CMS Draft guidelines

i. Providing generic advice on reduction of light pollution;
ii. Concerning migratory birds; and
iii. Concerning bats.

21st March 2022

This draft should not be cited as it is a work in progress.

Executive Summary

To be written

1. Background

i. CMS decisions

At its 13th ordinary meeting (COP13, Gandhinagar, February 2020) the Conference of the Parties to CMS considered the issue of light pollution. Through Resolution 13.5 *Light Pollution Guidelines for Wildlife*, COP13 noted that artificial light is significantly increasing globally and that it is 'known to adversely affect many species and ecological communities by disrupting critical behaviours in wildlife and functional processes, stalling the recovery of threatened species, and interfering with a migratory species' ability to undertake long-distance migrations integral to its life cycle, or by negatively influencing insects as a main prey of some migratory species'.

Resolution 13.5 also endorsed *National Light Pollution Guidelines* for some groups of migratory wildlife including Marine Turtles, Seabirds and Migratory Shorebirds, and recommended that Parties, non-Parties and other stakeholders should use the guidelines to limit and mitigate the harmful effects of artificial light on migratory species. With a view to complementing those guidelines, COP13 through Decision 13.138 requested that the Secretariat, subject to the availability of resources, prepare guidelines for adoption by COP14 on how to effectively avoid and mitigate the indirect and direct negative effects of light pollution for those taxa not yet in the focus of the guidelines endorsed by Resolution 13.5, also taking into account other existing guidance as relevant.

ii. General background to the issue

The use of artificial light to illuminate our streets, homes, sports grounds, commercial and industrial properties either permanently or intermittently during the hours of darkness has become the norm in most developed countries. Lighting at night is considered essential for our security and/or convenience. Monuments, churches, bridges and other landmarks may also be illuminated at night for aesthetic purposes, and light is also emitted by the vehicles we use on land, at sea and in the air.

The increasing use of electric lighting has modified the natural light environment dramatically and this can have effects on both humans and wild animals. The last century has seen an unprecedented increase in the use of artificial light at night (also known as ALAN). Between 2012 and 2016, the artificially lit outdoor area increased by 2.2% per year, there was a total radiance growth of 1.8% per year, with the brightness of continuously lit areas increasing by 2.2% per year (Kyba et al., 2017). There were few places where lighting growth was stable or decreasing in this period and it is expected that artificial light emissions will continue to increase. Secondi et al. (2019) point out that population growth as well as increases in urbanization, road networks and access to electricity in developing countries will all lead to increases in ALAN in the intertropical zone. As well as being an issue on land, light pollution impacts the marine environment particularly those areas with intensive offshore development and coastal urbanisation (Smyth et al., 2021). An area of 1.9 million km^2 of the world's coastal seas are exposed to ALAN at a depth of 1m (equivalent to 3.1% of the global exclusive economic zones).

ALAN is also referred to as 'light pollution'. From an organismal perspective, it can be described as occurring "when organisms are exposed to light in the wrong place, at the wrong time or at the wrong intensity" (Depledge et al., 2010). ALAN can be direct, such as the beam emitted by a streetlight and, indeed, many studies highlight impacts of artificial light that are localised and focused closely on the sources of the light (Davies and Smyth, 2017). However, when artificial light is scattered and reflected back from the atmosphere as artificial 'skyglow', it can have an influence far beyond the individual light sources and can be observed hundreds of kilometres away, affecting otherwise pristine areas (Russart and Nelson, 2018a; Falchi et al., 2016). This type of light pollution can reach levels of lunar illumination and thereby also disrupt light-sensitive processes (Torres et al., 2020; Stanley et al., 2020). As well as skyglow, other types of light pollution include glare (contrasts between bright and dark areas), over-illumination, light clutter (unnecessary numbers of light sources) and light trespass (unwanted light) (Rowse et al., 2016). Even when lights are shielded, in an attempt to reduce skyglow, local biodiversity may be impacted (Owens and Lewis, 2018).

Light pollution is not constant and atmospheric conditions including humidity, aerosols (small particles or droplets suspended in the air e.g. dust, sea salt, soot), clouds, haze, atmospheric pollution and snow can all impact sky brightness (Kyba et al., 2011; Falchi et al., 2016; Jechow and Hölker, 2019; ILP, 2021).

2. Actions taken to date

A report on the direct and indirect impacts of light pollution on migratory animals and on measures to mitigate those impacts was submitted to the 5th meeting of the Sessional Committee of the Scientific Council (ScC-SC5) in 2021 for consideration. Based on its review of the report, the Sessional Committee recommended the development of three sets of guidelines:

i. Providing generic advice on reduction of light pollution;
ii. Concerning migratory birds; and
iii. Concerning bats.

The generic advice on the reduction of light pollution will benefit taxa which are not yet covered by their own specific guidelines e.g. freshwater fish and arthropods.

It is intended that these new sets of draft guidelines should be reviewed by the 6th meeting of the Sessional Committee for approval prior to transmission to COP14 for final consideration and adoption by the Parties to the Convention.

3. Draft generic guidelines

3.1 Aims

These guidelines are intended to help reduce the impacts of artificial light at night on wildlife, and on specific taxa of migratory species of relevance to CMS.

3.2 Background

Organisms have evolved under consistent light conditions, which include day and night, lunar cycles, predictable star patterns, and seasonality (Seymoure, 2018). Natural light is used by wildlife as a resource and to gain spatial and temporal information about their environment (Gaston et al., 2013). Light is used to enable vision, for example for foraging, whilst darkness may be used to provide cover and these needs, thereby, affect movement to, or away from, the light (Vowles and Kemp, 2021; Santos et al., 2010). Light and darkness are also involved in mechanisms essential for regulating physiology (e.g. metabolism, melatonin secretion, immunocompetence), growth and behaviour, including synchronisation of biological clocks (Kyba et al., 2011; Dominioni et al., 2016; Falcón et al., 2020; Helm, 2021). Circadian rhythms are endogenous biological rhythms with 24-hour periods and, though they persist without environmental cues, they are highly sensitive to light cues, to which they entrain (Russart and Nelson, 2018b). Similar mechanisms exist for circannual and circalunar clocks (Andreatta and Tessmar-Raible, 2020).

It is increasingly recognised that hormonal synthesis and secretion are often under circadian, circalunar and circannual control, meaning that perturbation of these internal clocks will lead to hormonal imbalances and other problems (Falcón et al., 2020; Andreatta and Tessmar-Raible, 2020).

In their recent review, Falcón et al. (2020) describe how:

"… most of the basic functions of living organisms are controlled by these internal, genetically determined, clocks. These clocks depend absolutely on the 24 h LD[1] cycle to accurately synchronize their activity with solar time, and in turn they orchestrate a myriad of downstream biochemical, physiological and behavioural events so that the right process occurs at the right time. Thus, changing the natural LD cycle cannot be without consequences for biological organisms."

Diurnal, nocturnal, cathemeral and crepuscular animals may react differently to ALAN (Russart and Nelson, 2018a). According to Duffy et al. (2015): "ALAN can effectively increase the length of available activity time for diurnal species, reduce it for nocturnal species and cause more complex changes to the activity cycles of crepuscular and cathemeral species." Though increased urbanisation in areas rich in biodiversity may have consequences for all species, the accompanying increase in artificial light is believed to particularly impact

[1] LD = light-darkness

nocturnal species (Koen et al., 2018). As 30% of vertebrates and >60% of invertebrates are nocturnal, a significant proportion of species are at risk (Hölker et al., 2010).

Through a process known as photoperiodism, day length works as a cue for many animals living in a seasonal environment to time events such as reproduction, dormancy and migration, either directly or through entrainment of circannual rhythms (Bradshaw and Holzapfel, 2007). Preparation for reproduction through the acquisition of territory or other necessary resources, building up fat stores prior to dormancy or moulting prior to migration all need to take place at the appropriate time. Disruptions caused by ALAN can, therefore, impact critical behaviours which are triggered by day length (Longcore and Rich, 2004). Seasonal reproductive processes, such as the shrinking of reproductive organs in many species once the breeding season is over, can be disrupted by artificial light (Helm, 2021).

Night length and moonlight can both impact sleep patterns for diurnal species causing them to sleep less (van Hasselt et al., 2020; van Hasselt et al., 2021). For example, the reductions in non-rapid eye movement (NREM) sleep naturally caused by shorter nights and moonlight could also be triggered by artificial light and, hence, sleep deprivation could be a potential impact of light pollution particularly for diurnal species. This has been shown for pigeons (*Columba livia*) and Australian magpies (*Cracticus tibicen tyrannica*), which slept less and had more fragmented sleep patterns when they were exposed to ALAN (Aulsebrook et al., 2020). Moreover, many species especially, but not only, in marine environments, use moonlight to time reproduction and migration (Last et al., 2016; Andreatta and Tessmar-Raible, 2020; Torres et al., 2020; Murata et al., 2022).

In addition to physiological and temporal coordination, all natural sources of light (sun, moon, stars) provide important navigational information especially for migratory species (Padget, et al., 2018; Stanley et al. 2020; Torres et al., 2020; Zolotareva et al., 2021).

A recently published meta-analyses of the biological consequences of ALAN concluded that “natural light cycles are being eroded over large areas of the globe” and that this induces strong responses for physiological measures, daily activity patterns and life history traits, with “especially strong responses with regards to hormone levels, the onset of daily activity in diurnal species and life history traits, such as the number of offspring, predation, cognition and sea finding (in turtles)” (Sanders et al., 2021). Sanders et al. (2021) also noted that there has been little work on the effects of ALAN on whole ecosystems. Hölker et al. (2021) have also recommended that future research needs to consider how ALAN affects biodiversity at all levels (including genotypes, communities, ecosystems and landscapes). ALAN needs addressing alongside other global change drivers including other forms of pollution, climate change, and land-use change.

3.3 Light Mitigation Toolbox Recommendations

In this section, general principles for reducing the impacts of artificial light at night on wildlife are given, as well as recommendations for adapting lighting design and operation. Specific recommendations are given for certain sectors.

3.3.1 General principles

- Strictly avoid artificial light at night where and when possible
- Install artificial lighting only where it is necessary and where it has a specific and defined purpose for safety reasons
- Use minimum number and intensity of lights to meet lighting objectives
- Turn off lights when they are not needed (use smart technology)
- Minimise glare[2]
- Reduce skyglow
- Reduce spill light / light trespass[3]
- Eliminate façade lighting (also known as vanity lighting or decorative lighting)
- Use the absolute minimum of lighting in or near to natural heritage areas and migratory pathways
- Audit existing buildings, streetlights etc. and carry out retrofits to address unnecessary lighting where possible
- Make a formal Environmental Impact Assessment (EIA) for the effects of ALAN on wildlife as part of the planning process for new developments or when existing fixtures are being retrofitted

3.3.2 Lighting design

This section refers to exterior lighting. Some principles may be applicable to interior lighting.

Table 1: Recommendations for adapting lighting design to reduce the negative impacts of artificial light at night on wildlife

Measures	Recommendations
Types of lights	DISCUSSION POINT: Can we make a specific recommendation regarding LEDs, HPS, LPS, metal halide etc. or is specifying colour and intensity enough (see below)?
	Refer to the International Dark-Sky Association examples of acceptable and unacceptable lighting fixtures[4]
	Choose Dark Sky friendly lighting[5]
	Use luminaires with reflectors and clear covers, preferably of flat or lens-shaped glass[6]
	Install low glare lighting
	Use non-reflective finishes on light fixture mounts / poles
	Prohibit adjustable or swivel fixtures

[2] ILP (2021) recommends: "Keep glare to a minimum by ensuring that the main beam angle of all luminaires directed towards any potential observer is no greater than 70°. Higher mounting heights allow lower main beam angles, which can assist in reducing glare."
[3] According to the ILP (2021), "the term light trespass has been used in the past and should no longer be referenced, trespass is to physically encroach on land and light can't do that, so the term nuisance or spill light should always be used."
[4] https://www.darksky.org/our-work/lighting/lighting-for-citizens/lighting-basics/
[5] https://www.darksky.org/our-work/lighting/lighting-for-industry/fsa/fsa-products/
[6] de la Paz Gómez et al. (2019)

Light colour and intensity	Use the lowest light level required[7]
	Use warmer colour lights where possible (limit shorter wavelength light)[8]
	Use luminaires with a correlated colour temperature (CCT) of 2200K[9]
	If white light is required, use warm white LEDs (<2700K)[10]
	Minimise blue light or UV emissions (below 500 nm)[11]
Shielding	Shield light-emitting surfaces from direct view
	Use fully-shielded or cut-off fixtures on outdoor lights including streetlights and external building lights so that no upward light is emitted[12]
	Install shields on existing lights
	Shield adjacent surfaces if necessary to prevent excessive reflected light from adding to skyglow
	Recess external lights into overhanging roof eaves where possible
Light direction	Eliminate direct upward light
	Mount luminaires horizontally relative to the ground
	Use luminaires with a percentage of upper hemisphere emission below 0.2% (preferably 0%) and be sure to avoid directing light near the horizon[13]
	Consider reflective properties of the receiving environment when angling the light mounting
Light location	Consider locating exterior light fixtures as close to the ground as possible but taking into account light spill
	Do not place luminaires far from the area to be lit
	Minimise light projection beyond the useful zone
	Specify light spill beyond the property line[14]

[7] DISCUSSION POINT: Shall we include specific lumen limits?

[8] IDA and IES (2020)
Note that RASC and Dick (2020) Canadian Guidelines for Outdoor Lighting for dark sky parks states that: "All outdoor illumination shall be amber. Illumination described as "warm", "warm white", or Dark Sky Friendly are not necessarily compliant."

[9] IDA (2021). Light source should emit no more than 8% blue light emissions (IDA, 2021).
Standards of Low Impact Lighting (LIL) also recommend CCT equal to or lower than 2200K. See: https://www.licht-und-natur.eu/lpec-in-eeb/standards-of-low-impact-lighting/
DISCUSSION POINT: Do we want to specify different CCTs for different situations? For example: City of Toronto (2017) recommends using an appropriate correlated colour temperature for external lighting depending on the context e.g. a maximum of 3000K in residential areas and 4000k along high traffic arterial roads.

[10] de la Paz Gómez et al. (2019)

[11] de la Paz Gómez et al. (2019)

[12] According to US Fish and Wildlife Service (2016) '"Fully shielded" light fixtures are defined as those with an opaque shield so that all light is emitted below the lowest light emitting part of the fixture. "Fully shielded" is the same as "zero up light" and "dark sky compliant."'
RASC and Dick (2020) defines full cut-off luminaires as 0% up-light or "fully shielded", 10% of light from 80° and 90° from nadir (glare zone), cut-off luminaires as >0% and <2% up-light, semi-cut-off luminaires as <2% up-light, sharp cut off-luminaires 0% up-light, <1% between 80 -90 degrees of nadir

[13] de la Paz Gómez et al. (2019)

[14] EEPAC, ACE and AWAC (2018) recommend "Light trespass at the property line will not exceed 11.6 lumens / ft2 for commercial/industrial property boundaries or 5.8 lumens / ft2 for residential property boundaries. In the case of a mixed residential/commercial boundary, the value for the residential shall take precedence"
DISCUSSION POINT: Do we want to include specific lumens for light spill?

Floodlights[15]	Do not use ground-recessed floodlights[16]
	Use only asymmetric beam floodlights, with asymmetries adapted to the area to be lit, not installed at a tilt[17]
	Use aiming for floodlights with angles lower than 70°
Reduce the need for installed outdoor lighting	Use reflective paints or self-luminous markers for signs, curbs and steps[18]

3.3.3 Lighting operation

Table 2: Recommendations for adapting lighting operation to reduce the negative impacts of artificial light at night on wildlife

Measures	**Recommendations**
Use adaptive controls	Manage light timing according to season and time of night
	Manage light intensity
	Manage light colour
	Use occupancy sensors, timers and motion sensors to control interior and exterior lighting including security lighting
	Use adaptive lighting controls to dim street lighting when it is not needed
	Use gradual "staggered switching" to turn on building lights rather than instant light-up of the entire building
	Ensure that any lights that are not motion-activated are turned off at night (especially architectural lighting, upper storey interior lighting, lobby and atrium lighting)
Interior lighting	Block light spill from internal light sources (use window coverings such as black-out blinds and shutters, curtains, localised task lighting, glass with reduced visible light transmittance values / 'smart glass' [19])
	Create smaller zones in lighting layouts, directing lighting to where it is needed instead of lighting large areas
	In office blocks, turn off overhead lighting at night
	Use motion-sensitive lighting / light dimmers in lobbies, atria, walkways and corridors for night-time use
	Turn off non-motion activated lights at night
	If indoor lights must be left on at night, draw shades after dark and/or turn off lights nearest to windows
Exterior lighting	Avoid use of searchlights as permanent architectural features
	Avoid use of floodlights
	Turn off signage after hours

[15] DISCUSSION POINT: Add more details? E.g. in LoNNe (2015) it states "floodlighting must not exceed a luminance of 2cd/m^2 on the illuminated area."
[16] LoNNe (2015)
[17] de la Paz Gómez et al. (2019)
[18] IDA and IES (2020)
[19] Bat Conservation Trust and ILP (2018)

	Limit sign brightness
	On skyscrapers and other tall structures, install minimum intensity white strobe lighting with a three second flash interval instead of continuous flood lighting, rotating lights or red lighting
	See Table 3 below for specific guidance according to location of lighting
Maintenance	Ensure that lighting is regularly inspected and that fixtures are appropriately maintained

3.3.4 Lighting for specific locations

Table 3: Recommendations for adapting lighting design and management for particular sectors to reduce the negative impacts of artificial light at night on wildlife

Location	**Ways to minimise impacts of artificial light at night**
Car dealerships	Use a graduated illuminance level from the front row (between the roadway and the front row of merchandise) to the last row
	Limit light intensities in different areas[20]
	Turn off lighting after business hours
Car parks	Limit light intensity in parking lots and walkways[21]
	Mount lights on poles which are no higher than buildings / trees around the perimeter
	Turn off lights after business hours
	Include a lighting plan when designing a new car park[22]
Service stations and gas stations	Limit lighting fixtures to a canopy where possible
	Do not mount lights on top or sides of the canopy
	Do not illuminate sides of the canopy
	Limit horizontal illuminance[23]
Sports grounds	Mount and aim light fixtures so that direct illumination is kept on site[24]
	Screen fields with tall vegetation or landform to prevent glare and spill light
	Define appropriate levels of illumination for specific activities
	Establish and enforce light curfews
	Turn off lighting when facility is not in use

[20] DISCUSSION POINT: Shall we specify lux? City of Toronto (2017) recommends 30 lux illuminance to light the front row and 10 lux in other areas. EEPAC, ACE and AWAC (2018) recommend 100 lux at the front row, 50 lux at all other rows, 20 lux at all pathways/drives on the property.
[21] DISCUSSION POINT: Shall we specify lux? City of Toronto (2017) recommends an average of 10 lux. EEPAC, ACE and AWAC (2018) recommend an average horizontal illuminance of no more than 25 lux for car parks with a maximum point illuminance not to exceed 40 lux.
[22] City of Toronto (2017) recommends that this could include an analysis of the surface light levels in lux, horizontal and vertical light levels at the property boundary in lux, and the surface brightness of the luminaires in candela per m^2
[23] DISCUSSION POINT: Shall we specify lux? EEPAC, ACE and AWAC (2018) recommends not exceeding horizontal illuminance of 100 lux for pump island/under canopy, 30 lux for service areas, 20 lux for pathways/drives. City of Toronto (2017) recommends the average horizontal illuminance under the canopy should be no more than 10 lux, with a uniformity ratio no greater than 3:1.
[24] See IDA (2018) for a detailed approach of how to control backlight, uplight and glare

	Do not use installed field lighting for illuminating other areas (e.g. parking areas should be illuminated by separate luminaires and systems)
Security lighting	Only install lighting that is required specifically to ensure necessary security
	Ensure directionality of lighting minimises light spill
Advertising signs	Keep light to the minimum
	Direct light downwards where possible
	If up-lighting is necessary, use luminaires with the correct optical distribution coupled with shields, baffles and louvres to reduce spill light[25]
LED signs[26]	Implement maximum luminance levels
	Introduce a curfew for when LED signs should be turned off
	Do not place LED signs within or close to sensitive areas
	Gradually dim luminance levels between day and night
	Limit size and density of LED signs
	Refer to IDA Guidance for Electronic Message Centers (EMCs) for further information
Street lighting	Use luminaires with a 0% ratio of upward light output (RULO)[27]
	Use full cut-off fixtures to direct light to roadway and sidewalk surfaces
	DISCUSSION POINT: Can we recommend dimming controls?
	Use retro-reflective signage instead of installed lighting fixtures where traffic is at a low speed or infrequent
	Distance between poles must be at least 3.7 times greater than the pole height[28]
	Do not allow luminance of main roads in urban areas to exceed 0.5 cd/m^2 [29]
	Introduce curfews with a reduction of lumen output in late hours outside peak traffic[30]
Façade lighting (also known as vanity lighting or decorative lighting)	Eliminate this type of lighting wherever possible
	Use light fixtures which prevent unnecessary light spillage
	Use downlighting to highlight architectural features
	Do not emit light above the horizontal plane
	Do not aim lights at reflective or polished surfaces (e.g. glass, smooth stone, glazed tile etc)
	Establish light curfew periods (e.g. turn lights off from 11pm to 6am).
	Limit maximum total illuminance[31]

[25] ILP, 2021
[26] All information in this section on LED signs is from IDA (2019)
[27] Donatello et al. (2019) includes a discussion about appropriate ratio of upward light output (RULO) to prevent light pollution and also includes details of flux codes – DISCUSSION POINT: do we want to include such things in the guidelines?
[28] DISCUSSION POINT: do we want to include this kind of detail in the guidelines? From Standards of Low Impact Lighting (LIL): https://www.licht-und-natur.eu/lpec-in-eeb/standards-of-low-impact-lighting/
[29] DISCUSSION POINT: do we want to include this kind of detail in the guidelines? From Standards of Low Impact Lighting (LIL): https://www.licht-und-natur.eu/lpec-in-eeb/standards-of-low-impact-lighting/
[30] From Standards of Low Impact Lighting (LIL): https://www.licht-und-natur.eu/lpec-in-eeb/standards-of-low-impact-lighting/
[31] EEPAC, ACE and AWAC (2018) recommends maximum total luminance of 100 lux. ERA (2020) recommends the average luminance is not to exceed 1cd/m2 (roughly an illuminance of not more than 10 lux when measured at the surface). DISCUSSION POINT: Do we want to include specific details like this?

	Highlight specific features rather than flooding an entire façade with light[32]
Parks	Use full cut-off fixtures to light pathways or sitting areas
	Use full cut-off wall pack fixtures on park buildings, mounted at an appropriate height

4. Migratory Birds Guidelines

4.1 Aims

These guidelines are intended to help reduce the impacts of artificial light at night on migratory birds.

4.2 Background

4.2.1 Impacts of ALAN on migratory birds

It has long been known that light at night has powerful effects on migratory birds. For example, century-old records exist of extensive lighthouse collisions, and hunting, tourism and research have systematically employed light to capture migrants. Perhaps the globally most effective capture site of landbirds, Ngulia Lodge in Kenya, used flood lights to illuminate wildlife for tourism from the 1960s, before beginning a programme of mist-netting and ringing which has ringed nearly a million birds (Moreau, 1972; Watson, 2017). Thus, after seabirds and shorebirds (which are covered in the existing CMS light pollution guidelines), nocturnally migrating landbirds appear to be at particular risk from the negative impacts of artificial light at night (Cabrera-Cruz et al., 2018).

Of the 298 migratory bird species considered by Cabrera-Cruz et al. (2018), all but one had light pollution in their geographic distribution range and light pollution was found to be relatively greater within the passage ranges of nocturnally migrating birds compared to their distribution ranges at other phases of their annual cycle. Long distance migrants leave from and arrive to areas with low levels of light pollution but during migration they cross areas with high urban development and light pollution. Horton et al. (2019) found that in the eastern USA autumn migration routes take birds over areas with more light pollution than spring routes, whereas on the west coast of the USA, birds have higher exposure during spring migration. Chicago, Houston and Dallas are the US cities where birds were most exposed to anthropogenic light, regardless of season.

Flight routes of birds can be affected by ALAN either through attraction, or conversely, aversion. Migratory birds can be attracted to ALAN through a "beacon effect" which was described in the New York Audubon Bird-Safe Building Guidelines:

"The illumination of buildings at night, and in the early morning and evening, creates conditions that are particularly hazardous to nighttime migrating birds. Typically flying at

[32] ERA (2020)

heights over 500 feet, especially if weather conditions are favorable,…during inclement weather, these migrants often descend to lower altitudes,…and are liable to be attracted to illuminated buildings or other tall structures. Heavy moisture (humidity, fog or mist) in the air greatly increases the illuminated space around buildings, regardless of whether the light is generated by an interior or exterior source. Birds become disoriented and entrapped while circling in the illuminated zone and are likely to succumb to exhaustion, predation, or lethal collision." (Brown and Caputo, 2007).

The mechanism which causes birds to aggregate in light is not fully understood and could be due to magnetoreception disruption, misinterpretation of natural light cues, or due to an effect on avian vision such as disruption, or because it enables "a visual refuge" (Evans et al., 2007).

It is known that upward pointing lighting and lights on tall buildings or structures affect flight behaviour of night migrating birds (Cabrera-Cruz et al., 2021). Van Doren et al. (2017) found that birds reacted to vertically-oriented light beams up to ≈4km above the ground. However, low-rise lights which point downwards can also have an impact on bird behaviour, causing them to turn horizontally or vertically within their flight paths (Cabrera-Cruz et al., 2021).

Collision is one of the main concerns when considering how ALAN affects migrating birds. In the USA, between 365 and 988 million birds die each year due to collisions with buildings and other human-built structures (Loss et al., 2014). Most of these deaths involve collisions with buildings, particularly windows, and involve migrating native species (Elmore et al., 2021). The number of fatal bird collisions in USA, Canada and Mexico is greatest for migratory, insectivorous and woodland-inhabiting species (Elmore et al., 2020). Of the birds killed at communication towers in the USA and Canada, the majority are neotropical migrants and 97.4% of birds killed are passerines, mostly warblers (Parulidae, 58.4%) (Longcore et al., 2013). Some species have mortality due to tower collisions which is out of proportion with their population size and could, therefore, have consequences at a species level.

The timing of migration may affect a species' susceptibility to collision, with birds which migrate at night more likely to suffer a collision than diurnal migrants (Nichols et al., 2018). Collisions are more likely to take place at night during certain weather conditions, for example when there is low cloud, fog or rain and birds are flying at lower altitudes (Newton, 2007; Elmore et al., 2021). Studies at offshore installations have found that birds are more attracted to artificial light on overcast nights (Poot et al., 2008; Rebke et al., 2019). The attraction effect of blue light was also greatest during nights with fog and headwinds in a study in Southwest China (Zhao et al., 2020).

Most sampling regarding building collisions has taken place in the eastern USA during migration and this bias is represented in the literature and the species which have been identified as being particularly vulnerable to collisions (Loss et al., 2014).

A study in Minneapolis, Minnesota found that lighting area and lighting proportion had a statistically significant positive association with the number of bird collisions (Lao et al., 2020). This study found that "the area of lighted windows and proportion of glass lighted at night were important predictors of collisions, and that lighting area in particular was a better predictor than glass area, glass percentage, and the maximum and average sizes of glass panes." Loss et al.

(2019) also "found evidence that the proportion of glass lighted at night influences bird collision fatalities in spring, as well as the number of species colliding overall and in spring."

However, other studies have found glass or window area to be more of an influencing factor than lighted area. Parkins et al. (2015) examined bird-building collisions next to an urban park in New York and concluded that the amount of glass on a building façade may have a greater effect on collisions than the amount of light emitted from the façade. They suggested that most collisions occur during daylight hours. However, they recognised that in their study they did not take other light sources such as street lighting and stadium lighting into consideration and that this could also affect birds by attracting them to the park at night and then causing them to collide with glass in buildings the following day. Configuration of glass on building façades may also be relevant with reflections of nearby habitat confusing birds (Schneider et al., 2018).

A study which looked at over 70,000 nocturnal bird-building collisions in Cleveland, Ohio and Chicago, Illinois in the USA found an interaction between flight calling and collisions where birds had been attracted by ALAN (Winger et al., 2019), and similar observations were made in Europe (Gillings and Scott, 2021). This may be because calls from individuals which have been attracted to the light cause more birds to be attracted to the lit area. Flight-calling behaviour is therefore an important predictor of collision risk (Winger et al., 2019). In rural areas, more flight calls have been recorded in areas with ground-level artificial lights than in areas without lights, suggesting that ALAN alters bird behaviour (Watson et al., 2016). The mechanisms involved are not clear – whether birds are altering their routes to pass over lit areas, whether they fly at lower altitudes over lit areas, increase their call rate over lit areas or remain longer over lit areas.

Some studies have found that migrating birds avoid brightly lit areas. There is experimental evidence that bright beams led to aversive shifts in direction, speed and altitude of migratory birds (Bruderer et al., 1999). Some observational data support these findings. For example, birds stopping over in Mexico during their migration avoided bright lights in spring (Cabrera-Cruz et al., 2020). In Cancun, more birds stopped over in areas away from bright lights in the fall too, though there were still relatively high bird densities closest to bright areas. Cabrera-Cruz et al. (2020) proposed that naïve and ALAN-attracted birds are selected out during their southward migration in the fall and that a higher proportion of ALAN-resistant individuals return north in the spring.

Many of the above effects observed in landbirds also occur in seabirds. Fledgling burrow-nesting seabirds (mainly Procellariiformes – petrels and shearwaters) are attracted to light and may become grounded because of this attraction (Rodríguez et al, 2017; Rodríguez et al., 2022). The reasons for the attraction and disorientation are not fully understood but may be because light is perceived as a source of food either because the fledglings associate light with the burrow entrance where their parents brought them food, or because they mistake lights for bioluminescent prey (Rodríguez et al, 2017). Another potential reason is that artificial lights prevent them using the visual cues they need to find the ocean, or they confuse the lights for navigational cues. Atchoi et al. (2020) proposed that fledglings may be particularly at risk because of their untrained and undeveloped visual system combined with their behavioural inexperience. Some fledgling birds do manage to fly over light-polluted areas and reach the ocean, and it is not clear why some birds are able to do this while others are grounded (Rodríguez et al., 2022). It may be due to some "intrinsic factors, such as down abundance in the plumage" which have been associated with the probability of being grounded by artificial lights (Rodríguez et al., 2022). Procellariiform seabirds older than fledglings are also, sometimes, drawn to lights, exhibiting positive phototaxis (Rodríguez et al., 2017), but adults also exhibit behaviour suggesting they are repelled by artificial light (negative phototaxis) (Cianchetti-Benedetti et al., 2018). This may be due to differences in birds' eyes at different developmental stages (Syposz et al., 2021). Adult birds may also avoid light to avoid predators.

That birds are attracted to or repelled by ALAN during their migration could result in migration being less efficient, so that time and energy requirements to complete it are increased (La Sorte et al., 2017; Rebke et al., 2019). If birds are attracted to urban areas, they may find less suitable habitat for foraging as well as increased hazards such as predators (cats, dogs, rats etc) and collision risks (La Sorte et al., 2017).

Effects of ALAN on timing of migration and other seasonal behaviours are expected to be substantial especially through disruption of biological clocks. For example, birds are known to misinterpret ALAN as a longer photoperiod (Dominioni and Partecke, 2015). As predicted from this behaviour, purple martins (*Progne subis*) that experienced the highest number of nights with ALAN at their overwintering sites were found to depart for their spring migration an average of 8 days earlier than those that experienced no artificial light (Smith et al., 2021). They also arrived 8 days earlier at their breeding sites. It is possible that night migrants that synchronize migration to the lunar cycle suffer similar mistiming (Norevik et al., 2019). Delayed or early arrival at breeding or wintering grounds caused by ALAN mean that survival and reproductive success could potentially be impacted if there is a mistiming with environmental conditions.

Additionally, migratory and non-migratory birds suffer indirect effects of ALAN. These include impaired physiology and health because of disruption of the circadian clock (e.g. Dominoni et al., 2013; Kernbach et al., 2020). Because long-distance migrants are typically insectivores, they may also be particularly affected by massive declines in insects which have been linked to ALAN (Owens et al., 2020). Attraction to ALAN could also negatively impact nocturnally migrating birds by increasing their exposure to air pollution and fine particulate matter ($PM_{2.5}$) in particular (La Sorte et al., 2022). Of the three flyway systems assessed (Americas, Africa-Europe and East Asia Australasia) by La Sorte et al. (2022), the East Asia Australasia flyway had the strongest ALAN-$PM_{2.5}$ correlations within its regions of passage. For the Americas and Africa-Europe flyways, the combined threat of ALAN and $PM_{2.5}$ concentrations appeared to be less extreme.

4.2.1.1 Impact of colour and light intensity on migratory birds[33]

The spectral composition of artificial light may also be relevant when considering how ALAN affects birds. Birds are able to differentiate between light colours and, potentially, react differently to different colours (Rebke et al., 2019). Most birds have a visual spectrum which extends into the ultraviolet (UV) range and the UV cones in their eyes provide them with information for their magnetic compass (Wiltschko et al., 2014; Rebke et al., 2019).

Some studies have attempted to determine how birds react to different light wavelengths. Poot et al. (2008) found that red and white light (with visible long-wavelength radiation)

[33] DISCUSSION POINT: Input and clarification is required from experts regarding different light colours/wavelengths/intensity

attracted nocturnally migrating birds (mostly passerines including thrushes and smaller songbirds but also some shorebirds, ducks and geese) and that the birds were disoriented by these lights. Gauthreaux and Belser (2006) also reported that birds were attracted by longer wavelengths in the light emitted by ceilometers and that when longer wavelengths were filtered out so that mainly UV light was emitted, attraction was greatly reduced. They also reported greater disorientation caused by red lights than white strobe lights.

Poot et al. (2008) reported that birds were less disoriented by blue and green light (containing less or not visible long wavelength radiation). Evans (2010) questioned Poot et al.'s findings because of the variability in cloud conditions during the study periods, the sample sizes and the lack of information about migration density. Evans (2010) recommended further research but also suggested that "even though encountering red light may lead to disablement of a birds' geomagnetic navigation system, perhaps red light would ultimately be safer because birds are theoretically much less sensitive to it visually at night and fewer birds might therefore be influenced by it". A study carried out by Evans et al. (2007) had found "no evidence that bird aggregation occurs because a light is red", and Zhao et al. (2020) also found that nocturnally migrating birds were rarely attracted to long-wavelength red light. In their study, short-wavelength blue light caused the strongest phototactic response. Rebke et al. (2019) found that significantly more birds were attracted to continuous green, blue and white light than red light at an offshore installation. Recently, Adams et al. (2021) reviewed research looking at the effects of ALAN on birds and highlighted the need for further research into how different coloured lights affect birds as they found that most studies had focused on red light.

The colour of artificial light may also be relevant for seabirds. Syposz et al. (2021) observed fewer adult Manx shearwaters (*Puffinus puffinus*) flying under green/ blue light than under red light. This was expected as diving seabirds are more sensitive to blue and green colours than to red because of an adaptation to diving in sea water.

Bird mortality at dark structures should be compared to mortality at those with different kinds of lights including flashing or UV lights which are used as deterrents in some circumstances (Adams et al., 2021). Flashing lighting (on aviation obstruction towers, for example) causes less aggregation of birds than continuous lighting (Evans et al., 2007). Day et al. (2017) also found that eiders (*Somateria mollissima* and *S. spectabilis*), monitored during their autumn migration, were not attracted to white strobe lights which were pointed out to sea from an artificial oil-production island in Alaska. The eiders responded to the lights by reducing their flight velocity at night and altering their fine-scale movements. Rebke et al. (2019) found that nocturnally migrating passerines were drawn to continuous lights more than blinking lights when crossing the sea when stars were not visible.

Light intensity may be relevant as well as wavelength (Cohen et al., 2021), although nocturnally migrating passerines flying over the sea are known to have been attracted by even relatively weak sources of light (Rebke et al., 2019). Syposz et al. (2021) found that adult Manx shearwaters were more repelled by brighter light, although some caveats applied to this study, whereas colonies of three petrel species in the Balearic Islands exposed to higher radiance were grounded more than birds from colonies with lower radiance values (Rodríguez et al., 2015).

4.2.2. Mitigating risks posed by ALAN

Regarding collision risk, it is important for individual buildings to be assessed and for mitigation to be applied to problematic buildings. A study of 21 buildings in Minneapolis found that just four buildings (including a stadium) caused 74% (577) of the fatal collisions recorded over four migration seasons (Loss et al., 2019).

Since 1993, Fatal Light Awareness Program (FLAP) Canada has worked to reduce deadly bird collisions with buildings[34]. In 1995, FLAP Canada launched the first "Lights Out" initiative with World Wildlife Fund Canada with building managers turning off their lights at night to help migrating birds[35]. This campaign has led to many other similar initiatives across North America[36] and a number of cities and organisations have produced guidelines about how to reduce light pollution for birds and how to improve building design to prevent collisions (see Annex 1). In the USA, bird collision deterrence is included as a credit in the Green Building Council's LEED (Leadership in Energy and Environmental Design) system which determines standards of sustainability for the commercial, residential and institutional building industries[37].

Recent studies have investigated whether nights of intense migration can be forecast so that mitigation measures can be targeted at times when there is a greater risk for migratory birds. Weather radar can be used to predict migration and, therefore, the potential for birds to be attracted to artificial light allowing mitigation to be targeted at particular periods of time and/or specific weather conditions (Elmore et al., 2021). Horton et al. (2021) found that the majority of total migratory passage (54.3%) took place on 10% of nights for each season and, therefore, recommended that using near-term ecological forecasting would mean that mitigation actions could be taken according to "dynamic, real-time conservation alerts." Mitigation efforts such as "Lights Out" programmes, BirdCast "Lights Out Alerts" and other specific migration alerts e.g. https://aeroecolab.com/uslights could all be informed by radar data and could take into account particular periods of the night depending on migration speeds and weather conditions (Elmore et al., 2021).

Rodríguez et al. (2017) recommended the following mitigation measures to protect seabirds:

- Avoidance – eliminate external lights where possible especially in remote islands. Use blackout blinds to prevent interior light spilling out; and
- Minimisation – turn off streetlights during fledging periods, hold recreational events during the day instead of the night, remove unnecessary lights and shield those lights which are deemed necessary. Focus light minimisation at times of fledging and consider when, during the night, it is most effective (for some species the first few hours of darkness may be the critical time)

4.3 Light Mitigation Toolbox Recommendations

[34] https://flap.org/about/
[35] https://flap.org/our-impact/
[36] https://www.audubon.org/conservation/existing-lights-out-programs
[37] https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-data-41

In this section, general principles for reducing the impacts of artificial light at night on migratory birds are given, as well as recommendations for adapting lighting design, operation and planning.

4.3.1 General Principles

- Follow general principles in the generic guidelines presented in section 3.3.1 above
- Follow the precautionary principle and reduce artificial light at night to protect migratory birds whenever possible
- Follow bird-friendly guidelines for new developments where available

4.3.2 Lighting Design

- Follow the lighting design guidelines in the generic guidelines presented in section 3.3.2 above
- Follow the recommendations in Table 4 below

Table 4: Recommendations for adapting lighting design to reduce the negative impacts of artificial light at night on migratory birds

Measure	Recommendations
Adapt lamp type	DISCUSSION POINT: Can we recommend types of lamps to use / not use?
Adapt spectra	Avoid ultraviolet light (below 380 nm)[38]
	Use lights with reduced or filtered out blue, violet and ultraviolet wavelengths (380 - 520nm) as most migratory birds are sensitive to these short wavelengths[39], [40]
	Use red light, if continuous light is needed at offshore wind farms or oil/gas platforms[41]
Adapt light intensity	DISCUSSION POINT: Are the recommendations the same as those in Table 1?
Adapt light intervals	Use blinking lights rather than continuous light if light is needed at offshore wind farms or oil/gas platforms[42]

4.3.3 Lighting Operation and Planning

[38] IDA (2021)
[39] Australian Government (2020), Zhao et al. (2020), IDA (2021)
[40] Note that some guidelines e.g. Shepperd and Phillips (2015) state that there is evidence that "red light and white light (which contains red wavelengths) particularly confuse birds, while green and blue light may have far less impact)". As discussed in Section 4.2.1.1, different scientific studies have come to different conclusions regarding how different coloured light impacts birds and it is, therefore, important to refer to the latest peer-reviewed literature regarding this. DISCUSSION POINT: Expert input requested
[41] Rebke et al. (2019)
[42] Rebke et al. (2019)

- Follow lighting operation guidelines in generic guidelines presented in section 3.3.3 above
- Avoid, mitigate and compensate for ALAN
- Follow the recommendations in Table 5 below

Table 5: Recommendations for adapting lighting operation to reduce the negative impacts of artificial light at night on migratory birds

	Measures	**Recommendations**
Avoidance	Conserve dark areas	Introduce Dark Sky Parks along major flyways and stopover sites
Mitigation	Use minimum amount of light for task	All exterior lighting should be kept to a minimum
		Keep external lighting at a minimum on vessels and structures at sea (e.g. fishing boats where deck lights can attract seabirds[43], offshore wind farms and oil/gas platforms[44])
	Dimming	DISCUSSION POINT: Can we make a recommendation here?
	Timing of lighting	DISCUSSION POINT: Are the first few hours of darkness critical?
	Seasonal measures	During migration seasons, introduce a light curfew e.g. lights out from 11pm to 6am
		Do not use spotlights, searchlights, floodlights and roof-top lighting during migration seasons
		Encourage building owners and occupants to turn out all lights visible outside during migration seasons through "Lights Out" programmes
		Turn off façade lighting during migratory seasons (especially upward directed spotlights, floodlights and roof-top lighting)
		Consider migratory seasons when planning festival lighting or advertisement lighting effects
		Take into account bird migration forecasts in the management of artificial light at night on flyways[45]

[43] Glass and Ryan (2013)
[44] Rebke et al. (2019)
[45] https://birdcast.info forecasts migration in the USA and https://globam.science forecasts migration in Europe and North America

		Take into consideration differences in spring and fall migrations[46]
	Weather specific measures	In locations where more bird-building collisions are recorded during foggy/overcast days, alerts should be issued requesting lights to be turned off when bad weather is forecast.
Compensation[47]	Restore habitat	
	Restore dark areas	

Table 6: Recommendations for planning, monitoring and future research

	Recommendations
Planning	Integrate maps of hazard areas for migrating birds into the planning process
	Consider proximity of important habitat for migratory birds to areas where light is going to be installed and how it could impact birds
	Introduce incentives to encourage bird-safe lighting / building design / lighting operation
	Promote bird-friendly lighting in publicly funded parks and infrastructure
	Buildings with high levels of bird mortality should apply building specific mitigation methods[48]
Landscape planning	Minimize the reflection of vegetation on building façades
	Prevent nearby water features from reflecting in glazed building façades
	Refer to bird-friendly building guidelines in relation to glass[49]
Monitoring	Conduct regular surveys to monitor bird collisions
	Instruct monitors in methods of caring for injured birds before they can be transported to a wildlife rehabilitator
	Monitor the effectiveness of lights-out programmes including reductions in energy-usage, cost, light emissions, bird collisions and bird mortality
	Publicise positive outcomes to encourage further compliance with lights-out programmes
Research	Facilitate the provision of birds killed in collisions to appropriate scientific investigations to advance understanding of the issue[50]
	Fund research and development into bird-safe lighting

[46] For example, Horton et al. (2019) found "a 13.1% higher sum of exposure in the fall, when migrants moved through more photo-polluted airspaces in the eastern half of the US…Departures from this trend were evident in the western half of the country, where spring movements along the Pacific coast led to higher spring exposure."
[47] DISCUSSION POINT: How can we compensate for ALAN for migratory birds? The idea of having a section on compensation was from the EUROBATS guidelines, but is it relevant for birds too?
[48] Loss et al. (2019) DISCUSSION POINT: Can specific recommendations be made here regarding mitigation methods?
[49] For example City of Toronto (2017). Also see Annex 1 for other relevant guidelines.
[50] DISCUSSION POINT: Can this be made more specific?

5. Bats Guidelines

5.1 Aims

These guidelines are intended to help Parties to CMS reduce the impacts of artificial light at night on bats.

5.2 Background

Bats are a highly diverse group of flying mammals within the order Chiroptera and divided into 21 families. They include old world fruit bats (family Pteropodidae), some 191 species); the mouse-tailed bats (family Rhinopomatidae, some 6 species); hog-nosed bat (family Craseonycteridae, one species); false vampire bats (family Megadermatidae, some 6 species); trident bats (family Rhionycteridae, some nine species); Old World leaf-nosed bats (family Hipposideridae, some 88 species); horseshoe bats (family Rhinolophidae, some 109 species); sheath-tailed bats (family Emballonuridae, some 56 species); slit-faced bats (family Nycteridae, some 15 species); Madagascar sucker-footed bats (family Myzopodidae, some two species); New Zealand short-haired bats (family Mystacinidae, some two species); the bulldog bats (family Noctilionidae, some two species); the smoky bat and thumbless bat (family Furipteridae, some two species); disk-winged bats (family Thyropteridae, some 5 species); the family Mormoopidae, which includes the ghost-faced bats, naked backed bats and mustached bats (some 18 species); New World leaf-nosed bats (family Phyllostomidae, some 219 species); funnel-eared bats (family Natalidae, some 12 species); free-tailed bats (family Molossidae, some 129 species); long-fingered bats (family Miniopteridae, some 38 species); wing-gland bats (family Cistugidae, some two species); Vesper bats (family Vespertilionidae, some 503 species) (Burgin et al., 2020). Apart from rodents, Chiroptera is the most speciose mammalian group and yet there remain key challenges in understanding their taxonomy, which to some extent remains in flux, and their ecological roles (Kruskop, 2021). Bats exhibit a wide variety of lifestyles – for example in their foods, with many eating insects and others eating fruit and nectar - and their wide range of behaviours and habitats makes it challenging to provide global light pollution guidelines for all. Hence, the overarching recommendation that guidelines should be developed on a local basis to suit the species and habitat concerned.

As largely nocturnal mammals, bats are particularly susceptible to disruption from ALAN. They may be affected in a number of ways, for example roosting, emerging, commuting, foraging, swarming, migrating and mating behaviours could all potentially be disrupted. More examples are provided below and bats are considered under two broad headings dividing them into principally insect feeding and fruit/nectar feeding species (including pteropodid and old world phyllostomid bats). Bat with other feeding regimes such as fishing species and those that feed on blood (subfamily Desmodontinae) are not considered here due to a lack of information regarding how they are impacted by ALAN. Future research could look at these groups. This is not meant to be an exhaustive review but is intended to highlight what is known of some of the concerns and hence the rationale for addressing light pollution for bat species.

5.2.1 Insectivorous bats

5.2.1.1 Insects and artificial light

A large part of understanding insectivorous bat behaviour around lights requires understanding how their insect prey is attracted to lights (Voigt et al., 2018a). Eisenbeis (2006) reviewed the different ways in which insect behaviour is affected by artificial lights including the "fixation" or "captivity" effect, the "crash barrier" effect and the "vacuum cleaner" effect. In the first of these, the insect may fly directly into the light and die immediately, it may orbit the light until caught by a predator or until it dies from exhaustion, or it may manage to move away from the light for a while but as it remains inactive because of exhaustion or because it is dazzled by the light it is, therefore, at greater risk of predation. The "crash barrier" effect occurs when streetlights prevent insects from following their original foraging or migratory route subsequently causing them to get trapped by the "captivity" effect. The "vacuum cleaner" effect is when lights attract insects which are not foraging or migrating, leading to their deaths and, potentially, causing a reduction in the local population. As well as attraction, lights can have other impacts on nocturnal insects such as their visual systems being desensitised, a loss of ability to recognise objects in their environment and temporal or spatial disorientation (Owens and Lewis, 2018).

Male nocturnal insects are generally more attracted to light than females (Desouhant et al., 2019). The strength of attraction also depends on the type of lamp used and the wavelengths it emits. Spectral composition may be more important than light intensity for insects (Longcore et al., 2015) with UV emitting lights attracting more insects (Barghini and Souza de Medeiros, 2012). However, Bolliger et al. (2020) found that intensity could also be relevant and that the more light emitted by LED streetlights in Switzerland, the more insects were caught in insect traps. Heteroptera were particularly sensitive to light levels and the dimming of lights seemed to benefit them. Caution is needed when using how many insects are attracted to a light to assess a particular light source's ecological impact as some types of light may suppress flying activity and, therefore, attract fewer insects (Boyes et al., 2021). The distance from which insects can be attracted to lights varies depending on background illumination and the height of the artificial light (Eisenbeis, 2006). During the full moon, fewer insects are attracted to artificial lights.

There may be differences between insect orders in terms of what kind of light they are attracted to (Desouhant et al., 2019). Wakefield et al. (2018) found that Diptera were more common around LEDs whereas Coleoptera and Lepidoptera were more attracted to metal halide lights in their experiments. Different families of Lepidoptera respond differently to light. For example, shorter wavelength lighting attracted more Noctuidae than longer wavelength lighting (Somers-Yeates et al., 2013). Geometridae were attracted by both wavelengths. Certain moth species or families might be more attracted by UV light than others, with those attracted to UV emitting lamps dying from either exhaustion or predation, while others are less affected (Straka et al., 2021).

There is concern that light pollution, alongside other drivers including habitat loss, pesticide use, invasive species and climate change, is contributing to the rapid decline of insects worldwide (Owens et al., 2020). This decline in insects has many implications including, of course, for insect predators such as bats (Voigt et al., 2018a).

It is worth noting that some actions which are recommended for reducing obtrusive light, light spill and skyglow, such as shielding of lights, is not sufficient to protect insects in the immediate area of a light (Owens et al., 2020). Insect conservation requires the limiting of lighting to desired areas, using the lowest acceptable intensity and reducing the number of fixtures installed especially close to ecologically vulnerable areas. Seasonal approaches may also be appropriate in some cases. How insects are affected by polarization and flicker rate needs further investigation.

Guidelines for reducing the impacts of light pollution on insects are urgently required and this is recommended as a priority area of work for further engagement by CMS.

5.2.1.2 Impacts of artificial light on bat foraging activity

Presence of insects under lights may attract foraging bats, particularly fast-flying aerial hawking species which forage in open areas (e.g. genera *Eptesicus, Nyctalus* and *Pipistrellus*) (Stone et al., 2015; Lacoeuilhe et al., 2014). *Eptesicus* species in Sweden have been found to benefit from the increase in prey available at bright streetlights (Rydell, 1992). Other, more light-averse species such as *Myotis, Plecotus* or *Rhinlophus* may be deterred from foraging near both bright and dimmed streetlights and could, therefore, lose foraging sites when artificial light is installed (Stone et al., 2015; Luo et al., 2021). In Missouri, USA, Eastern red bats (*Lasiurus borealis*) were found to actively forage around lights, particularly just after sunset, whereas other species, including big brown bats (*Eptesicus fuscus*) and gray bats (*Myotis grisescens*), avoided lit areas (Cravens and Boyles, 2019).

These differences in foraging around artificial lights have led to bat species being divided into light-sensitive or light-tolerant/light-exploiting species. However, Voigt et al. (2018a; 2021) warned against such labels, as the reaction of a species to light can vary depending on several factors according to the specific situation. They categorised the likely responses of the different European bat genera in different situations as either an averse response, a neutral response or an opportunistic response (see Annex 2). A recent review found that how bats are impacted by ALAN depends on the context as well as on the species' foraging guild (Voigt et al., 2021). All European species react sensitively to ALAN near their roosts and to the illumination of drinking sites, possibly because of the increased risk of predation. In areas where they commute or forage, effects are more varied.

ALAN can cause a shift in community composition and may disadvantage some species (Seewagen and Adams, 2021). LED lighting led to a decrease in the presence and activity of little brown bats (*Myotis lucifugus*) and a reduction in activity for big brown bats (*Eptesicus fuscus*) and silver-haired bats (*Lasionycteris noctivagans*) in Connecticut, USA, while red bats and hoary bats (*Lasirus cinereus*) were not affected by the lights. A study in Italy found that ALAN influenced niche separation between Common pipistrelles (*Pipistrellus pipistrellus*) and Kuhl's pipistrelles (*Pipistrellus kuhlii*), which are both streetlamp foragers (Salinas-Ramos et al., 2021). *P. kuhlii* used artificially lit areas more frequently than *P. pipistrellus.* Species richness in Peru decreased with artificial light intensity although eight species were recorded using urban areas with high levels of ALAN (Mena et al., 2021).

ALAN along forest edges increases the probability of bats flying inside the forest (Barré et al., 2021). This may be because they are trying to avoid predation and suggests that bats use landscape structures when they react to light. A study in Sydney, Australia found that bat activity was higher in forest interiors compared to forest edges and that slower-flying species which are adapted to cluttered environments or with high characteristic echolocation call frequency were negatively affected by ALAN at the forest edge (Haddock et al., 2019a). Their activity decreased after high UV mercury vapour lights were changed to low UV LEDs

(Haddock et al., 2019b). The change to LED streetlights could therefore cause a decline in some insectivorous bats in cities although this may depend on previous exposure to ALAN. Bats which are relatively naïve to ALAN are more likely to show a reaction to it than bats in environments with long-term sources of ALAN (Seewagen and Adams, 2021). In Singapore, for example, where there are extremely high levels of light pollution (Falchi et al., 2016), changing high-pressure sodium streetlights for LED streetlights did not influence bat activity (Lee et al., 2021). Species which are less adapted to urban areas or areas with significant levels of ALAN may demonstrate behavioural changes.

Bat activity was found to be impacted by an LED lamp with a light intensity of 6480 lm (4000-4500K) illuminating a cross section of river in the Central Italian Apennines (Russo et al., 2019). However, reactions were species specific. Daubenton's bat (*Myotis daubentonii*) activity declined under lit conditions and later at night, whereas Kuhl's pipistrelle's activity significantly increased under the light. Other species or species groups showed no significant effects. The decline in Daubenton's bat activity was not due to a change in food availability because Chironomidae and Ceratopogonidae numbers increased under the lit conditions, mainly closer to the LED lamp, although the insect community over the water showed no qualitative or quantitative changes. The bats, therefore, appeared to be avoiding the artificial lighting.

5.2.1.3 Impacts of artificial light on bat roosts

Artificial lights near roost sites can negatively impact bats by disrupting their emergence activity and subsequently leading to reduced foraging opportunities because of a reduction of time available for foraging as well as access to the peak availability of insects at dusk (Stone et al., 2015; Voigt at al., 2018a). Rydell et al. (2017) found that bat colonies in churches require one side or end of the church to remain unlit, preferably the part that is nearest to surrounding tree canopies, so that bats can exit and return to the roost in safety. Artificial light at a roost site can lead to increased predation particularly if bats are forced to use an alternative, suboptimal exit (Stone et al., 2015). In some circumstances, light can force a colony to abandon their roost. For example, a whole colony (1000-1200 females) of Geoffroy's bats (*Myotis emarginatus*) abandoned a roost at a church in Hungary when floodlights were installed (Boldogh et al., 2007). A survey of country churches in Sweden found that colonies of Brown long-eared bats (*Plecotus auritus*) were lost at several churches which had floodlights installed (Rydell et al., 2017).

The presence of neutral white (broad spectrum of ~420-700 nm with peaks around 450 and 540-620 nm), red (spectrum between 620 and 640 nm with a peak around 630 nm) or amber (spectrum between 580 and 610 nm with a peak around 597 nm) LED at a cave entrance reduced the activity of four bat species: Schreiber's bent winged bats (*Moniopterus schreibersii*), long-fingered bats (*Myotis capaccinii*), Mediterranean horseshoe bats (*Rhinolophus euryale*) and Mehely's horseshoe bats (*R. mehelyi*), with red LED having the least negative effect (Straka et al., 2020). *Rhinolophus* species showed the strongest reaction. Straka et al. (2020) investigated the short-term effects of light on cave-dwelling bats but pointed out the potential for cumulative and long-term effects which could negatively impact entire colonies.

5.2.1.4 Impacts of artificial light on commuting behaviour

When artificial light disrupts commuting routes, bats may have to use suboptimal routes requiring increased flight time and energetic expenditure to arrive at their foraging grounds (Stone et al., 2015). They may also be at greater risk of predation or exposure to wind and rain. If no alternative route is available, then a colony may have to abandon its roost. Colony losses of Brown long-eared bas in Sweden may also be associated with artificial illumination in their flight corridors (Rydell et al. 2021). Vertical illuminance has been found to be a better predictor of bat activity than horizontal illuminance and so light orientation needs to be taken into consideration when assessing the impacts of ALAN on bats (Azam et al., 2018).

Streetlight placement can create barriers which impact the movements of bats which are especially sensitive to light (Azam et al., 2018). The serotine (*Eptesicus serotinus*), for example, avoided light when it was further away from lights when compared to other species, meaning that its movements were blocked by the barrier effect. It was negatively impacted by light at 25m and 50m but showed no difference between lit and unlit sites at 0 and 10m, suggesting that it is more tolerant of light near streetlights and able to forage around it, but that it will avoid lights when further away from them, meaning that its commuting routes can be blocked (Azam et al., 2018). Bat activity in Sydney, Australia has been shown to be higher in forest interiors compared to forest edges (whether there is artificial light at the forest edge or not) (Haddock et al., 2019a). This highlights the importance of maintaining connections or corridors between forest areas, especially forests in or close to urban areas.

Foraging Daubenton's bats may be more impacted by artificial light than commuting individuals. A study by Spoelstra et al. (2018) found that commuting Daubenton's bats flying through culverts were not affected by artificial LED light of different colours (red, white, green) with a light intensity of 5.0 ± 0.2 lx at the water level. The lack of response could have been due to the experimental set-up, the low light levels used or the location of the culverts, which passed under a road, and thereby the traffic noise may have deterred the bats more and encouraged them to still use the culverts despite the addition of the LEDs.

5.2.1.5 Impact of colour and light intensity on bats[51]

Bats are impacted by lights of differing colours and intensities (Voigt et al., 2021) though different species may be affected differently. During migration, soprano pipistrelles (*Pipistrellus pygmaeus*) and Nathusius's pipistrelles (*Pipistrellus nathusii*) showed increased activity when a red LED (with a dominant wavelength of 623 nm) was on, though this was not associated with increased feeding, suggesting that the association of the bats with red light was due to phototaxis (Voigt et al., 2018b). Spoelstra et al. (2017), however, found that *Pipistrellus, Plecotus* and *Myotis* species were equally abundant in red illuminated areas compared to a dark control, suggesting that there was no phototactic response when bats were not migrating. Barré et al. (2021) found that *Pipistrellus* species were more likely to fly inside a forest area when they were near red or white lights (compared to dark control areas) and that the probability was greater for red light as the bats got closer to the light.

During migration, *Pipistrellus* did not show increased general activity at a warm-white LED light source (dominant wavelength 581 nm) but they did demonstrate increased foraging compared to the dark control (Voigt et al., 2018b). Spoelstra et al. (2017) found that *Pipistrellus*

[51] DISCUSSION POINT: Can we make recommendations on what light is good/bad for bats when it seems to be species specific and/or seasonal?

species were more abundant around white and green lights while *Myotis* and *Plecotus* species avoided them. Barré et al. (2021) also found that for *Myotis* and *Plecotus*, white lights had a more significant effect than red lights, prompting them to fly inside a forest area when near the lights. For *Eptesicus* and *Nyctalus*, bats were significantly more likely to fly inside a forest near white light, though as they got closer to the lights, the probability of flying in the forest was stronger for both red and white lights. Contrasting results in studies on light spectra could be due to condition-dependent effects of ALAN on bats, for example before and during the migration period when vision plays a more dominant role than echolocation (Voigt et al., 2018b).

A study using dim, flickering UV lights (>400 nm) to deter bats from a wind turbine found that, in fact, bats' responses were more indicative of attraction than deterrence (Cryan et al., 2022). As there was not a significant increase in insect activity, it appeared to be the illuminated surface of the wind turbine rather than the presence of insects which attracted the bats. Straka et al. (2019) found that different species respond differently to the emission of UV wavelengths. Common pipistrelles and Nathusius's pipistrelles showed increasing activity with an increasing number of UV emitting streetlamps whereas Soprano pipistrelles, and bats in a group including the species *Nyctalus* and *Eptesicus* and the Particoloured bat (*Vespertilio murinus*) (which could not be distinguished according to their echolocation calls) responded negatively to mercury vapour and metal halide streetlights which emitted UV light.

Light intensity is important as well as spectrum. ALAN that is brighter than moonlight can disrupt foraging and mating in bats as well as interfering with entrainment of the circadian system (Voigt et al., 2018a). Increasing LED intensity led to a decrease in bat activity and buzz ratio while the opposite effect was found with low pressure sodium lamps (LPS) (Kerbiriou et al., 2020). This could have been due to an associated greater predation risk under stronger LED light which resembles daylight more than the light produced by LPS. Different species are sensitive to different light intensities and some species avoid lit environments, regardless of light intensity or spectrum (Kerbiriou et al., 2020). Illuminance values lower than 1 lx had a negative effect on light-sensitive *Myotis* species, whereas common pipistrelles and lesser noctules (*Nyctalus leisleri*), were most active between 1 lx and 5 lx. (Azam et al., 2018).

Even relatively short periods of artificial lighting can have a negative impact on bats. Boldogh et al. (2007) reported that for Greater horseshoe bat (*Rhinolophus ferrumequinum*), Geoffroy's Bat and Lesser mouse-eared bat (*Myotis oxygnathus*), even a one-hour lighting period after dusk can cause significant disruption in behaviour and growth. Geoffroy's bat was particularly sensitive to light and would not leave the roost until it was totally dark. Azam et al. (2018) also found that the negative effect of ALAN on *Myotis* species continued even after streetlights had been turned off.

5.2.2 Fruit and nectar feeding bats

Little is known about how tropical fruit and nectar feeding bats are affected by ALAN (Rowse et al., 2016), although they tend to avoid areas which are well-illuminated (Hoyos-Díaz et al., 2018). ALAN may prevent them from commuting and dispersing seeds leading to genetic isolation of illuminated plants and other important impacts on ecosystems (Lewanzik and Voigt, 2014). In areas where deforestation and light pollution are increasing, ecosystem functioning may be seriously affected. Six times fewer Great fruit-eating bats (*Artibeus lituratus*) and Jamaican fruit-eating bats (*A. jamaicensis*) were captured in a secondary growth forest patch in Venezuela when High Pressure Sodium lamps were installed (Hoyos-Díaz et al., 2018). Light pollution was also found to impact the intensity with which Great and Jamaican fruit-eating bats visited *Ceiba pentandra* trees in Yucatan, Mexico (Dzul-Cauich and Munguía-Rosas, 2022). As pollinators, the reduction in bat visitations could have impacted reproductive success for the trees but, in fact, this was not the case and the artificial light (mean level 5.06 ± 0.86 lx with the highest level of 18.20 lx in this study) had a direct and positive effect on *C. pentandra* reproductive success.

The time when Indian flying foxes (*Pteropus giganteus*) emerge from their tree roosts is highly correlated with sunset and day length (Kumar et al., 2018). All individuals from a roost will emerge within less than an hour, as will Greater shortnosed fruit bats (*Cynopterus sphinx*) (Murugavel et al., 2021). For pteropodid bats which roost in dark caves (e.g. Leschenault's Rousette, *Rousettus leschenaultii*), emergence times are more spread out with peak emergence time varying according to the moon phase. Their flight activity is restricted to lower light levels than tree-roosting species. Different species may, therefore, respond differently to light pollution. Floodlights have been used successfully as a management tool to deter flying foxes from roosting in particular trees in Queensland, Australia (State of Queensland, 2020). In areas where flying foxes are being protected, therefore, it is necessary to remove floodlights. Further investigation into how pteropodids respond to artificial light at night is needed.

Green cover is important for plant-eating bats and so increasing the presence of vegetation may be an important mitigation method to prevent any negative impacts from light pollution (Dzul-Cauich and Munguía-Rosas, 2022).

5.3 Light Mitigation Toolbox Recommendations

In this section, general principles for reducing the impacts of artificial light at night on bats are given, as well as recommendations for adapting lighting design, operation and planning.

5.3.1 General Principles

- Follow general principles in the generic guidelines presented in section 3.3.1 above
- Bats can be disturbed by all types of light including streetlights, external security lighting, façade lighting, light spill from windows, sports floodlighting and car headlights
- Different bat species respond differently to artificial light and the intensity and spectrum of light can have varying effects
- Follow the precautionary principle where no data is available regarding how artificial light affects a particular bat species / behaviour / habitat and reduce light pollution

5.3.2 Lighting Design

- Follow the lighting design guidelines in the generic guidelines presented in section 3.3.2 above

- Follow the recommendations in Table 7 below

Table 7: Recommendations for adapting lighting design to reduce the negative impacts of artificial light at night on bats

Measure	Recommendations
Adapt lamp type	Do not use metal halides or fluorescent sources
	Use LED, LPS or HPS lights considering the colour of the light (see below)
Adapt spectra	Avoid light with ultraviolet wavelengths
	Use amber and orange lights as preferred colours
	Use LEDs with warmer spectral composition (<2700 K)[52]
	Consider using lights of appropriate colour according to location/species present[53]
Adapt light intensity	Limit LED intensity[54], particularly close to daytime roosts and drinking sites

5.3.3 Lighting Operation and Planning

- Follow lighting operation guidelines in generic guidelines presented in section 3.3.3 above
- Carry out an Environmental Impact Assessment (EIA) to determine whether planned lighting installations could impact bats[55]
- Determine the presence of roosts, commuting habitat, foraging habitat[56]
- Avoid, mitigate and compensate for ALAN[57]
- Consult EUROBATS "Guidelines for consideration of bats in lighting projects" (Voigt et al., 2018a)
- Follow the recommendations in Table 8 below

Table 8: Recommendations for adapting lighting operation to reduce the negative impacts of artificial light at night on bats

	Measures	Recommendations
Avoidance	Conserve dark areas	Do not illuminate key habitats and features including roosts, caves, hibernacula, swarming sites, associated flightpaths, commuting habitat, foraging areas and water sources
		Do not illuminate façades of buildings which are close to forests

[52] Bat Conservation Trust and ILP (2018)
[53] Straka et al. (2020) recommended using red LED light at cave entrances
[54] Kerbiriou et al. (2020)
[55] Rydell et al. (2017) highlight the importance of carrying out an EIA before floodlights are installed on historic buildings
[56] Bat Conservation Trust and ILP (2018)
[57] Voigt et al., (2018a)

		Do not illuminate façades of buildings where there could be a bat roost present
		Do not illuminate inside bat roosts, at roost entrances or exits
		Do not allow illuminance levels from distant lights to exceed 0.1 lx at roost entrances, exits and emergence corridors[58]
		Do not illuminate flyways between roost entrances/exits and hedgerows, treelines and other commuting routes. Light levels should be below 0.1 lx
		Avoid ALAN at foraging areas such as water bodies (rivers, ponds, canals) and forests. Illuminance from distant lights must be below 0.1 lx
		Eliminate direct illumination of buildings with roosts during the whole reproductive season[59]
		Do not install lights inside caves used by bats
		Reduce ALAN in urban parks, gardens, forest edges, hedgerows and treelines used by foraging and commuting bats
	Seasonal measures[60]	Prohibit tourists from visiting caves with nursery colonies or hibernating bats
		In some cases, it may be better to maintain an area dark all year round even if bats only use it seasonally
Mitigation	Directional light / Avoid light spill	Separate streetlights from ecological corridors by at least 50m [61]
		Locate streetlights so that rear shields are adjacent to habitats
		Limit vertical light trespass on vegetation to less than 0.1 lx [62]
		If lights need to be installed inside buildings with roosts, use weak and highly directed light sources
		Where tourists visit large cave systems, only use lights in the area away from bats and dim them to a very low level
		Direct lights in caves on specific cave formations and switch them off when tourists are not present
		Install lights at lower heights to only illuminate target areas
		Use bollard lights to light paths keeping light low to the ground and maintaining dark areas above

[58] Voigt et al., (2018a). It is recommended that lux is measured by holding a luxmeter in a vertical position at 1.5m above the ground, measuring perpendicular to the sky, or next to the roost entrance or exit
[59] Boldogh et al. (2007)
[60] Some areas are only used by bats seasonally and light management should take this into consideration
[61] Azam et al. (2018)
[62] Azam et al. (2018)

		Create buffer zones between key bat habitat and areas to be lighted[63]
		Use buildings, walls, fences and soft landscaping to block light spill where appropriate
		Use vegetation to provide a buffer between lighting installations and habitat ensuring that lighting does not directly illuminate vegetation
		Use orientation of light to mitigate negative impacts[64]
		Consider placement of footpaths, open space, and number/size of windows in new developments to minimise light spill on to key habitat
	Dimming	Install dimmable streetlights in areas where roads fragment bat corridors or biodiversity-rich habitats[65]
	Timing of lighting	Reduce light intensity in the early night[66]
		Start the dark phase of a lighting scheme within the first two hours after sunset[67]
		Use motion sensors where lighting may be necessary at times during that period
	Seasonal measures	Control lighting when bats are present e.g. Churches should not use external lighting when bats are roosting inside
		Consider seasonal activities of bats including migration to make appropriate lighting choices
Compensation	Restore habitat	Overplant fencing with hedgerow species or climbing plants
	Restore dark areas	Maintain corridors of dark, unlit habitat so that bats can commute and migrate. This is particularly important in and around urban areas

Table 9: Recommendations for planning, monitoring and future research[68]

	Recommendations
Planning	Integrate maps of hazard areas for bats into the planning process
	Consider proximity of important habitat for bats to areas where light is going to be installed and how it could impact bats

[63] The key habitat should be maintained with no artificial light, the area next to the key habitat should have strictly limited illuminance, the area next to that should be moderately illuminated with the use of light barriers or screening, and, in the main development area where lighting is deemed most necessary, illuminance levels should be kept as low as possible. See Bat Conservation Trust and ILP (2018) for a useful diagram illustrating this.
[64] Barré et al. (2021)
[65] Bolliger et al. (2020)
[66] Lacoeuilhe et al. (2014)
[67] Voigt et al. (2018a)
[68] DISCUSSION POINT: are there key areas of monitoring/research that should be done to improve guidance for bats

	Introduce incentives to encourage bat-safe lighting / building design / lighting operation
	Promote bat-friendly lighting in publicly funded parks and infrastructure
Monitoring	Take baseline lighting measurements at the site/feature where lighting is to be installed
	Take post-completion lighting measurements to ensure that proposed lighting levels have been achieved
Research	Long-term studies are needed to understand how ALAN impacts foraging success, survival, recruitment, population sizes, bat community composition, migration and whether impacts vary according to latitude and biome[69]
	Keep up to date with the latest information about interactions between windfarms[70] and other infrastructure, illumination and bats

[69] Voigt et al. (2021)
[70] In their review of bat attraction to wind turbines, Guest et al. (2022) reported that artificial lights do not appear to be the main cause of bat attraction.

6. Next steps

i. Technical Workshop

A Technical Workshop is being organized for 29th, 30th and 31st March 2022. Invited experts will be asked to review the guidelines before the Workshop and then the guidelines will be further edited during the Workshop.

ii. Finalisation and submission

Following the Technical Workshop, the draft guidelines will be edited and resubmitted to the CMS Secretariat by 30th April 2022.

iii. World Migratory Bird Day

At the Technical Workshop, recommendations will be agreed by experts which can be used in campaign material.

iv. Other

Future work on light pollution should include the production of guidelines for insects, terrestrial and marine wildlife.

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Any mistakes in this first draft are not the fault of those who provided help!

Post workshop: Add acknowledgment recognising those who attend the workshop and helped refine the guidelines

This draft should not be cited as it is a work in progress.

8. Annexes

Annex 1

Table A: Guidelines in Canada with recommendations for reducing the negative impacts of artificial light at night on birds

City	Guidelines
Calgary	Bird-Friendly Urban Design Guidelines (2011)[71]
London	Green Standards for Light Pollution and Bird-Friendly Development, 4th draft (2018)[72]
Markham	Bird Friendly Guidelines (2014)[73]
Toronto	Bird-Friendly Development Guidelines (2007) and two companion books:
	Best Practices for Bird-Friendly Glass (2016)[74]
	Best Practices for Effective Lighting (2017)[75]
Vancouver	Bird Friendly Design Guidelines – Considerations for Development Permit (2015)[76]
	Bird Friendly Design Guidelines – Explanatory Note (2014)[77]
	Vancouver Bird Strategy (2015, updated December 2020)[78]

Table B: Guidelines in USA with recommendations for reducing the negative impacts of artificial light at night on birds

Organisation / City	Guidelines
American Bird Conservancy and New York City Audubon	Bird-Friendly Building Design, 2nd edition (2015)[79]
Audubon Minnesota	Bird-Safe Building Guidelines (2010)[80]
City of Santa Cruz	Bird-Safe Building Design Standards[81]

[71] https://www.calgary.ca/pda/pd/current-studies-and-ongoing-activities/urban-design.html
[72] https://pub-london.escribemeetings.com/filestream.ashx?DocumentId=46167
[73] https://www.conveniencegroup.com/usercontent/Bird_Friendly_-_Appendix_A_-_Guidelines.pdf
[74] https://www.toronto.ca/wp-content/uploads/2017/08/8d1c-Bird-Friendly-Best-Practices-Glass.pdf
[75] https://www.toronto.ca/wp-content/uploads/2018/03/8ff6-city-planning-bird-effective-lighting.pdf
[76] https://guidelines.vancouver.ca/B021.pdf
[77] https://vancouver.ca/files/cov/bird-friendly-strategy-design-guidelines-draft-2014-09-01.pdf
[78] https://vancouver.ca/files/cov/vancouver-bird-strategy.pdf
[79] https://abcbirds.org/wp-content/uploads/2019/04/Bird-Friendly-Building-Design_Updated-April-2019.pdf
[80] https://mn.audubon.org/sites/default/files/05-05-10_bird-safe-building-guidelines.pdf
[81] https://www.cityofsantacruz.com/Home/ShowDocument?id=75970

New York City Audubon	Bird-Safe Building Guidelines (2007)[82]
Portland, Oregon	Resource Guide for Bird-friendly Building Design (2012)[83]
San Francisco Planning Department	Standards for Bird-Safe Buildings (2011)[84]
US Fish and Wildlife Service	Reducing Bird Collisions with Buildings and Building Glass Best Practices (2016)[85]

[82] https://www.darkskysociety.org/handouts/birdsafebuildings.pdf
[83] https://audubonportland.org/wp-content/uploads/2019/08/Resource-Guide-for-Bird-safe-Building-Design.pdf
[84] https://sfplanning.org/sites/default/files/resources/2019-09/Design%20Guide%20Standards%20for%20Bird%20Safe%20Bldgs_Final.pdf
[85] https://www.fws.gov/southeast/pdf/guidelines/reducing-bird-collisions-with-buildings-and-building-glass-best-practices.pdf

Annex 2

Table C: Likely responses of bats to ALAN in specific situations (From Voigt et al., 2018a)

Genera	Daytime Roosts	Commuting	Foraging	Drinking	Hibernacula
Rousettus	Averse	Neutral	Neutral	Averse	Averse
Rhinopoma	Averse	Data Deficient	Data Deficient	Averse	Averse
Rhinolophus	Averse	Averse	Averse	Averse	Averse
Barbastella	Averse	Averse	Averse	Averse	Averse
Eptesicus	Averse	Averse	Opportunistic	Averse	Averse
Pipistrellus and *Hypsugo*	Averse	Neutral/ opportunistic	Opportunistic	Averse	Averse
Myotis	Averse	Averse	Averse	Averse	Averse
Plecotus	Averse	Averse	Averse	Averse	Averse
Vespertilio	Averse	Data Deficient	Not applicable / opportunistic	Averse	Averse
Nyctalus	Averse	Data Deficient	Not applicable / opportunistic	Averse	Averse
Miniopterus	Averse	Data Deficient	Not applicable / opportunistic	Averse	Averse
Tadarida	Averse	Data Deficient	Not applicable / opportunistic	Averse	Averse

Table key: An averse response = the bat would normally avoid ALAN. A neutral response = ALAN would not influence the spatial distribution and activity of a bat. An opportunistic response = the bat turns towards locations with ALAN under certain conditions

9. Glossary [86]

ALAN	Artificial Light at Night
Backlight	
Baffle	an opaque or translucent element to shield a light source from direct view
candela (cd)	Unit of luminous intensity emitted from a point source. One candela is one lumen per steradian
CCT	Correlated Colour Temperature. A measure in degrees Kelvin of light warmness/coolness
Colour temperature	
Cut-off fixture	An IES definition "Intensity at or above 90° (horizontal) no more than 2.5% of lamp lumens, and no more than 10% of lamp lumens at or above 80°".
Decorative lighting	
EIA	Environmental Impact Assessment
Façade lighting	
Floodlight	A fixture designed to "flood" a well-defined area with light.
full cut-off	
fully-shielded	
glare	intense and blinding light that reduces visibility
HID	
HPS lamp	High Pressure Sodium lamp. A high-intensity discharge lamp where radiation is produced from sodium vapour at relatively high partial pressures (100 torr).
illuminance	
IR	Infrared. Electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometers to 1 mm

[86] WORK IN PROGRESS! Contributions welcome!

Compiled from the following sources: https://www.darksky.org/our-work/grassroots-advocacy/resources/glossary/, Bat Conservation Trust and ILP (2018), EEPAC, ACE, and AWAC (2018), ILP (2021)

Kelvin (K)	
LED	Light emitting diode
Light fixture	A lamp, its housing, reflector, mounting bracket and/or pole socket
Light pollution	
Light spill	Light which spills beyond the area being lit
Louvres	Physical light spill control accessory
LPS lamp	Low Pressure Sodium lamp. A discharge lamp where the light is produced by radiation from sodium vapor at a relatively low partial pressure (about 0.001 torr). LPS is a "tube source". It is monochromatic light.
Lumen (lm)	Measure of brightness as perceived by the human eye. Unit of luminous flux; the flux emitted within a unit solid angle by a point source with a uniform luminous intensity of one candela.
Luminous flux	
luminaire	the protective case around a light source OR A complete lighting unit that usually includes the fixture, ballasts, and lamps. OR lighting enclosure, lantern or unit designed to distribute light from a lamp or lamps
Luminance	At a point and in a given direction, the luminous intensity in the given direction produced by an element of the surface surrounding the point divided by the area of the projection of the element on a plane perpendicular to the given direction. Units: candelas per unit area.
Lux (lx)	Measure of light on a flat surface. One lumen per square metre.
Mercury lamp	An HID lamp where the light is produced by radiation from mercury vapor.
Metal-halide lamp	An HID lamp where the light is produced by radiation from metal-halide vapors.
Nadir	A point on the celestial sphere directly below the observer, diametrically opposite the zenith.
Nanometer (nm)	Used as the unit for wavelength
Obtrusive light	An alternative name for light pollution. "Obtrusive light, whether it keeps you awake through a bedroom window, impedes your view of the night sky or adversely affects the performance of an adjacent lighting installation, is a form of pollution. It may also be a nuisance in law and can be substantially mitigated without detriment to the requirements of the task." (ILP, 2021)
Photoperiod	
Phototaxis	

RULO	Ratio of Upward Light Output
Searchlight	
Semi-cutoff fixture	An IES definition; "Intensity at or above 90° (horizontal) no more than 5% of lamp lumens and no more than 20% at or above 80°".
Shielding	The use of an opaque material that blocks the transmission of light.
Skyglow	Diffuse, scattered sky light attributable to scattered light from sources on the ground.
Task lighting	The lighting necessary to carry out a particular task
Uplight	
UV	Ultraviolet light. Electromagnetic radiation with wavelengths from 400 nm to 100 nm, shorter than that of visible light but longer than X-rays.
Vanity lighting	
Wavelength	measured in nanometers (humans can see between 400 and 700 nm)
Zenith	An imaginary point directly "above" a particular location, on the imaginary celestial sphere.

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