# Application of Light Sensitivity to Luminaire Requirements

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## SPECTRUM

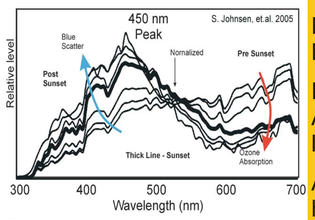
Although humans are primarily daytime creatures, survival has depended on our ability to see through the twilight period and, to a limited extent, throughout the night.

Sleep and restorative biochemical processes are enabled once blue light falls below the ipRGCs detection threshold (twilight detectors). But white ALAN has blue spectral components that delay or prevent these processes.

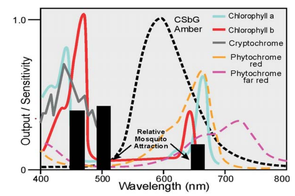
Reducing white-light ALAN also reduces the attraction and concentration of disease-bearing insects - such as mosquitoes.

ALAN exposure to the rod cell's action spectrum enables vision at low light levels. The broad spectral sensitivity of rod cells enhances the benefit of low light levels in the green and yellow even if the light has no blue spectral components. There are few natural blue surfaces.

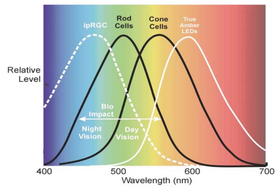
A compromise between ipRGC and rod cell action spectrum leads us to ***recommend limiting the <500 nm spectrum for non critical ALAN to < 1%.*** This amber colour is not distracting at low levels because it has limited effect on the colour discriminating cone cells. At brighter levels it provides reasonable colour rendering.




The sky becomes enhanced with blue light after the Sun's yellow photosphere disappears below the horizon. Our retina's ipRGCs have evolved to detect this enhanced blue light to keep us alert during this period of day/night transition.



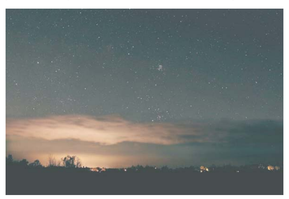

Plants are primarily sensitive to blue and red wavelengths. Mosquitoes are also sensitive to colour. Minimizing blue light reduces the impact of ALAN on these species.




"Amber" has very low impact on the ipRGCs, while providing enough light for rod vision to see at low illumination levels. At higher levels (3-lux) amber provides reasonable colour rendering (CRI=48) whereas HPS is only 19.

## ILLUMINATION LEVEL

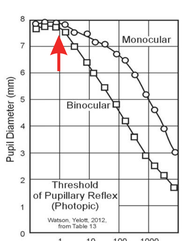
The natural night is rarely "dark". Starlight illuminates the countryside to 0.001-lux, the crescent Moon to 0.02-lux and a full moon to 0.1-lux. Yet, even the crescent Moon affects the behaviour of animals. For humans and many animals, white ALAN above 0.1-lux begins to suppress the secretion of melatonin.



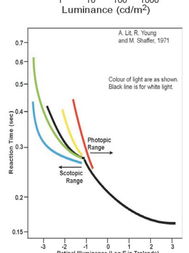
Urban sky glow reflecting off clouds can be brighter than the full Moon. The luminance can reduce human and animal dark adaptation, and can mask starlight to produce false navigation cues for wildlife.

Comparison between high-impact 13-watt CFL (top) and a 14-watt low-impact luminaire that was designed by CSbG for ecologically sensitive areas.

- No blue light,
- Sharp Cut-off shielding,
- 3:1 uniformity over wide target area,
- max. illumination of 3-lux, and
- no glare or light trespass.




The pupillary reflex is a proxy for the sensitivity of the ipRGC system to relatively bright light. At a luminance of 1-3 cd/m$^2$, the iris begins to restrict the amount of light entering the eye.




Human reaction time vs. luminance shows that high illumination levels promote faster reactions. However, we mostly benefit from 1-3-lux. At higher photopic illumination levels, visual clutter becomes a distraction, which significantly slows our reactions to >1 sec.

Distant urban sky glow can illuminate the countryside to levels brighter than the full Moon. This affects the behaviour of wildlife in the same way as moonlight - hindering their ability to recover with foraging during the dark time of new Moon. By reducing the lumen output from luminaires, we can reduce the amount of reflected light and reduce sky glow's impact on rural wildlife.

Let's be practical: 1-lux - Read phonebook, reactions = ½ sec. (pedestrian pace).
3-lux - Read faster, detect colour, reactions = ¼ second.

***We recommend limiting illumination for pedestrian paths and non-major streets to 1-3-lux (saving >50% on electricity).***


## ABSTRACT

No amount of Artificial Light at Night (ALAN) is good for nature. But when it is deemed necessary, its impact must be minimized.

Recent studies on wildlife and humans highlight a sensitivity to ALAN and question the current trend towards high-impact lighting policies and the use of urban-style luminaires in parks.

A multi disciplinary study of biology, biochemistry, botany, human physiology and cognition (scotobiology) has revealed thresholds below which illumination has relatively little impact. This information has been applied to develop guidelines for outdoor lighting and has been demonstrated with a low-impact luminaire for environmentally sensitive areas.

ALAN can originate outside the park from nearby urban areas. Therefore, parks require an outreach program to help limit the illumination by sky glow from these communities. These towns can also benefit from applying these lighting guidelines.

These guidelines are an alternative to urban lighting policies.

## SUMMARY

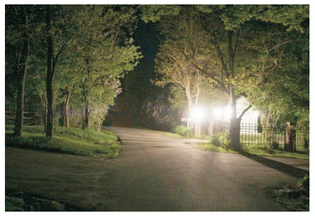
Scotobiology allows us to define limits on four characteristics of ALAN that will minimize its impact on wildlife and human health. These should be promoted in adjacent urban areas.

**SPECTRUM** - > 500 nm (i.e. no blue components)
**LEVEL** - 1 to 3-lux maximum (3-lux around motor vehicles)
**GLARE** - Sharp Cut-off shielding (<1% within 80$^O$-90$^O$ of nadir)
**DURATION** - < 2-hours after/before sunset/sunrise


## GLARE / TRESPASS

Animal and human vision are sensitive to glare, which is caused by high illumination levels and poor shielding. Glare is exacerbated by white light with blue spectral components.

Comparison of FCO luminaires (near field) and non-FCO luminaires in the distance. Maximum illumination level was about 17-lx. Unregulated commercial signs cause significant distracting clutter for motorists - especially the flashing or animated signs that delay driver reaction times.



Even rural ALAN can be disruptive. Although the illuminated trees and bushes create a local "sense of place", the resulting glare makes it impossible to see animals and hazards beyond the immediate area. The glare cuts visibility by undermining our scotopic vision.

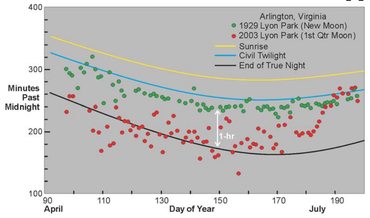
Luminaire optics and shielding can effectively reduce glare, and light trespass to minimal levels.

Just preventing light from shining upward is not enough. The worst glare is from light emitted just below the horizon, between 80-90 degrees from nadir (the glare zone).

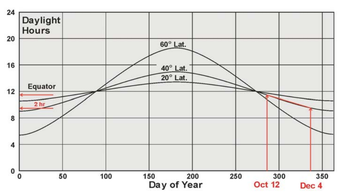
As a minimum: Full Cut-off fixtures (10% of the light in glare zone),

Much better: "Sharp Cut-off fixtures (<1% of the light in glare zone).

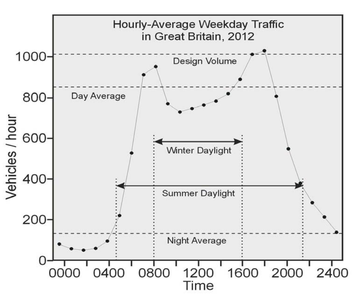
***We recommend "Sharp Cut-off shielding" (<1% in glare zone).***




Urban robins become active about an hour earlier in the morning due to the additional illumination from ALAN. This activity may be out-of-synch with the availability of food.




At mid-latitudes, winter-snow can arrive between Oct. and Dec. and may not melt promptly in early spring. This results in a variation in daylight of an hour in the evening and again in the morning.




Traffic density at a traffic monitoring station in London, UK. Only winter rush hours are in twilight or darkness requiring relatively high levels of illumination. Average traffic densities (hence human activity) drop to about ¼ throughout the night.

## DURATION

Using birds as just one example, ALAN increases the pre-dawn light that may cue activity too early. We estimate a practical duration for ALAN based on astronomy, biology and human activity (animals don't need extra light).

Twilight falls below our photopic level after 30 minutes. The effects of twilight, cloud cover and the variation in onset of winter snow combine to have produced a behavioural "plasticity" for wildlife to the light cues. We use these to help provide a rough estimate for limiting the duration of ALAN.

Twilight - 1hr, morn.+ eve. Clouds - 1 hr, morn.+ eve.

Length of daylight varies over the seasons. Winter's crippling effects vary due to the early and late arrivals of snow-cover at temperate latitudes. This introduces an uncertainty in the animal's use of the length-of-day as a cue for activity and onset of snow.

Onset of snow - 2 hours, morning + evening

***We recommend limiting ALAN to within 2 hours of sunset and sunrise (saving 50-70% in electricity).***

Roadway traffic, when used as a proxy for outdoor human activity, shows that only about 25% of the population are active after dark. These low traffic densities do not require as much light as times of high density. And "rush hours" during Spring to Autumn occur in daylight. These are sensitive biological periods, when ALAN should be minimized.

**REFERENCES** are available on request, or Lighting Res. Technol. 2014; Vol 46: 50–66