupt circadian rhythms. This is important for sleep, immune function and health in both humans and non-human animals **Weaknesses:** Some animals can perceive long wavelength light and are unlikely to benefit from low colour temperature lighting. Seasonal cues in plants (growth, flowering) respond to changes in long wavelength light – plants are unlikely to benefit from low colour temperature lighting Networks and Department of Transport lighting palettes do not include low colour temperature luminaires – at present would require non-standard installation (at additional cost) Very low colour temperatures may struggle to meet AS/ANZ 1158.6 requirements for colour rendering (CRI ≥ 70), although colour rendering on shared paths may not be very important for safety
Timers and curfews • **Lights turned off after evening and before morning peaks**	**Strengths:** Provides natural darkness for part of the night, reducing impacts on animal movement and behaviour Reduces impacts of spill on nearby residents Signals to users that path may not be suitable for use late at night Reduces electricity consumption Can often be retrofitted

Strategy	Strengths and weaknesses
	Weaknesses: Increases risk of fall, collision etc for users between these peaks May increase fear of crime for path users late at night Doesn't reduce impacts of artificial light on animals with peak activity in early evening (many invertebrates) May not be supported by networks and Department of Transport.
Dimming & Sensors • **Dimming light after peak periods** • **Light returns to full power when activated by sensor**	**Strengths:** Provides reduced lighting impact on wildlife and residents Reduces electricity consumption Reduces risk of fall, collision etc for late night users Can often be retrofitted **Weaknesses:** Doesn't reduce impacts of artificial light on animals with peak activity in early evening (many invertebrates), or that are impacted by low light levels May not be supported by networks and Department of Transport.
Structural changes • **Plantings, walls or earthworks to reduce light spill**	**Strengths:** Permit standards-compliant lighting whilst limiting spill into wider habitat **Weaknesses:** Cost-prohibitive for long stretches of shared path May increase isolation and reduce sight-lines for path users.
Community engagement • **Signs or correspondence to communicate need for wildlife sensitive lighting along shared path**	**Strengths:** Increases community awareness of the ecological effects of ALAN and the benefits of wildlife sensitive lighting May also improve safety and personal security (community will be aware that path is unlit, or lit less intensely, and behave accordingly) **Weaknesses:** Some users will remain unaware and may be at increased risk of collision etc.

Case Study 2: Sports facility

Image: Tim Patch

Likely ecological impacts of ALAN from sports facilities

For outdoor sports grounds or courts adjacent to a waterway, bushland or grassland, potential impacts of artificial light at night (ALAN) include:

- spread of artificial light over large areas; sports ground lighting in particular may be visible to fauna many kilometres away. This is particularly the case for flying animals or animals that rest or forage in tree canopies.
- substantial reduction in effective size of neighbouring habitat due to 'edge effects' (habitat near sporting facility becomes uninhabitable for light-avoiding species). These effects may extend hundreds of metres.
- increased mortality of invertebrates (especially flying insects) attracted to lights, with cascading impacts on pollination and insectivorous birds, frogs and mammals
- increased mortality of seabirds attracted to lights – some will circle lights endlessly or become disoriented
- barrier to movement of light-avoiding animals (most possums, bats, gliders and frogs; some birds) and also light-attracted animals (invertebrates and some birds get 'trapped' by lights); habitat is effectively fragmented by sports ground lighting
- disrupted sleep for daytime animals
- masking of natural seasonal lighting cues from the sun and moon; this can lead to mistimed reproduction, growth, migration and development
- masking of natural sunrise and sunset cues; this can lead to animals being active at the wrong time of day, which can increase mortality due to exposure to new predators or mismatch with prey availability

- suppression of the daily vertical movement of aquatic invertebrates: these spend the day on the riverbed (or sea floor) then rise to the surface at night to feed on microscopic plants and algae. ALAN suppresses this movement and disrupts food chains.

Human interests to consider

- Organised sporting activities have important social, cultural and health values, contribute to fitness, mental health, connection and inclusion, and are highly popular.
- Many people can only realistically participate in training and competition outside of business hours, due to work, education or caring commitments. In winter, these opportunities coincide with darkness.
- Increased demand by sporting competitions for use of facilities places pressure on councils to make facilities available later into the night.
- Night-time sporting activities require some level of artificial lighting for practical and human safety reasons. Sports involving fast-moving people (running, tackling) or objects (balls, bats, clubs, sticks, racquets) require higher lighting levels to be played safely.
- High-intensity sports lighting is a common cause of disturbance for neighbouring residents.
- Prolonged exposure to intense lighting at night (especially light containing a high proportion of short wavelength blue light) disrupts human health, sleep and circadian rhythms (see Annexure B: Resource guide).

Best practice outcomes

A best practice sports lighting project should have most, or preferably all, of the following features:

- No lighting applied except where necessary for sporting activity or human safety
- Facilities closest to habitat are unilluminated, or lit only for reduced hours
- Lowest possible illuminance levels used (including use of training light levels outside of competition)
- High quality, focussed and shielded LED luminaires to minimise spill of lighting outside the play area
- Lights only turned on when players actually on site
- Lights turned off when not in use, with user-activation for occasional late-night users
- Explore use of lower colour-temperature luminaires where available.

Lighting strategies to reduce wildlife impacts from sports facilities

Not all strategies will be appropriate in all scenarios, however at least some of the following strategies will be applicable to nearly all sports facilities

Strategy	Strengths and weaknesses
Curfews and adaptive controls • **Curfews: lights switch off after a certain time** • **Training / exercise lights: lower intensity lighting for non-competition use** • **Remote and local switching: lights are enabled remotely but not actually turned on unless users on site** • **Timer switches: occasional users (e.g. joggers, dog walkers) can switch lights on after curfew for limited amount of time**	**Strengths:** Provides natural darkness or reduced intensity for part of the night, reducing impacts on animal movement and behaviour Reduces impacts of spill on nearby residents Reduces electricity consumption Can be retrofitted (in most cases via changes to controls rather than light fixtures) **Weaknesses:** Doesn't reduce impacts of artificial light on animals with peak activity in early evening (many invertebrates)
Focussed beams, cut-offs and shielding • **High-quality LED sports lights can reduce spill and increase useful (on-field) lighting** • **Full cut-offs prevent direct light emissions above the horizontal** • **Additional shielding may be required to prevent light spill**	**Strengths:** Keeps light only where needed – on the ground/court and away from surrounding habitat Cut-offs and shielding can be retrofitted to some existing lights Benefits both wildlife and neighbouring residents **Weaknesses:** Reduces localised light spill but not a complete solution – lights above canopy level may still be visible over long distances
Lower light fixtures • **shorter poles** • **box-type fixtures for courts**	**Strengths:** Reduces lighting spill into nearby habitat Reduces distance from which light can be seen by birds, bats, flying invertebrates and arboreal mammals (especially if lights can be installed below canopy level) May reduce installation and maintenance costs **Weaknesses:** May require additional fixtures to light same area May increase lateral spill at larger sports ground (as lights must be angled closer to the horizontal to cover the area) Not practical for largest sporting grounds
Reduced lighting intensity • **using lower lux fixtures**	**Strengths:** Reduces intensity of light spill and distance over which it is perceived May reduce electricity consumption

Strategy	Strengths and weaknesses
	Reduces 'edge effect' on neighbouring habitat; larger proportion of habitat remains unaffected Reduces impact on neighbouring residents **Weaknesses:** May not be consistent with sporting code requirements for minimum lux levels for training / competition
No lighting • **switch off or remove existing lighting** • **do not install new lighting** • **when installing lighting to increase hours/capacity, prioritise facilities away from high-value habitats**	**Strengths:** Appropriate for sporting facilities in close proximity to high-value habitats, populations of threatened species or along migration routes. Appropriate for sporting facilities that are typically only played on during the day (e.g. golf courses) Can be adopted short-term during key biological events (e.g. breeding or migration periods) to minimise effects on animal populations Natural darkness is ecologically optimal. Wildlife can exhibit natural movement, behaviours and development Absence of light will discourage use of facilities late at night – less disruptive for neighbouring residents and will not encourage use of unsafe spaces. Substantially reduces installation and maintenance costs of facility. **Weaknesses:** Facility will not be available for play after sunset – not realistic for many facilities, and likely to increase demand on facilities elsewhere.

Strategy	Strengths and weaknesses
Lower colour temperature • **2700K lighting is sufficient for most outdoor activities** • **Even lower colour temperatures (< 2200K) should be considered if lighting must be placed close to high value habitats**	**Strengths:** Low colour temperature light contains more long-wavelength (amber, red) light, which is invisible to many animals as they do not have the cells or structures to perceive it. Low colour temperature light thus appears much less intense to many animals. Low colour temperature light contains less short wavelength (blue) light, so is less able to disrupt circadian rhythms. This is important for sleep, immune function and health in both humans and non-human animals. Even if not appropriate for playing surfaces, can be installed in car parks, grandstands, pavilions etc. **Weaknesses:** Availability of low-CCT lighting products for playing surface applications is uncertain Unclear whether low-CCT lighting for playing surfaces will be accepted by some codes Some animals do perceive long wavelength light and are unlikely to benefit from low colour temperature lighting. Seasonal cues in plants (growth, flowering) respond to changes in long wavelength light – plants are unlikely to benefit from low colour temperature lighting
Structural changes • **Plantings, walls or berms to reduce light spill**	**Strengths:** Permit code-compliant lighting whilst limiting spill into wider habitat **Weaknesses:** Not viable for tallest sports ground lighting fixtures (but worth considering in conjunction with lowered fixtures) Cost-prohibitive if required on all sides of large facilities May increase isolation and reduce sight-lines for late-night users
Community engagement • **Signs or correspondence to communicate need for wildlife sensitive lighting along shared path**	**Strengths:** Increases community awareness of the ecological effects of ALAN and the benefits of wildlife sensitive lighting May also improve safety and personal security (community will be aware that path is unlit, or lit less intensely, and behave accordingly) **Weaknesses:** Some users will remain unaware – cannot be a complete solution (but may reduce negative feedback)

Case Study 3: Carpark

Image: WE-EF Leuchten GmbH

Likely ecological impacts of ALAN from carparks

For outdoor car parks adjacent to a waterway, bushland or grassland, potential impacts of artificial light at night (ALAN) include:

- spread of artificial light over large areas; this is particularly the case for flying animals or animals that rest or forage in tree canopies.
- substantial reduction in effective size of neighbouring habitat due to 'edge effects' (habitat near carpark becomes uninhabitable for light-avoiding species). These effects may extend hundreds of metres.
- increased mortality of invertebrates (especially flying insects) attracted to lights, with cascading impacts on pollination and insectivorous birds, frogs and mammals
- barrier to movement of light-avoiding animals (most possums, bats, gliders and frogs; some birds) and also light-attracted animals (invertebrates and some birds get 'trapped' by lights); habitat can be fragmented by extensive lighting
- disrupted sleep for daytime animals
- masking of natural seasonal lighting cues from the sun and moon; this can lead to mistimed reproduction, growth, migration and development
- masking of natural sunrise and sunset cues; this can lead to animals being active at the wrong time of day, which can increase mortality due to exposure to new predators or mismatch with prey availability
- suppression of the daily vertical movement of aquatic invertebrates: these spend the day on the riverbed (or sea floor) then rise to the surface at night to feed on microscopic plants and algae. ALAN suppresses this movement and disrupts food chains.

Human interests to consider

- Carpark lighting is largely driven by human safety (trips and falls, pedestrian-vehicle interactions) and security concerns (fear of crime).
- Drivers need to see parking spaces and the driving surface between parking spaces; pedestrians may need to see between parked vehicles as well as the interior of their own vehicle. Thus the majority of the functional surface area of the carpark may require illumination for the benefit of drivers, pedestrians, or both.
- Lighting can encourage night-time gatherings in car parks, causing disturbance for neighbouring residents.
- Many carparks are closed or unused overnight.
- Prolonged exposure to intense lighting at night (especially light containing a high proportion of short wavelength blue light) disrupts human health, sleep and circadian rhythms (see Annexure B: Resource guide).

Best practice outcomes

A best practice car park lighting project should have most, or preferably all, of the following features:

- No lighting applied except where it will improve a specific, identified human safety outcome
- Lowest possible illuminance levels
- Bollards or lower poles to prevent spill of light beyond carpark and into nearby habitat
- Using full cut-off and shielded luminaires to prevent upward and outward light spill
- Lights facing inward and away from nearby habitat
- Use of adaptive lighting – lights dimmed or turned off outside of peak activity times, with sensor-activation for occasional late-night users
- Use of low colour-temperature luminaires – e.g. 2700-3000K – with minimal UV/violet/blue light content.

Lighting strategies to reduce wildlife impacts from carparks

Not all strategies will be appropriate in all scenarios, however at least some of the following strategies will be applicable to nearly all outdoor carparks

Strategy	Strengths and weaknesses
Curfews and adaptive controls • **Curfews: lights switch off (or dim) after a certain time** • **Timer switches: occasional users can switch lights on after curfew for limited amount of time** • **Sensors: dimmed or switched off lights can be returned to full strength when a person or vehicle is detected using the carpark**	**Strengths:** Provides natural darkness for part of the night, reducing impacts on animal movement and behaviour Provides full illumination when required by vehicles and pedestrians Reduces impacts of spill on nearby residents Reduces likelihood of night-time gatherings Reduces electricity consumption Can be retrofitted (in some cases via changes to controls rather than light fixtures). **Weaknesses:** Curfews don't reduce impacts of artificial light on animals with peak activity in early evening (many invertebrates).
Full cut-offs and shielding • **Full cut-offs prevent direct light emissions above the horizontal** • **Additional shielding may be required to prevent light spill**	**Strengths:** Keeps light only where needed – on the ground/vehicles and away from surrounding habitat Cut-offs and shielding can be retrofitted to some existing lights Benefits both wildlife and neighbouring residents. **Weaknesses:** Does not provide any period of full darkness Light reflected from surfaces may spill into neighbouring habitat.
Lower light fixtures • **shorter poles** • **bollards**	**Strengths:** Reduces lighting spill into nearby habitat Reduces distance from which light can be seen by birds, bats, flying invertebrates and arboreal mammals (especially if lights can be installed below canopy level) May reduce installation and maintenance costs. **Weaknesses:** May require additional fixtures to light same area More vulnerable to vandalism (paint, structural damage) Bollards may not be able to light interior of vehicles.
Reduced lighting intensity • **using lower lux fixtures**	**Strengths:** Reduces intensity of light spill and distance over which it is perceived Reduces 'edge effect' on neighbouring habitat; larger proportion of habitat remains unaffected

Strategy	Strengths and weaknesses
	Reduces impact on neighbouring residents May reduce electricity consumption Can be Australian Standards compliant by deeming activity and fear of crime levels to be low (for example changing a carpark from category PC1 to PC3). **Weaknesses:** Not consistent with lighting requirements for car spaces for people with disabilities and pedestrian crossing sites (these will require higher illuminance).
No lighting • **remove existing lighting** • **do not install new lighting**	**Strengths:** Appropriate for carparks in close proximity to high-value habitats, populations of threatened species or along migration routes Appropriate for carparks that are typically only used during the day Natural darkness is ecologically optimal. Wildlife can exhibit natural movement, behaviours and development Absence of light will discourage use of carpark late at night – less disruptive for neighbouring residents and will not encourage use of unsafe spaces Substantially reduces installation and maintenance costs of carpark. **Weaknesses:** Carpark will not be available for use after sunset (or it will not be compliant with Australian Standards if used after dark). This may not be realistic for many carparks (e.g. retail, business and transport hubs, sporting facilities), and likely to increase demand on facilities elsewhere.
Lower colour temperature • **2700K lighting is sufficient for most outdoor activities** • **Even lower colour temperatures (< 2200K) should be considered if lighting must be placed close to high value habitats**	**Strengths:** Contains more long-wavelength (amber, red) light, which is invisible to many animals, and thus appears much less intense to these animals Contains less short wavelength (blue) light, so is less able to disrupt circadian rhythms. This is important for sleep, immune function and health in both humans and non-human animals. **Weaknesses:** Some animals can perceive long wavelength light and are unlikely to benefit from low colour temperature lighting. Seasonal cues in plants (growth, flowering) respond to changes in long wavelength light – plants are unlikely to benefit from low colour temperature lighting. Networks' lighting palettes do not include low colour temperature luminaires – at present would require non-standard installation (at additional cost) for network-operated carpark lights. Very low colour temperatures may struggle to meet AS/ANZ 1158.6 requirements for colour rendering (CRI ≥ 70), although colour rendering in carparks may not be very important for safety (low-speed

Strategy	Strengths and weaknesses
	environment).
Structural changes • **Plantings, walls or berms to reduce light spill**	**Strengths:** Permit Australian Standards-compliant lighting whilst limiting spill into wider habitat May be appropriate where carpark is within or directly adjacent to habitat. **Weaknesses:** Cost-prohibitive for large or elevated (e.g. rooftop) carparks May increase isolation and reduce sight-lines for carpark users.
Community engagement • **Signs or correspondence to communicate need for wildlife sensitive lighting along shared path**	**Strengths:** Increases community awareness of the ecological effects of ALAN and the benefits of wildlife sensitive lighting May also improve safety and personal security (community will be aware that carpark is unlit, or lit less intensely, and behave accordingly). **Weaknesses:** Some users will remain unaware and may be at increased risk of collision etc.

Case Study 4: New or upgraded road lighting

Image: WE-EF Leuchten GmbH

Likely ecological impacts of ALAN from road lighting

For illuminated roadways located beside a waterway or amongst bushland or grassland, potential impacts of artificial light at night (ALAN) include:

- barrier to movement of light-avoiding animals (most possums, bats, gliders and frogs; some birds) and also light-attracted animals (invertebrates and some birds get 'trapped' by lights); habitat is effectively fragmented by lighting
- reduction in size of habitat due to 'edge effects' (habitat near road becomes uninhabitable for light-avoiding species)
- increased mortality of invertebrates (especially flying insects) attracted to lights, with cascading impacts on pollination and insectivorous birds, frogs and mammals
- disrupted sleep for daytime animals
- masking of natural seasonal lighting cues from the sun and moon; this can lead to mistimed reproduction, growth, migration and development
- masking of natural sunrise and sunset cues; this can lead to animals being active at the wrong time of day, which can increase mortality due to exposure to new predators or mismatch with prey availability
- suppression of the daily vertical movement of aquatic invertebrates: these spend the day on the riverbed then rise to the surface at night to feed on microscopic plants and algae. ALAN suppresses this movement and disrupts food chains.

These effects may add to or interact with the considerable environmental disturbance caused by other aspects of roadways, including land clearing, run off from hard surfaces, air and water pollution and traffic noise.

Human interests to consider

- Roads are key transport corridors, facilitating the movement of high volumes of vehicular traffic, often at high speeds. In winter, peak commuting times coincide with darkness.
- Footpaths and shared paths adjacent to roadways are also key transport corridors for pedestrians and cyclists, and are often illuminated by street lightings.
- Visibility is important to the safety of motorists, pedestrians and cyclists, including at points where they interact (intersections, pedestrian and cycle crossings).
- Evidence for the importance of lighting in improving visibility and road safety is mixed (see Appendix B: Resource guide).
- There is little evidence that streetlighting improves personal security or reduces crime, however its absence may exclude people from night-time travel due to fear of crime (see Appendix B: Resource guide).
- In agricultural areas, artificial light has been found to interfere with plant productivity by masking changes in daylength that otherwise trigger developmental events such as flowering, seed set and fruit set. In addition, the effects of artificial light on livestock are likely to be similar to those on wild animals, included altered behaviour, disrupted development and reduced immune response.

Best practice outcomes

A best practice road lighting project should have most, or preferably all, of the following features:

- No lighting applied except where it will improve a specific, identified human safety outcome
- Lowest possible illuminance levels
- Safe, unlit 'dark corridors' to allow wildlife to travel between habitat patches
- Lower poles to prevent spill of light beyond roadway and illumination of tree canopies
- Using full cut-off and shielded luminaires to prevent upward and outward light spill beyond road/footpath
- Lights facing away from nearby habitat
- Use of adaptive lighting – lights dimmed or turned off outside of peak activity times
- Where lighting is mandated (e.g. roundabouts), use of flag lighting as a default
- Use of low colour-temperature luminaires – e.g. 2700-3000K – with minimal UV/violet/blue light content.

Lighting strategies to reduce wildlife impacts from road lighting

Road lighting is highly prescriptive (see report re: Australian Standards, Department of Transport (VicRoads) and Austroads design guides), with limited scope for avoiding the effect of prescribed standards.

Accordingly, not all of the following strategies will be appropriate in all scenarios, however at least some should be considered when planning lighting and related infrastructure. Consideration may extend to whether the creation of infrastructure for which lighting is mandated (e.g. roundabouts) is appropriate in areas adjacent to sensitive habitats.

Strategy	Strengths and weaknesses
Avoid or limit new lighting • **Department of Transport design guidelines provide that some road types do not require illumination, or require only 'flag' lighting** • **Includes rural freeways, some urban freeways, some arterial roads** • **'Flag' lighting can be installed at the lowest V-category level (V5)**	**Strengths:** Natural darkness is ecologically optimal. Wildlife can exhibit natural movement, behaviours and development Darkness can provide similar benefits to livestock and agricultural plantings adjacent to roadways Costs of lighting infrastructure and operation are avoided. **Weaknesses:** Not consistent with Australian Standards in many instances (intersections, roundabouts, pedestrian crossings, arterial roads with footpaths, freeways with complex interchanges or high rates of collision).
Avoid creation of infrastructure for which lighting is mandated (especially in areas adjacent to habitat) including: • **roundabouts** • **footpaths** • **pedestrian crossings & underpasses**	**Strengths:** Natural darkness is ecologically optimal. Wildlife can exhibit natural movement, behaviours and development Darkness can provide similar benefits to livestock and agricultural plantings adjacent to roadways Costs of lighting infrastructure and operation are avoided. **Weaknesses:** Not applicable where there are overriding safety reasons for infrastructure (e.g. need to introduce roundabout to deal with dangerous intersection) May require placement of infrastructure (e.g. pedestrian crossings) at points where they are less convenient for users.
Reduce categorisation of traffic, pedestrian activity and fear of crime • **Opting for lower lighting categories allows less intense lighting to be employed** • **Australian Standards impose lighting categories according to the level of activity, fear of crime, vehicle speed and need for amenity** • **Determination of whether these factors are 'low', 'moderate' or 'high' is subjective**	**Strengths:** Reduces intensity of light spill and distance over which it is perceived Reduces glare for road users and reflection of light off footpath Reduces 'edge effect' on neighbouring habitat; larger proportion of habitat remains unaffected Reduces impact on neighbouring residents May reduce electricity consumption. **Weaknesses:** Typically requires multiple factors to be assessed as 'moderate' or 'low'. For example:

Strategy	Strengths and weaknesses
• **Complimentary changes (e.g. reduction in night-time speed limits) can enable lower categories to be used**	• on minor roads (Category P lighting) both pedestrian activity and fear of crime must be assessed as moderate or low to allow lower lighting subcategories • on major roads (Category V lighting) both vehicle speeds and activity must be assessed as moderate or low to allow lower lighting subcategories.
Lower light fixtures • **shorter poles (for both V- and P-category lighting)** • **bollards (P-category only)** • **handrail lighting (P-category only)**	**Strengths:** Reduces lighting spill into nearby habitat Reduces distance from which light can be seen by birds, bats, flying invertebrates and arboreal mammals Intensity of each luminaire can be reduced Supported by VicRoads Technical Guideline TCG 006 (paragraph 2.3 allows shorter mountings where light spill is likely to be an issue). **Weaknesses:** May not be fully AS/NZS1158.3.1 compliant (if spill off path is removed entirely) unless wildlife impact provision (paragraph 3.1.3.5) can be invoked May increase ecological impacts on ground-dwelling animals (beetles, wombats, reptiles, birds) More vulnerable to vandalism (paint, structural damage) May require increased number of luminaires (as each has less reach).
Light cut-offs and shielding • **Full cut-offs prevent direct light emissions above the horizontal** • **Additional shielding may be required to prevent light spill**	**Strengths:** Keeps light only where needed – on the road/footpath and away from surrounding habitat Can be retrofitted to many existing lights Can be used on standard network and Department of Transport lights. **Weaknesses:** May not be fully AS/NZS1158.3.1 compliant (if spill off path is removed entirely) unless wildlife impact provision (paragraph 3.1.3.5) can be invoked Sudden change in light levels between footpath and nearby habitat may increase fear of crime (cannot see person hiding in bushes).

Strategy	Strengths and weaknesses
Lower colour temperature • **Australian Standards do not impose limits on colour temperature (provided colour rendering requirements are met)** • **2700K lighting that meets colour-rendering requirements is now available** • **Even lower colour temperatures (< 2200K) should be considered if lighting must be placed close to high value habitats**	**Strengths:** Contains more long-wavelength (amber, red) light, which is invisible to many animals, and thus appears much less intense to these animals Contains less short wavelength (blue) light, so is less able to disrupt circadian rhythms. This is important for sleep, immune function and health in both humans and non-human animals. Is less disruptive of human night vision (dark-adapted vision) – this is important for vehicles transitioning from lit to unlit roads, or pedestrians leaving lit footpaths for unlit spaces Scatters less and penetrates better in mist, fog, rain, haze and smoke, reducing glare and improving visibility Can be a good, lower-impact option where there is pressure to install flag lighting. **Weaknesses:** Some animals can perceive long wavelength light and are unlikely to benefit from low colour temperature lighting. Seasonal cues in plants (growth, flowering) respond to changes in long wavelength light – plants are unlikely to benefit from low colour temperature lighting. Networks and Department of Transport lighting palettes do not include low colour temperature luminaires – at present would require non-standard installation (at additional cost). Very low colour temperatures may struggle to meet AS/ANZ 1158.6 requirements for colour rendering (CRI ≥ 70).
Adaptive lighting • **Lights dimmed or turned off between evening and morning peaks** • **May include sensor to temporarily re-instate full intensity when user is present**	**Strengths:** Provides natural darkness or reduced intensity for part of the night, reducing impacts on animal movement and behaviour Reduces impacts of spill on nearby residents Reduces electricity consumption Can often be retrofitted Supported by Australian Standards for both major road and minor road/pedestrian lighting (AS/NZS 1158.1.1 paragraph 2.4.2 and AS/NZS1158.3.1 paragraph 3.1). **Weaknesses:** May increase installation costs May increase fear of crime for footpath users late at night Doesn't reduce impacts of artificial light on animals with peak activity in early evening (many invertebrates).

Strategy	Strengths and weaknesses
Dark corridors • **Unlit crossings, culverts or other infrastructure to allow wildlife to travel between habitat patches**	**Strengths:** Improves ecological connectivity between habitat patches Increases access to resources (foraging, water, roosting and nesting sites, potential mates) Prevents isolation and inbreeding of light-avoiding wildlife populations. **Weaknesses:** Can only be implemented intermittently (reduces but does not eliminate isolation) On busy roads requires wildlife crossing structures (culverts, rope bridges) to avoid conflict between wildlife and motorists.
Structural changes • **Plantings, walls or berms to reduce light spill**	**Strengths:** Permit standards-compliant lighting whilst limiting spill into wider habitat. **Weaknesses:** Cost-prohibitive for long stretches of road May increase isolation and reduce sight-lines for footpath users.
Community engagement • **Signs or correspondence to communicate need for wildlife sensitive lighting along footpath or roadway**	**Strengths:** Increases community awareness of the ecological effects of ALAN and the benefits of wildlife sensitive lighting. **Weaknesses:** Some users will remain unaware.

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