UN environment

CMS

CONVENTION ON MIGRATORY SPECIES

UNEP/CMS/COP13/Doc.26.4.9.1/Rev.1

30 January 2020

Original: English

13th MEETING OF THE CONFERENCE OF THE PARTIES
Gandhinagar, India, 17 - 22 February 2020
Agenda Item 26.4

LIGHT POLLUTION GUIDELINES FOR WILDLIFE INCLUDING MARINE TURTLES,SEABIRDS AND MIGRATORY SHOREBIRDS

(Prepared by the Government of Australia)

Summary:

Decision 12.17 on Marine Turtles requested the Scientific Council to review relevant scientific information on conservation and threats to marine turtles, such as climate change and sky glow.

To assist in the consideration of the threat of sky glow on marine turtles, the Australian Government took a proactive approach to the emerging conservation challenge of increasing artificial light and its impacts on the conservation of wildlife by developing *National Light Pollution Guidelines for Wildlife, including Marine Turtles, Seabirds and Migratory Shorebirds*.

The Guidelines aim to raise awareness of the potential impacts of artificial light on wildlife and provide a framework for assessing and managing these impacts on susceptible wildlife, including migratory species. The Guidelines are built around a concept of best practice lighting design principles and a risk assessed and adaptive management approach to light management near protected wildlife.

Adoption and implementation of the Guidelines will contribute towards the implementation of targets 1, 2, 3, 7 and 11 of the Strategic Plan for Migratory Species 2015 – 2023.

In Rev.1 of the document, the guidelines attached as Annex 2 contain some minor editorial amendments which do not change the substantive nature of the document.

LIGHT POLLUTION GUIDELINES FOR WILDLIFE INCLUDING MARINE TURTLES, SEABIRDS AND MIGRATORY SHOREBIRDS

Background

1. Globally, artificial light is increasing by around two per cent per year and is recognised as an emerging issue for the conservation of wildlife, astronomy and human health. Artificial light is needed for human safety, increased productivity and amenity.

2. However, it can have negative implications for wildlife conservation. When artificial light contributes to the brightening of the night sky, it is called light pollution. Artificial light can disrupt critical behaviours in wildlife, stalling the recovery of threatened species and interfering with a migratory species' ability to undertake long-distance migrations integral to its life cycle.

3. Artificial light is known to adversely affect many species and ecological communities. It can change behaviour and/or physiology, reducing survivorship or reproductive output. It can also have the indirect effect of changing the availability of habitat or food resources. It can attract predators and invasive pests, both of which may pose a threat to threatened and/or migratory species.

4. Behavioural changes in wildlife in response to artificial light have been well described for some migratory species. Adult marine turtles avoid nesting on beaches that are artificially lit, and adult and hatchling turtles can be disoriented and unable to find the ocean in the presence of direct light or sky glow. Similarly, lights can disorient flying birds and cause them to collide with infrastructure. Birds may starve when artificial lighting disrupts foraging, and fledgling seabirds may not be able to take their first flight if their nesting habitat never becomes dark. Migratory shorebirds may use less preferable roosting sites to avoid lights and may be exposed to increased predation where lighting makes them visible at night.

5. The indirect effects of artificial light can also be detrimental to many species. For example, in Australia, the Mountain Pygmy Possum feeds primarily on the Bogong Moth, a long-distance nocturnal migrator that is attracted to light. Recent declines in moth populations, in part due to artificial light, have reduced the food supply for the Possum. Changes in food availability due to artificial light affect other animals, such as bats, and can cause changes in fish assemblages. Lighting may also attract invasive pests such as Cane Toads, or predators, increasing pressure on protected species.

Discussion and analysis

6. To address this conservation challenge, the Australian Government developed *National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds* (Annex 2). The Guidelines aim to raise awareness of the potential impacts of artificial light on wildlife and provide a framework for assessing and managing these impacts around susceptible listed wildlife.

7. The Guidelines are built around a concept of best practice in lighting design principles; and a risk assessed and adaptive management approach to light management near protected wildlife.

8. The Guidelines recognize the potential of conflicting requirements for human safety and wildlife conservation, and do not seek to inhibit the benefits afforded by artificial light, but aim to find a balance between wildlife conservation needs and human safety.

9. Through the development of the Guidelines, it became evident that artificial light has the potential to impact on a broad range of threatened and migratory species, and so the scope of the Guidelines was broadened to include all of Australia's listed protected species for which artificial light has been demonstrated to negatively affect species' behaviour, survivorship or reproduction.

10. The Guidelines outline the process to be followed where there is the potential for artificial lighting to affect wildlife. They apply to new projects, lighting upgrades and where there is evidence of wildlife being affected by existing artificial light.

11. The Guidelines recommend:
    a. using Best Practice Lighting Design to reduce light pollution and minimize the effect on wildlife; and
    b. undertaking an Environmental Impact Assessment for Effects of Artificial Light on Wildlife for species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.

12. The benefits of developing best practice management for artificial light will ultimately be broader than conservation of threatened and migratory wildlife, but will also have benefits for biodiversity more broadly including reduced energy consumption.

13. The technology around lighting hardware, design and control is changing rapidly and biological responses to artificial light vary by species, location and environmental conditions. It is not possible to set prescriptive limits on lighting. Instead, the Guidelines take an outcomes approach to assessing and mitigating the effect of artificial light on wildlife.

14. While the Guidelines were developed within the Australian context, the pervasive nature of light pollution means that the broad parameters, process, and technical and practical information contained in the Guidelines can be applied in other countries experiencing similar situations.

15. The Guidelines provide theoretical, technical and practical information required to assess if a lighting project is likely to affect wildlife; and the management tools to minimize and mitigate that affect. These techniques can be applied regardless of scale: from small, domestic projects to large-scale industrial developments.

16. The CMS Family is invited to adopt the Guidelines presented at Annex 2 for use by Parties and subsidiary instruments. It is envisaged that the Guidelines, if adopted, will form part of the CMS Family Guidelines.

<u>Recommended Actions</u>

17. The Conference of Parties is recommended to:

    a) adopt the proposed Resolution contained in Annex 1; and

    b) adopt the Guidelines contained in Annex 2[1], which will form an Annex to the Resolution.

[1] In order to save resources, the Secretariat has only translated the actual guidelines which are appended at Annex 2. The full 98-page document including many useful Appendices is posted in English only as Information Document UNEP/CMS//COP13/Inf.5.

ANNEX 1

DRAFT RESOLUTION

LIGHT POLLUTION GUIDELINES FOR WILDLIFE

Acknowledging that artificial light is increasing globally by around 2 per cent per year,

Recognizing that artificial light is an emerging issue for the conservation of wildlife, astronomy and human health,

Further recognizing that when artificial light contributes to the brightening of the night sky it is called light pollution,

Alarmed that artificial light is known to adversely affect many species and ecological communities by disrupting critical behaviours in wildlife, stalling the recovery of threatened species and interfering with a migratory species' ability to undertake long distance migrations integral to its life cycle,

Appreciating that artificial light at night also provides for human safety, amenity and increased productivity, and sometimes there are conflicting requirements for human safety and wildlife conservation,

Fully aware that there are both direct and indirect effects of artificial light that can be detrimental to many migratory species, including changing behaviour and/or physiology, reducing survivorship or reproductive output,

Noting that there are many documented instances of the negative effect of artificial light on migratory species, including avoidance of marine turtles to nesting on beaches that are artificially lit, migratory shorebirds using less preferable roost sites to avoid lights, and disruption in foraging and fledgling for a number of seabirds,

Recalling CMS Decision 12.17 on Marine Turtles that requests the Scientific Council to review relevant scientific information on conservation and threats to marine turtles, such as climate change and sky glow,

Noting with appreciation the endeavours of the Australian Government in developing guidance in relation to managing light pollution and identifying a process that can be followed where there is the potential for artificial lighting to affect wildlife,

The Conference of the Parties to the
Convention on the Conservation of Migratory Species of Wild Animals

1. *Agrees* that when artificial light contributes to the brightening of the night sky, it is referred to as light pollution;

2. *Acknowledges* that both humans and wildlife need the right light, in the right place, at the right time;

3. *Adopts* the Guidelines contained in the Annex to this Resolution designed to aid CMS Parties by providing a framework for assessing and managing the impact of artificial light on susceptible wildlife in their jurisdiction, noting that the Guidelines do not seek to inhibit the benefits afforded by artificial light;

4. *Encourages* Parties, in instances where artificial light is impacting migratory species, to find creative solutions that meet both human safety requirements and wildlife conservation;

5. *Implores* Parties to manage artificial light so that migratory species are not disrupted within, nor displaced from, important habitat, and are able to undertake critical behaviours such as foraging, reproduction and migration;

6. *Urges* Parties to use the Guidelines to adopt appropriate measures and processes designed to assess if a lighting project is likely to affect wildlife and identify management tools to minimise and mitigate that affect;

7. *Recommends* that non-Parties and other stakeholders, including non-governmental organizations, use and promote the Guidelines to facilitate broad uptake of processes designed to limit and mitigate the harmful effects of artificial light on migratory species; and

8. *Requests* the Secretariat to promote the Guidelines to the CMS Family, including its subsidiary agreements and memoranda of understanding, and more broadly to other relevant multi-lateral environment agreements such as the Convention on Biological Diversity, the Inter-American Sea Turtle Convention, the Western Hemisphere Migratory Shorebird Initiative and the Secretariat of the Pacific Regional Environment Programme.

ANNEX 2

Australian Government
Department of the Environment and Energy

GOVERNMENT OF WESTERN AUSTRALIA
Department of **Biodiversity, Conservation and Attractions**

Light Pollution Guidelines

National Light Pollution Guidelines for Wildlife

Including marine turtles, seabirds and migratory shorebirds

January 2020

Version 1.0

Acknowledgments

The Department of the Environment and Energy (the Department) would like to acknowledge those who contributed to the development of these Light Pollution Guidelines.

Funding for the development of the Guidelines was provided by the North West Shelf Flatback Conservation Program in the Western Australian Department of Biodiversity, Conservation and Attractions and by the Australian Government's National Environmental Science Program (NESP) Emerging Priorities Funding.

These Guidelines are based on the draft written by Kellie Pendoley, Catherine Bell, Chris Surman and Jimmy Choi with contributions from Airam Rodriguez, Andre Chiaradia, Godfrey Bridger, Adam Carey, Adam Mitchell and Phillipa Wilson. Simon Balm, Steve Coyne, Dan Duriscoe, Peter Hick, Gillian Isoardi, Nigel Jackett, Andreas Jechow, Mike Salmon and Warren Tacey generously provided technical reviews of sections of this document.

The Department acknowledges the traditional owners of country throughout Australia and their continuing connection to land, sea and community. We pay our respects to them and their cultures and to their elders both past and present.

Front cover images: Clown fish - DSEWPaC; Hawksbill Turtle hatchling – Scott Whiting; Mountain Pygmy Possum – Linda Broom; Black Browed Albatross – Alan Danks; Curlew Sandpiper – Brian Furby; Fleshfooted Shearwater - Richard Freeman.

Contents

National Light Pollution Guidelines

Introduction

Natural darkness has a conservation value in the same way that clean water, air and soil has intrinsic value. Artificial light at night is increasing globally by about two per cent per year[1]. Animals perceive light differently from humans and artificial light can disrupt critical behaviour and cause physiological changes in wildlife[2]. For example, hatchling marine turtles may not be able to find the ocean when beaches are lit[3], and fledgling seabirds may not take their first flight if their nesting habitat never becomes dark[4]. Tammar wallabies exposed to artificial light have been shown to delay reproduction[5] and clownfish eggs incubated under constant light do not hatch[6].

Consequently, artificial light has the potential to stall the recovery of a threatened species. For migratory species, the impact of artificial light may compromise an animal's ability to undertake long-distance migrations integral to its life cycle.

Artificial light at night provides for human safety, amenity and increased productivity. Australian legislation and standards regulate artificial light for the purpose of human safety. These Guidelines do not infringe on human safety obligations. Where there are competing objectives for lighting, creative solutions may be needed that meet both human safety requirements for artificial light and threatened and migratory species conservation.

The Guidelines outline the process to be followed where there is the potential for artificial lighting to affect wildlife. They apply to new projects, lighting upgrades (retrofitting) and where there is evidence of wildlife being affected by existing artificial light.

The technology around lighting hardware, design and control is changing rapidly and biological responses to artificial light vary by species, location and environmental conditions. It is not possible to set prescriptive limits on lighting. Instead, these Guidelines take an outcomes approach to assessing and mitigating the effect of artificial light on wildlife.

Figure 1 Pink anemone fish and marine turtle laying eggs. Photos: Nigel Marsh and Robert Thorn.

How to use these Guidelines

These Guidelines provide users with the theoretical, technical and practical information required to assess if artificial lighting is likely to affect wildlife and the management tools to minimise and mitigate that affect. These techniques can be applied regardless of scale, from small, domestic projects to large-scale industrial developments.

The aim of the Guidelines is that artificial light will be managed so wildlife is:

1. **Not disrupted within, nor displaced from, important habitat; and**
2. **Able to undertake critical behaviours such as foraging, reproduction and dispersal.**

The Guidelines recommend:

1. Always using Best Practice Lighting Design to reduce light pollution and minimise the effect on wildlife.
2. Undertaking an Environmental Impact Assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.

Technical Appendices

The Guidelines are supported by a series of technical appendices that provide additional information about Best Practice Lighting Design, What is Light and How Wildlife Perceive it, Measuring Biologically Relevant Light, and Artificial Light Auditing. There is also a checklist for artificial light management, and species-specific information for the management of artificial light for Marine Turtles, Seabirds and Migratory Shorebirds. The range of species covered in taxa-specific appendices will be broadened in the future.

Regulatory Considerations for the Management of Artificial Light around Wildlife

These Guidelines provide technical information to guide the management of artificial light for *Environment Protection and Biodiversity Conservation Act (1999)* (EPBC Act) listed threatened and migratory species, species that are part of a listed ecological community, and species protected under state or territory legislation for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.

Environment Protection and Biodiversity Conservation Act (1999)

The EPBC Act regulates any action that will have, or is likely to have, a significant impact on a Matter of National Environmental Significance (MNES), including listed threatened and migratory species. Any action likely to have a significant impact on a MNES must be referred to the Australian Government for assessment. Further, it is an offence under the EPBC Act to kill, injure, take or trade a listed threatened, migratory or marine species in a Commonwealth area. Anyone unsure of whether the EPBC Act applies, is strongly encouraged to seek further information.

State and territory legislation and policy

State and territory environmental legislation and policy frameworks may also have provisions for managing threats, such as light, to listed species. For example, artificial light is a form of pollution regulated for impacts on humans and the environment under the Australian Capital Territory *Environment Protection Act 1997*. Consideration should be given to the function of relevant state and territory environment and planning legislation and policy concerning the protection of wildlife from artificial light.

Local and regional government requirements

Advice should also be sought from local government as to whether specific requirements apply in the area of interest concerning artificial light and wildlife. For example, the Queensland Government *Sea Turtle Sensitive Area Code* provides for local governments to identify sea turtle sensitive areas within local government planning schemes. Development in these areas will need to avoid adverse effects to sea turtles from artificial lighting.

Australian standards

Australian standards provide agreed limits for various lighting scenarios, generally for the purposes of human safety and for the provision of amenity. For example, Australian Standard DR AS/NZS 1158.3.1:2018 *Lighting for roads and public spaces pedestrian area (Category P) lighting* provides minimum light performance and design standards for pedestrian areas.

Australian standards also provide for consideration of environmental concerns. Australian Standard *AS/NZS 4282:2019 Control of the obtrusive effects of outdoor lighting* recognises the impact of artificial light on biota.

These Light Pollution Guidelines should be followed to ensure all lighting objectives are adequately addressed. This may require solutions to be developed, applied and tested to ensure lighting management meets the needs of human safety and wildlife conservation. The Case Studies illustrate examples of how a liquefied natural gas processing plant, a transport authority and a marine research vessel have addressed this challenge.

Associated guidance

These Guidelines should be read in conjunction with:

- EPBC Act 1999 Significant Impact Guidelines 1.1 Matters of National Environmental Significance
- EPBC Act 1999 Significant Impact Guidelines 1.2 Actions on, or impacting upon, Commonwealth land and Actions by Commonwealth Agencies
- Recovery Plans and approved conservation advices for listed threatened species
- approved Wildlife Conservation Plans for listed migratory species
- state and territory environmental legislation, regulations, and policy and guidance documents
- up-to-date scientific literature
- local and Indigenous knowledge.

Wildlife and Artificial Light

Vision is a critical cue for wildlife to orient themselves in their environment, find food, avoid predation and communicate[7]. An important consideration in the management of artificial light for wildlife is an understanding of how light is perceived by animals, both in terms of what the eye sees and the animal's viewing perspective.

Animals perceive light differently from humans. Most animals are sensitive to ultra-violet (UV)/violet/blue light[8], while some birds are sensitive to longer wavelength yellow/orange[9] and some snakes, can detect infra-red wavelengths[10] (Figure 2). Understanding the sensitivity of wildlife to different light wavelengths is critical to assessing the potential effects of artificial light on wildlife.

The way light is described and measured has traditionally focused on human vision. To manage light appropriately for wildlife, it is critical to understand how light is defined, described and measured and to consider light from the wildlife's perspective.

For a detailed explanation of these issues see What is Light and how do Wildlife Perceive it? The Glossary provides a summary of terms used to describe light and light measurements and notes the appropriate terms for discussing the effects of light on wildlife.

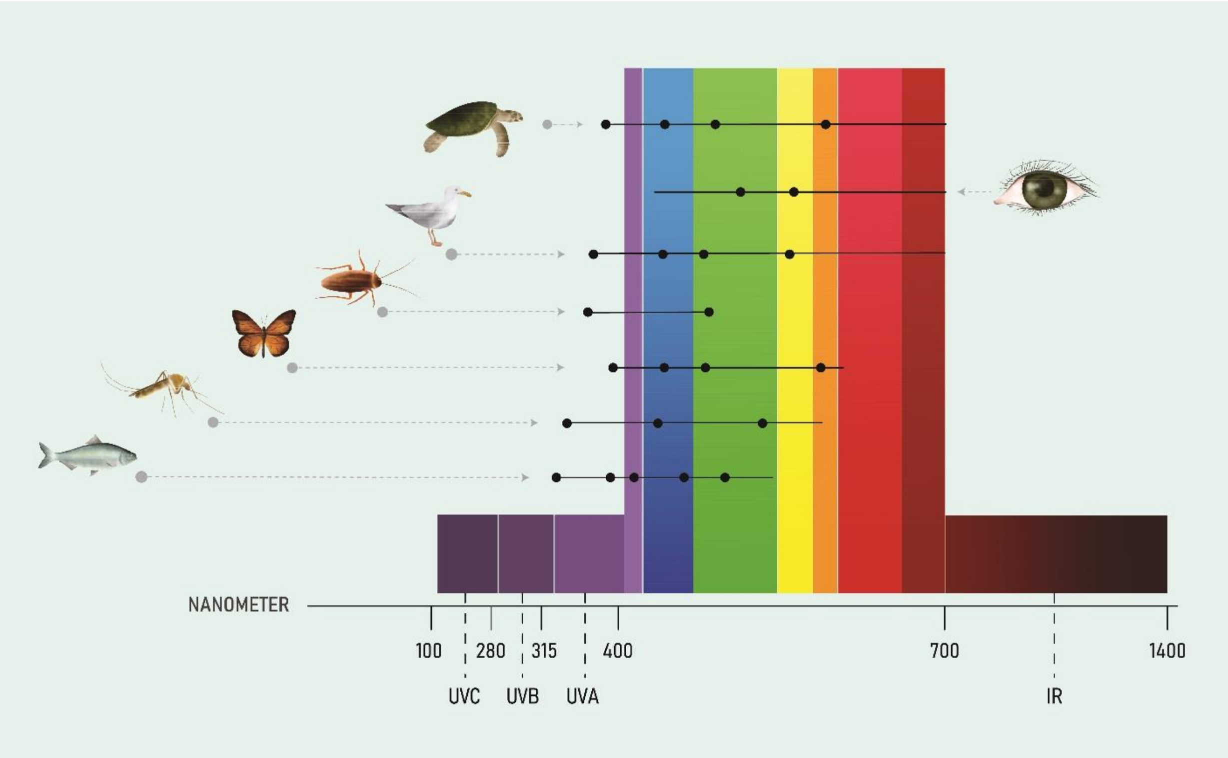

Figure 2 Ability to perceive different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivities. Figure adapted from Campos (2017)[8].

How light affects wildlife

Artificial light is known to adversely affect many species[2,11] and ecological communities[12,13]. It can change behaviour and/or physiology, reducing survivorship or reproductive output. It can also have the indirect effect of changing the availability of habitat or food resources. It can attract predators and invasive pests, both of which may pose a threat to listed species.

Behavioural changes in wildlife have been well described for some species. Adult marine turtles may avoid nesting on beaches that are brightly lit[14,15], and adult and hatchling turtles can be disoriented and unable to find the ocean in the presence of direct light or sky glow[3,15,16]. Similarly, lights can disorient flying birds, particularly during migration, and cause them to divert from efficient migratory routes or collide with infrastructure[17]. Birds may starve when artificial lighting disrupts foraging, and fledgling seabirds may not be able to take their first flight if their nesting habitat never becomes dark[4]. Migratory shorebirds may use less preferable roosting sites to avoid lights and may be exposed to increased predation where lighting makes them visible at night[4].

Physiological changes have been described in the Tammar Wallaby when exposed to artificial light, resulting in delayed reproduction[5], and clownfish eggs incubated under constant light do not hatch[6]. The stress hormone corticosterone in free living song birds has been shown to increase when exposed to white light compared with green or red light and those with high stress hormone levels had fewer offspring[18]. Plant physiology can also be affected by artificial light with changes to growth, timing of flowering and resource allocation. This can then have flow-on affects for pollinators and herbivores[13].

The indirect effects of artificial light can also be detrimental to threatened species. The Mountain Pygmy Possum, for example, feeds primarily on the Bogong Moth, a long distance nocturnal migrator that is attracted to light[19]. Recent declines in moth populations, in part due to artificial light, have reduced the food supply for the possum[20]. Changes in food availability due to artificial light affect other animals, such as bats[21], and cause changes in fish assemblages[22]. Lighting may also attract invasive pests such as cane toads[23], or predators, increasing pressure on listed species[24].

The way in which light affects a listed species must be considered when developing management strategies as this will vary on a case by case basis.

These Guidelines provide information on the management of artificial light for Marine Turtles, Seabirds and Migratory Shorebirds in the technical appendices. Consideration should be given to the direct and indirect effect of artificial light on all listed species for which artificial light has been demonstrated to negatively affect behaviour, survivorship or reproduction.

Light Emitting Diodes (LEDs)

During the life of these Guidelines, it is anticipated that light technology may change dramatically. At the time of writing, LEDs were rapidly becoming the most common light type used globally. This is primarily because they are more energy efficient than earlier light sources. LEDs and smart control technologies (such as motion sensors and timers) provide the ability to control and manage the physical parameters of lighting, making them an integral tool in managing the effects of artificial light on wildlife.

Whilst LEDs are part of the solution, consideration should be given to some of the characteristics of LEDs that may influence the effect of artificial light on wildlife. White LEDs generally contain short wavelength blue light. Short wavelength light scatters more readily than long wavelength light, contributing more to sky glow. Also, most wildlife is sensitive to blue light (Figure 2). More detailed consideration of LEDs, their benefits and challenges for use around wildlife are provided in the Technical Appendix What is Light and how does Wildlife Perceive it?

When to Consider the Impact of Artificial Light on Wildlife?

Is Artificial Light Visible Outside?

Any action or activity that includes externally visible artificial lighting should consider the potential effects on wildlife (refer Figure 3 below). These Guidelines should be applied at all stages of management, from the development of planning schemes to the design, approval and execution of individual developments or activities, through to retrofitting of light fixtures and management of existing light pollution. Best Practice Lighting Design is recommended as a minimum whenever artificial lighting is externally visible.

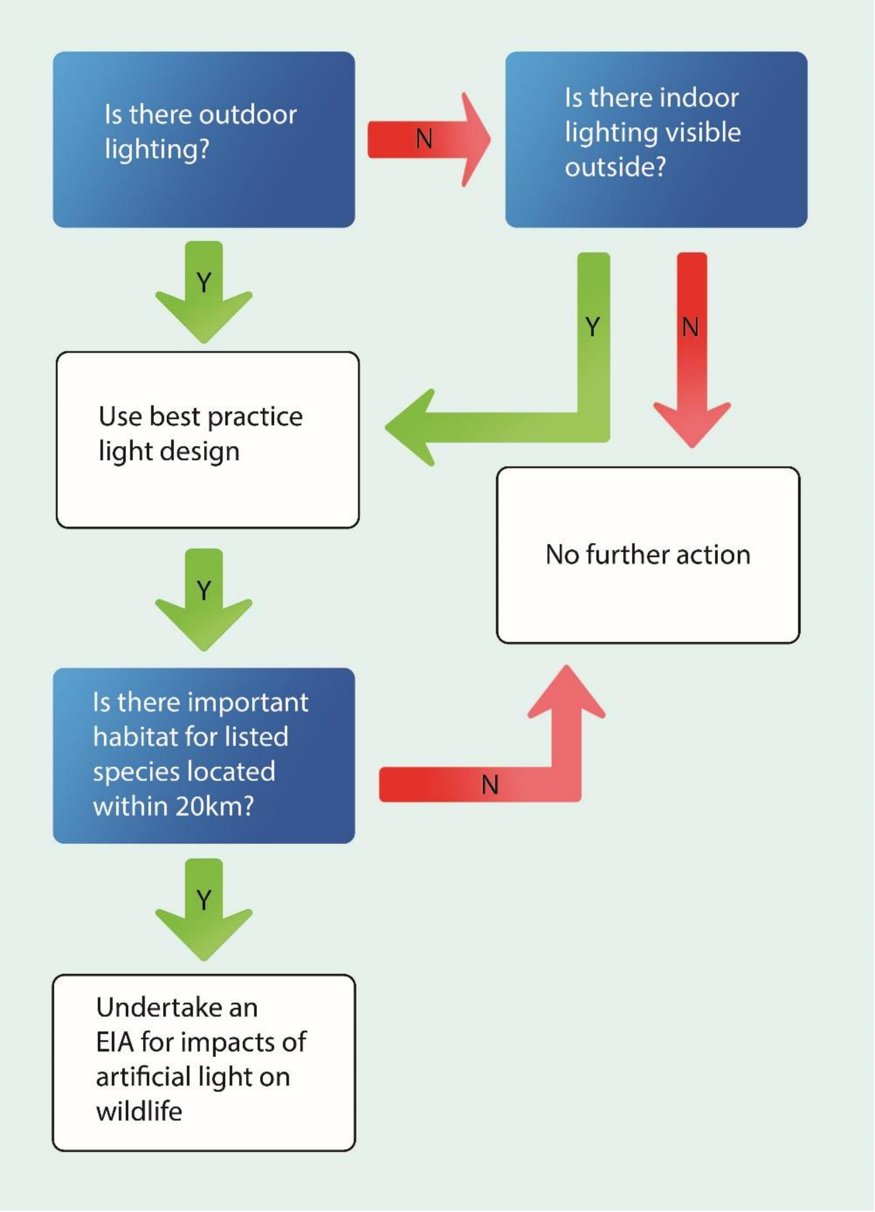

Figure 3 Decision tree to determine whether to undertake an environmental impact assessment for the effects of artificial light on wildlife.

Best practice lighting design

Natural darkness has a conservation value and should be protected through good quality lighting design and management for the benefit of all living things. To that end, all infrastructure that has outdoor artificial lighting or internal lighting that is externally visible should incorporate best practice lighting design.

Incorporating best practice lighting design into all infrastructure will not only have benefits for wildlife, but will also save energy and provide an economic benefit for light owners and managers.

Best practice lighting design incorporates the following design principles.

1. **Start with natural darkness and only add light for specific purposes.**
2. **Use adaptive light controls to manage light timing, intensity and colour.**
3. **Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill.**
4. **Use the lowest intensity lighting appropriate for the task.**
5. **Use non-reflective, dark-coloured surfaces.**
6. **Use lights with reduced or filtered blue, violet and ultra-violet wavelengths.**

Figure 4 provides an illustration of best practice light design principles. For a detailed explanation see Technical Appendix Best Practice Lighting Design.

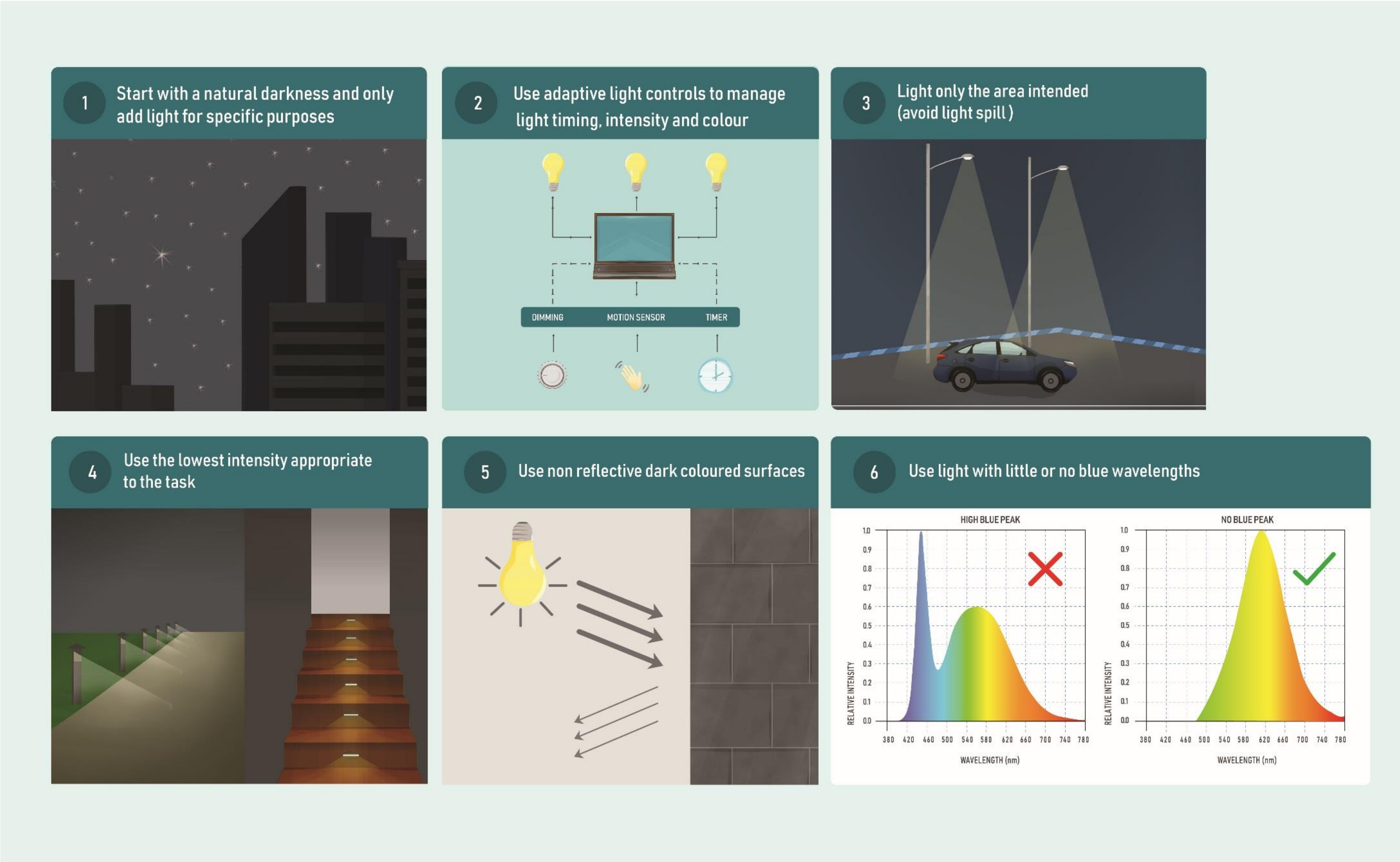

Figure 4 Principles for best practice lighting design.

Is there Important Habitat for Listed Species Located within 20km?

Important habitats are those areas necessary for an ecologically significant proportion of a listed species to undertake important activities such as foraging, breeding, roosting or dispersal. This might include areas that are of critical importance for a particular life stage, are at the limit of a species range or habitat, or where the species is declining. They may also be a habitat where the presence of light pollution may cause a significant decline in a listed threatened or migratory species.

Important habitat will vary depending on the species. For some species, areas of importance have been designated through recovery plans, conservation advice, and under planning regulations (for example Queensland Sea Turtle Sensitive Areas). Important habitat would include those areas that are consistent with 'habitat critical to the survival' of a threatened species and 'important habitat' for listed migratory species as described in the EPBC Act Significant Impact Guidelines[25]. Important habitat may include areas designated as Biologically Important Areas (BIAs), or in the case of migratory shorebirds, Internationally Important or Nationally Important Habitat. Consideration should be given to the ecological characteristics of Ramsar sites and the biological and ecological values of National and World Heritage Areas.

Species specific descriptions of important habitat can be found in Technical Appendices relating to Marine Turtles, Seabirds and Migratory Shorebirds. For other listed species see relevant information available in Associated guidance and Desktop Study of Wildlife.

Where there is important habitat for listed species that are known to be affected by artificial light within 20 km of a project, species specific impacts should be considered through an Environmental Impact Assessment (EIA) process.

The 20 km threshold provides a precautionary limit based on observed effects of sky glow on marine turtle hatchlings demonstrated to occur at 15-18 km[26,27] and fledgling seabirds grounded in response to artificial light 15 km away[28]. The effect of light glow may occur at distances greater than 20 km for some species and under certain environmental conditions. The 20 km threshold provides a nominal distance at which artificial light impacts should be considered, not necessarily the distance at which mitigation will be necessary. For example, where a mountain range is present between the light source and an important turtle nesting beach, further light mitigation is unlikely to be needed. However, where island infrastructure is directly visible on an important turtle nesting beach across 25 km of ocean in a remote location, additional light mitigation may be necessary.

Managing existing light pollution

The impact of artificial light on wildlife will often be the result of the effect of all light sources in the region combined. As the number and intensity of artificial lights in an area increases there will be a visible, cumulative increase in sky glow. Sky glow is the brightness of the night sky caused by the reflected light scattered from particles in the atmosphere. Sky glow comprises both natural and artificial sky glow. As sky glow increases so does the potential for adverse impacts on wildlife.

Generally, there is no one source of sky glow and management should be undertaken on a regional, collaborative basis. Artificial light mitigation and minimisation will need to be addressed by the community, regulators, councils and industry to prevent the escalation of, and where necessary reduce, the effects of artificial light on wildlife.

The effect of existing artificial light on wildlife is likely to be identified by protected species managers or researchers that observe changes in behaviour or population demographic parameters that can be attributed to increased artificial sky glow. Where this occurs, the population/behavioural change should be monitored, documented and, where possible, the source(s) of light identified. An Artificial Light Management Plan should be developed in collaboration with all light owners and managers to mitigate impacts.

Environmental Impact Assessment for Effects of Artificial Light on Wildlife

There are five steps involved in assessing the potential effects of artificial light on wildlife, and the adaptive management of artificial light requires a continuing improvement process (Figure 5). The amount of detail included in each step depends on the scale of the proposed activity and the susceptibility of wildlife to artificial light. The first three steps of the EIA process should be undertaken as early as possible in the project's life cycle and the resulting information used to inform the project design phase.

Marine Turtle, Seabird and Migratory Shorebird Technical Appendices give specific consideration to each of these taxa. However, the process should be adopted for other protected species affected by artificial light.

Qualified personnel

Lighting design/management and the EIA process should be undertaken by appropriately qualified personnel. Management plans should be developed and reviewed by appropriately qualified lighting practitioners in consultation with appropriately qualified wildlife biologists or ecologists.

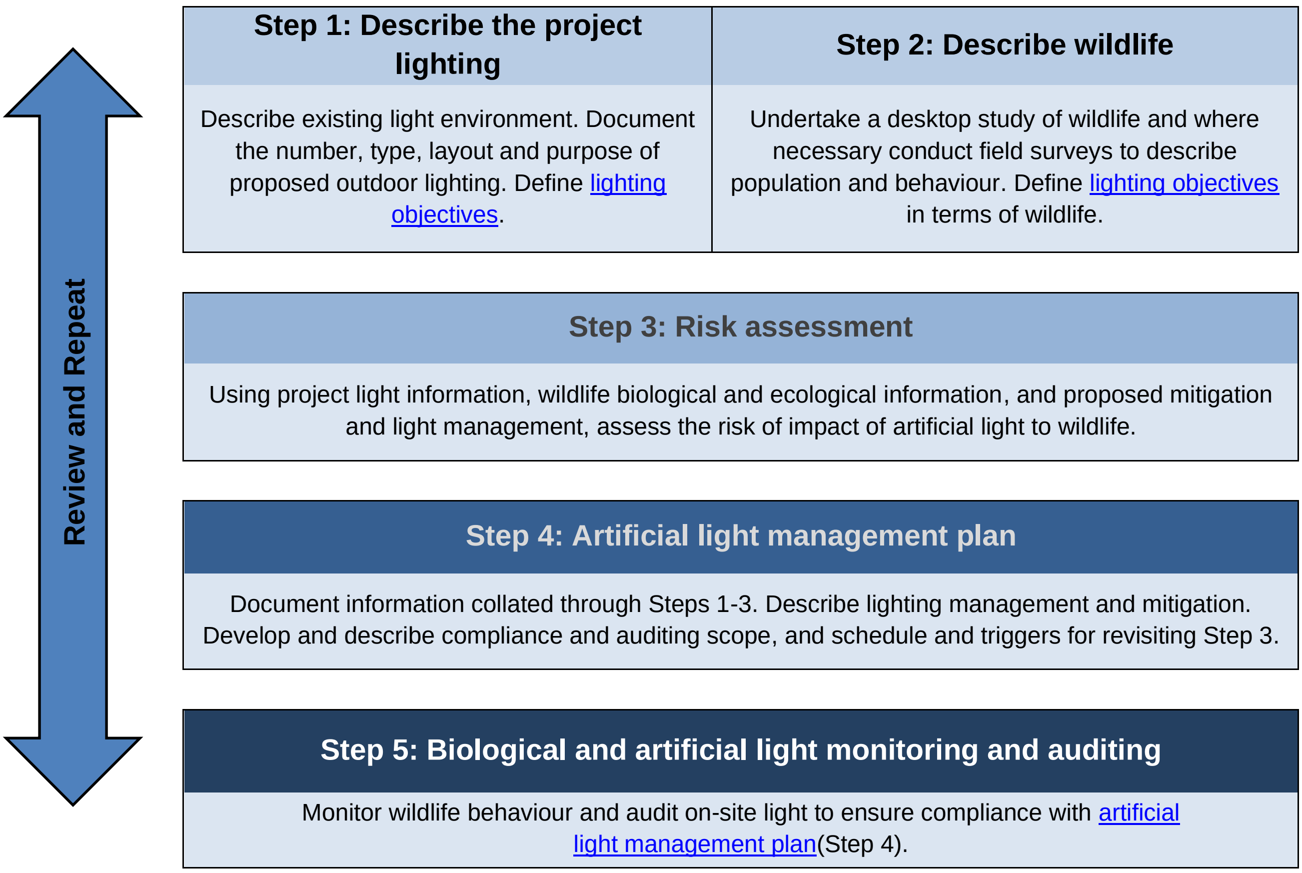

Figure 5 Flow chart describing the environmental impact assessment process.

Step 1: Describe the project lighting

Describe the existing light environment and characterise the light likely to be emitted from the site. Information should be collated, including (but not limited to): the location and size of the project footprint; the number and type of lights; their height, orientation and hours of operation; site topography and proximity to wildlife and/or wildlife habitat. This information should include whether lighting will be directly visible to wildlife or contribute to sky glow; the distance over which this artificial light is likely to be perceptible; shielding or light controls used to minimise lighting; and spectral characteristics (wavelength) and intensity of lights.

Project specific lighting should be considered in the context of the existing light environment and the potential for cumulative effects of multiple light sources. The information collected should be sufficient to assess the likely effects of artificial light on wildlife given the biology and ecology of species present (Step 2).

Where there will be a need to monitor the effectiveness of artificial light mitigation and management strategies (Step 5), baseline monitoring will be necessary. Measurements of the existing light environment should recognise and account for the biologically relevant short (violet/blue) and long (orange/red) wavelengths of artificial lighting (see Measuring Biologically Relevant Light).

Lighting objectives

During the planning phase of a project the purpose of artificial lighting should be clearly articulated, and consideration should be given as to whether artificial light is required at all. Lighting objectives should be specific in terms of location and times for which artificial light is necessary, whether colour differentiation is required and whether some areas should remain dark. The objectives should include the wildlife requirements identified in Step 2 and be consistent with the aims of these Guidelines.

For more information about developing lighting objectives see Best Practice Lighting Design.

Step 2: Describe wildlife

Describe the biology and ecology of wildlife in the area that may be affected by artificial light (species identified during the screening process, Figure 3). The abundance, conservation status and regional significance of wildlife will be described, as will the location of important habitat. Recognise biological and ecological parameters relevant to the assessment, particularly how artificial light will be viewed by an animal. This includes an animal's physiological sensitivity to wavelength and intensity, and its visual field.

Depending on the availability of information, scale of the activity and the susceptibility of wildlife to artificial light, this step may only require a desktop analysis. Where there is a paucity of information or the potential for effects is high, field surveys may be necessary. Where there will be a need to monitor the effectiveness of lighting mitigation and management strategies (Step 5), baseline monitoring will be necessary.

Desktop study of wildlife

A review of the available government databases, scientific literature and unpublished reports should be conducted to determine whether listed or protected wildlife that are susceptible to the effects of artificial light could be present. Tools to identify species or Important Habitat that may occur within 20 km of the area of interest include (but are not limited to):

- Protected Matters Search Tool
- National Conservation Values Atlas
- State and territory protected species information
- Scientific literature
- Local and Indigenous knowledge

To assess the risks to a species, an understanding of the animal's susceptibility to the effects of light should be evaluated, as well as the potential for artificial light to affect the local population.

The species conservation status should be identified and relevant population demographic and behavioural characteristics that should be considered include population size, life stages present and normal behaviour in the absence of artificial light. This step should also identify biological and ecological characteristics of the species that will be relevant to the assessment. This may include understanding the seasonality of wildlife using the area; behaviour (i.e. reproduction, foraging, resting); migratory pathways; and life stages most susceptible to artificial light. Consideration should also be given to how artificial light may affect food sources, availability of habitat, competitors or predators.

Field surveys for wildlife

Where there are insufficient data available to understand the actual or potential importance of a population or habitat it may be necessary to conduct field surveys. The zone of influence for artificial lighting will be case and species specific. Surveys should describe habitat, species abundance and density on a local and regional scale at a biologically relevant time of year.

Baseline monitoring

Where it is considered likely that artificial lighting will impact on wildlife, it may be necessary to undertake baseline monitoring to inform mitigation and light management (Step 5).

Field survey techniques and baseline monitoring needs will be species specific and detailed parameters and approaches are described in the Marine Turtles, Seabirds and Migratory Shorebirds Technical Appendices. Guidance from species experts should be sought for other species.

Step 3: Risk assessment

Using information collated in steps one and two, the level of risk to wildlife should be assessed. Risk assessments should be undertaken on a case by case basis as they will be specific to the wildlife involved, the lighting objectives and design, and the prevailing environmental conditions. Assessments should be undertaken in accordance with the *Australian Standard Risk Management – Guidelines (AS ISO 31000:2018)* (or superseding equivalent), which provides for adaptive management and continuous improvement. The scale of the assessment is expected to be commensurate with the scale of the activity and the vulnerability of the wildlife present.

In general, the assessment should consider how important the habitat is to the species (e.g. is this the only place the animals are found), the biology and ecology of wildlife, the amount and type of artificial light at each phase of development (e.g. construction/operation) and whether the lighting scenario is likely to cause an adverse response. The assessment should take into account the artificial light impact mitigation and management that will be implemented. It should also consider factors likely to affect an animal's perception of light; the distance to the lighting source; and whether light will be directly visible or viewed as sky glow. The process should assess whether wildlife will be disrupted or displaced from important habitat, and whether wildlife will be able to undertake critical behaviours such as foraging, reproduction, and dispersal.

Where a likely risk is identified, either the project design should be modified, or further mitigation put in place to reduce the risk.

If the residual risk is likely to be significant, consideration should be given as to whether the project should be referred for assessment under the EPBC Act and/or relevant state or territory legislation.

Step 4: Artificial light management plan

The management plan will document the EIA process. The plan should include all relevant information obtained in Steps 1-3. It should describe the lighting objectives; the existing light environment; susceptible wildlife present, including relevant biological characteristics and behaviour; and proposed mitigation. The plan should clearly document the risk assessment process, including the consequences that were considered, the likelihood of occurrence and any assumptions that underpin the assessment. Where the risk assessment deems it unlikely that the proposed artificial light will effect wildlife and an artificial light management plan is not required, the information and assumptions underpinning these decisions should be documented.

Where an artificial light management plan is deemed necessary, it should document the scope of monitoring and auditing to test the efficacy of proposed mitigation and triggers to revisit the risk assessment. This should include a clear adaptive management framework to support continuous improvement in light management, including a hierarchy of contingency management options if biological and light monitoring or compliance audits indicate that mitigation is not meeting the objectives of the plan.

The detail and extent of the plan should be proportional to the scale of the development and potential impacts to wildlife.

A toolbox of species specific options are provided in the Marine Turtles, Seabirds and Migratory Shorebirds Technical Appendices. Guidance from species experts should be sought for other species.

Step 5: Biological and light monitoring and auditing

The success of the impact mitigation and artificial light management should be confirmed through monitoring and compliance auditing. Light audits should be regularly undertaken and biological and behavioural monitoring should be undertaken on a timescale relevant to the species present. Observations of wildlife interactions should be documented and accompanied by relevant information such as weather conditions and moon phase. Consideration should be given to monitoring control sites. Monitoring should be undertaken both before and after changes to artificial lighting are made at both the affected site and the control sites. The results of monitoring and auditing are critical to an adaptive management approach, with the results used to identify where improvements in lighting management may be necessary. Audits should be undertaken by appropriately qualified personnel.

Baseline, construction or post construction artificial light monitoring, wildlife biological monitoring and auditing are detailed in Measuring Biologically Relevant Light, Light Auditing and species specific Marine Turtles, Seabirds and Migratory Shorebirds Technical Appendices.

Review

Once light audits and biological monitoring have been completed, a review of whether the lighting objectives have been met should be conducted. The review should incorporate any changing circumstances and make recommendations for continual improvement. The recommendations should be incorporated through upgraded mitigations, changes to procedures and renewal of the light management plan.

Case Studies

Unlike many forms of pollution, artificial light can be removed from the environment. The following case studies show it is possible to balance the requirements of both human safety and wildlife conservation.

Gorgon Liquefied Natural Gas Plant on Barrow Island, Western Australia

The Chevron-Australia Gorgon Project is one of the world's largest natural gas projects. The liquefied natural gas (LNG) processing facility is on Barrow Island a Western Australian Class A nature reserve off the Pilbara Coast known for its diversity of fauna, including important nesting habitat for flatback turtles[29].

The LNG plant was built adjacent to important turtle nesting beaches. The effect of light on the turtles and emerging hatchlings was considered from early in the design phase of the project and species-specific mitigation was incorporated into project planning[29]. Light management is implemented, monitored and audited through a light management plan and turtle population demographics and behaviour through the *Long Term Marine Turtle Management Plan*[30].

Lighting is required to reduce safety risks to personnel and to maintain a safe place of work under workplace health and safety requirements. The lighting objectives considered these requirements while also aiming to minimise light glow and eliminate direct light spill on nesting beaches. This includes directional or shielded lighting, the mounting of light fittings as low as practicable, louvered lighting on low level bollards, automatic timers or photovoltaic switches and black-out blinds on windows. Accommodation buildings were oriented so that a minimal number of windows faced the beaches and parking areas were located to reduce vehicle headlight spill onto the dunes.

Lighting management along the LNG jetty and causeway adopted many of the design features used for the plant and accommodation areas. LNG loading activity is supported by a fleet of tugs that were custom built to minimise external light spill. LNG vessels are requested to minimise non-essential lighting while moored at the loading jetty.

To reduce sky glow, the flare for the LNG plant was designed as a ground box flare, rather than the more conventional stack flare. A louvered shielding wall further reduced the effects of the flare.

Lighting reviews are conducted prior to the nesting season to allow time to implement corrective actions if needed. Workforce awareness is conducted at the start of each turtle breeding season to further engage the workforce in the effort to reduce light wherever possible.

Figure 6 Liquefied natural gas plant on Barrow Island. Photo: Chevron Australia.

The *Long Term Marine Turtle Management Plan*[30] provides for the ongoing risk assessment of the impact of artificial light on the flatback turtles nesting on beaches adjacent to the LNG plant, including mitigation measures to minimise the risk from light to turtles. The plan also provides for an ongoing turtle research and monitoring program. The plan is publicly available.

Phillip Island

Victoria's Phillip Island is home to one of the world's largest colonies of listed migratory Short-tailed Shearwaters (*Ardenna tenuirostris*). It supports more than six per cent of the global population of this species[28]. Shearwaters nest in burrows and are nocturnally active at their breeding colonies. Fledglings leave their nests at night. When exposed to artificial light fledglings can be disoriented and grounded. Some fledglings may reach the ocean, but then be attracted back toward coastal lighting. Fledglings are also vulnerable to collision with infrastructure when disoriented and once grounded become vulnerable to predation or road kill[4] (Figure 7).

Phillip Island also attracts over a million visitors a year during peak holiday seasons to visit the Little Penguin (*Eudyptula minor*) ecotourism centre, the Penguin Parade®. Most visitors drive from Melbourne across a bridge to access the island. The increase in road traffic at sunset during the Easter break coincides with the maiden flight of fledgling shearwaters from their burrows[28].

In response to the deaths of fledglings, Phillip Island Nature Parks has an annual shearwater rescue program to remove and safely release grounded birds[28]. In collaboration with SP Ausnet and Regional Roads Victoria, road lights on the bridge to the island are turned off during the fledgling period[31]. To address human safety concerns, speed limits are reduced and warning signals put in place during fledgling season[31,32]. The reduced road lighting and associated traffic controls and warning signals, combined with a strong rescue program, have reduced the mortality rate of shearwaters[28].

Figure 7 Short-Tailed Shearwater (*Ardenna tenuirostris*) fledgling grounded by artificial light, Phillip Island. Photo: Airam Rodriguez.

Raine Island research vessel light controls

The Queensland Marine Parks primary vessel *Reef Ranger* is a 24 m catamaran jointly funded by the Great Barrier Reef Marine Park Authority and the Queensland Parks and Wildlife Service under the Field Management Program (FMP). The *Reef Ranger* is often anchored at offshore islands that are known marine turtle nesting sites and is regularly at Raine Island, one of the world's largest green turtle nesting sites[33] and a significant seabird rookery.

Vessels often emit a lot of artificial light when at anchor and the FMP took measures to minimise direct lighting spillage from the vessel. A lights-off policy around turtle nesting beaches was implemented, where the use of outdoor vessel lights was limited, except for safety reasons.

The original fit out of the vessel did not include internal block-out blinds (Figure 8A). These were installed before the 2018-19 Queensland turtle nesting season. The blinds stop light being emitted from inside the vessel, therefore limiting light spill around the vessel (Figure 8B). This can make an important difference at remote (naturally dark) sites such as Raine Island.

Anecdotal evidence suggests hatchlings previously attracted to, and captured in, light pools around the vessel are no longer drawn to the *Reef Ranger*.

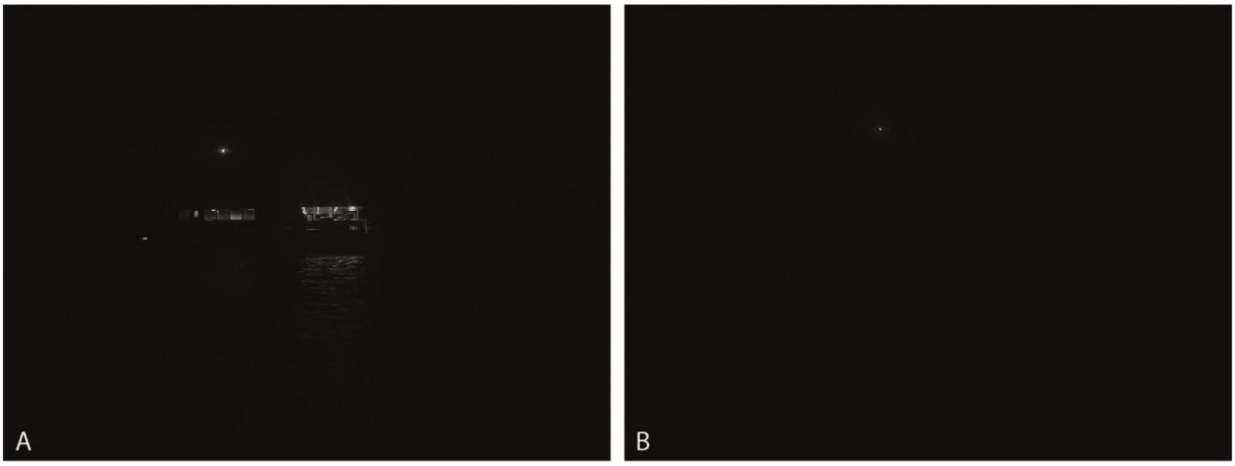

Figure 8 Vessel lighting management at Raine Island A. Vessel with decking lights, venetian blinds down and anchor light on; and B. Vessel with outside lights off, and block-out blinds installed (note the white anchor light is a maritime safety requirement). Photo: Queensland Parks and Wildlife Service.