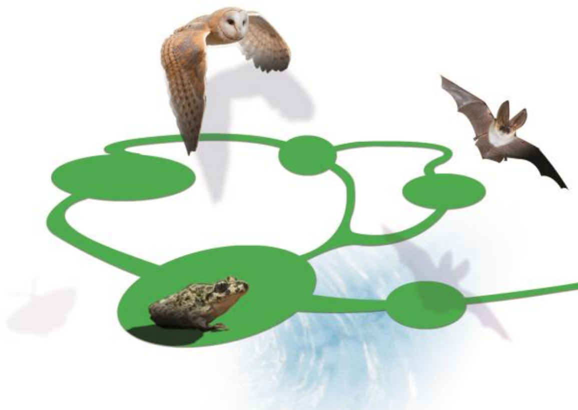


Dark Infrastructure: an ecological network for night-time wildlife

Romain Sordello, Fabien Paquier and Aurélien Daloz – September 2021

As an upshot of the expansion of land artificialisation, artificial light at night, due to both public and private lighting, leads to the loss of natural habitats, increased habitat fragmentation and direct mortality for nocturnal species. Following the example of France's Green and Blue Infrastructure developed mainly with a focus on diurnal species, we now need to protect and restore the good environmental status of nocturnal ecological networks, against a backdrop of ever increasing light pollution.

Light pollution - an increasing impact on biodiversity

From the very beginning, life on Earth has been influenced by the alternating pattern of day and night which has shaped the evolution of living organisms. For diurnal animals, as well as for plants, the dark phase is an essential part of their daily cycle, corresponding to their resting period. Nocturnal animals, on the other hand, are able to be active in an environment with low or no light thanks to various adaptations, in particular their night vision.

The development of human societies over recent decades has resulted in large-scale urbanisation, bringing with it a proliferation of artificial night-time lighting generating light pollution.

Globally, between 2012 and 2016, the Earth's artificially lit outdoor area grew by around 2.2% per year, with an increase in radiance of 1.8% per year [1]. Other diachronic studies [2] reveal that light pollution continues to escalate, especially in Europe, with a worldwide increase of around 6% per year. Today, more than 80% of the world population, and 99% of European populations, live under light-polluted skies [3].

Natural sites, including protected areas, are also affected by such pollution. Protected areas are experiencing a decline in night-time darkness (around a 15% drop in Europe between 1992 and 2010) [4] and are under increasing pressure from artificial light at their periphery [2]. At a global level, biodiversity hotspots are severely threatened by light pollution [5].

Light pollution has various negative effects: energy consumption, public health, astronomy, but also numerous impacts on biodiversity (see Figure 2 on the following pages).

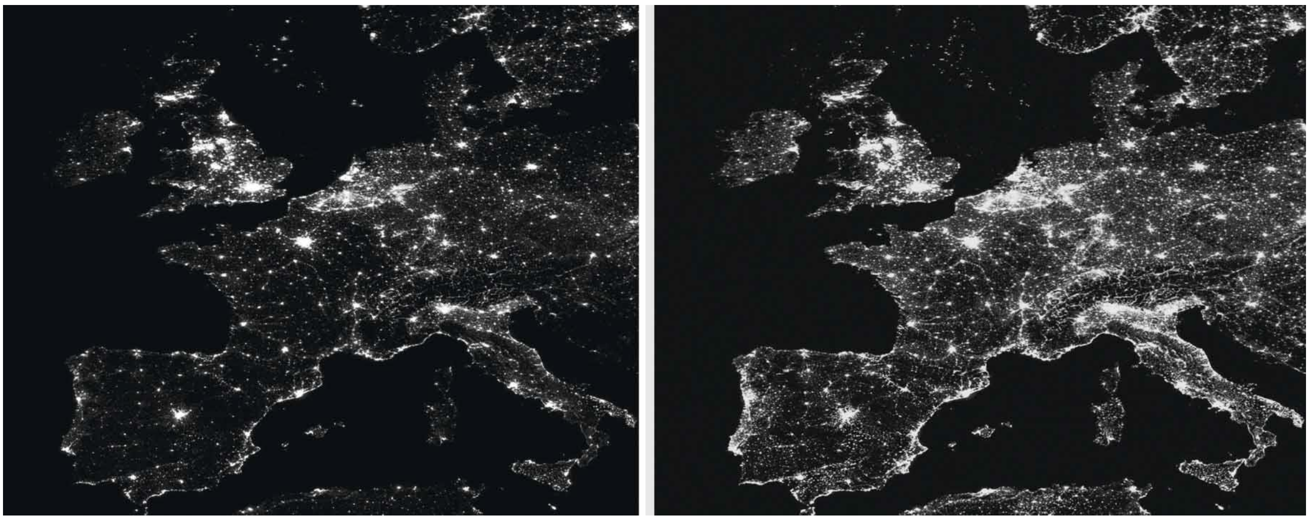


Figure 1: Evolution of artificial light at night in Western Europe. Left: 1992; right, 2013. Source: Image and data processing by NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency. Acquisition & Production by La TeleScop

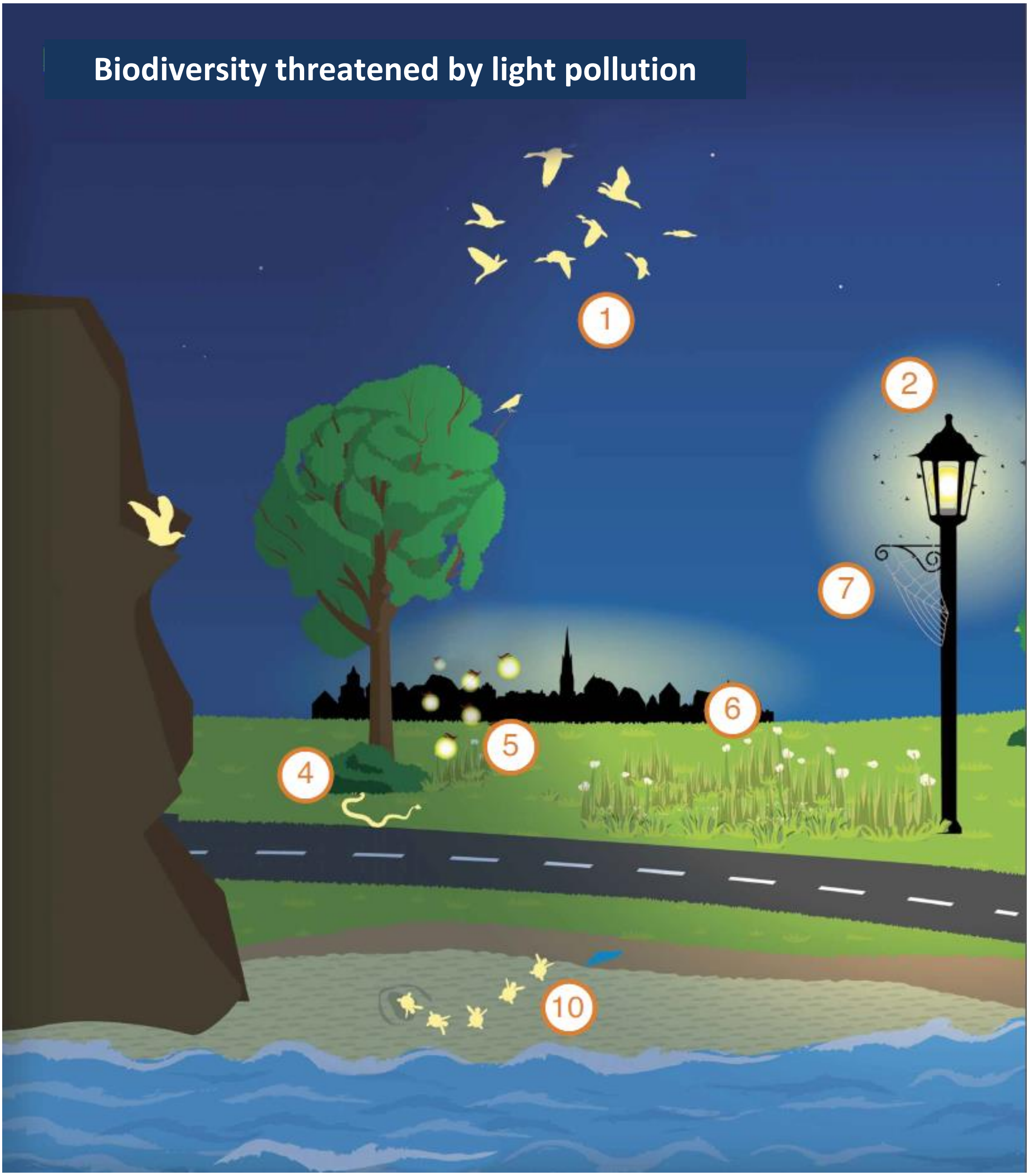


Figure 2: Biodiversity threatened by light pollution. Illustration of some of the effects of light pollution on biodiversity.

1. Birds

During their journey, migrating birds rely on the stars to navigate the night sky. City lights can cause them to lose their bearings; they can fly round light sources for hours and die of exhaustion or due to collision (illuminated towers, lighthouses). The day/night cycle of urban-dwelling diurnal birds is disrupted by artificial lighting. Male birds, unable to distinguish between dawn and night, sing all night long to the point of exhaustion.

2. Flying insects

Flying insects navigate at night using the stars or moon. They are inherently attracted to any artificial lights where most die of exhaustion or are burnt by the heat of the lamps.

3. Bats

European bats are strictly nocturnal insectivores and are extremely sensitive to light. They flee from light, some species even suspend their activity during the full moon. Yet locally, certain bats tolerate light because it attracts insects.

4. Snakes

Snakes have an infrared sensory system they use to detect thermal radiation in their environment. Depending on the type of bulbs used, artificial lighting can interfere with this sensing system. Young snakes tend to flee from light to avoid being spotted by predators.

5. Fireflies

Fireflies (like glow worms) emit light from their abdomen. This light is used mainly as a signal between males and females. Since light pollution disrupts their communication, these animals are vanishing from artificially lit areas.

6. Plants

Excessive light disturbs plants' seasonal patterns (flowering, defoliation, refoliation), as well as causing stress in some species, potentially leading to disease. Furthermore, certain insect pollinators, on which 90% of flowering plants are dependent, are nocturnal and are significantly affected by artificial light. Flowers exposed to artificial light at night are visited by fewer nocturnal pollinators than those in an unlit meadow. This reduction in pollination has repercussions on fruit production.

7. Spiders

Spiders naturally spin their webs in dark areas, sheltered from sight. This behaviour is changing for almost half of the species living in urban environments. These spiders appear to be taking advantage of artificial light by spinning their webs close to light sources to increase their chances of catching prey.

8. Terrestrial mammals

Cervidae *(deer, roe deer, etc.) tend to avoid crossing artificially lit roads. The range of these animal species is therefore restricted by artificial light, limiting their access to food. Lighting also affects the daily rhythm of these mammals.*

9. Amphibians

When exposed to artificial light, female amphibians will mate with the first male they encounter to avoid predators. Males, which are ordinarily highly vocal and clearly visible, tend to keep a lower profile. Consequently, mating frequency is falling in certain species.

10. Turtles

On hatching, young turtles spontaneously move towards the light. This behaviour naturally guides them towards the sea, which is brighter than land because it reflects light and because of its white foam. In artificially lit areas of shoreline, the light contrast between land and sea is reversed; the newly hatched turtles are disorientated and make their way inland.

11. Fish

Fish can be strongly attracted to light which can cause exhaustion or an increase in predation. In fact, certain fishing techniques use light to attract fish.

Artificial light at night has both physiological and metabolic effects. In behavioural terms, artificial light sources may attract or repel nocturnal animals, depending on their natural behaviour in relation to light (called **phototaxis***). Artificial lighting is thus a factor that contributes to habitat degradation or even loss for many species (bats, terrestrial mammals, fireflies and glow worms, etc.) entailing population-scale effects and even affecting the entire distribution area [6,7,8]. This attraction/repulsion phenomenon has landscape-level repercussions and artificial lighting can create impassable areas for certain animals, which find themselves either drawn in or driven out [9,10,11]. Artificial light at night therefore leads to habitat fragmentation and isolated nocturnal pockets (Figure 3).

Light pollution also affects other levels of biodiversity such as relationships between species (pollination, predation). For example, one study shows that night-time lighting could reduce nocturnal insects' visits to plants by around 60%, resulting in a fall in pollination and a 10% decrease in fruit formation [12]. Ultimately, this threatens certain ecosystem services [13]. Lastly, artificial lighting throws animals' biological clocks out of sync, whether they be nocturnal or diurnal (passerine birds, diurnal birds of prey). Plants are also affected: artificial lighting can cause budburst in urban trees to occur around a week early and delay autumn leaf-fall.

The effects of light pollution can also be due to the light intensity [14], its **spectral composition*** [15] or light timings [16] (on/off times, duration, flashing or intermittent etc.).

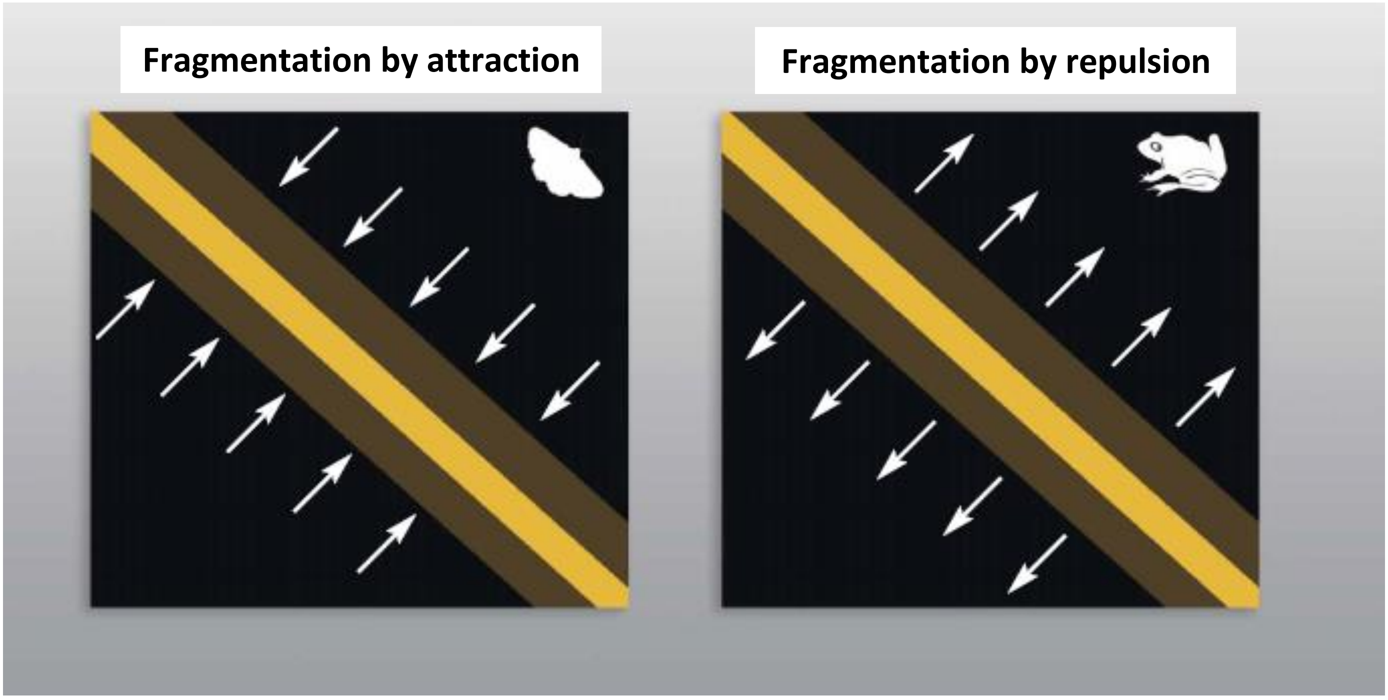


Figure 3: Fragmentation effect of an artificially lit infrastructure, attracting or repulsing wildlife. Source: based on Sordello, 2017 [9].

** Definitions for the terms in bold face followed by an asterisk are provided in the Glossary on page 15.*

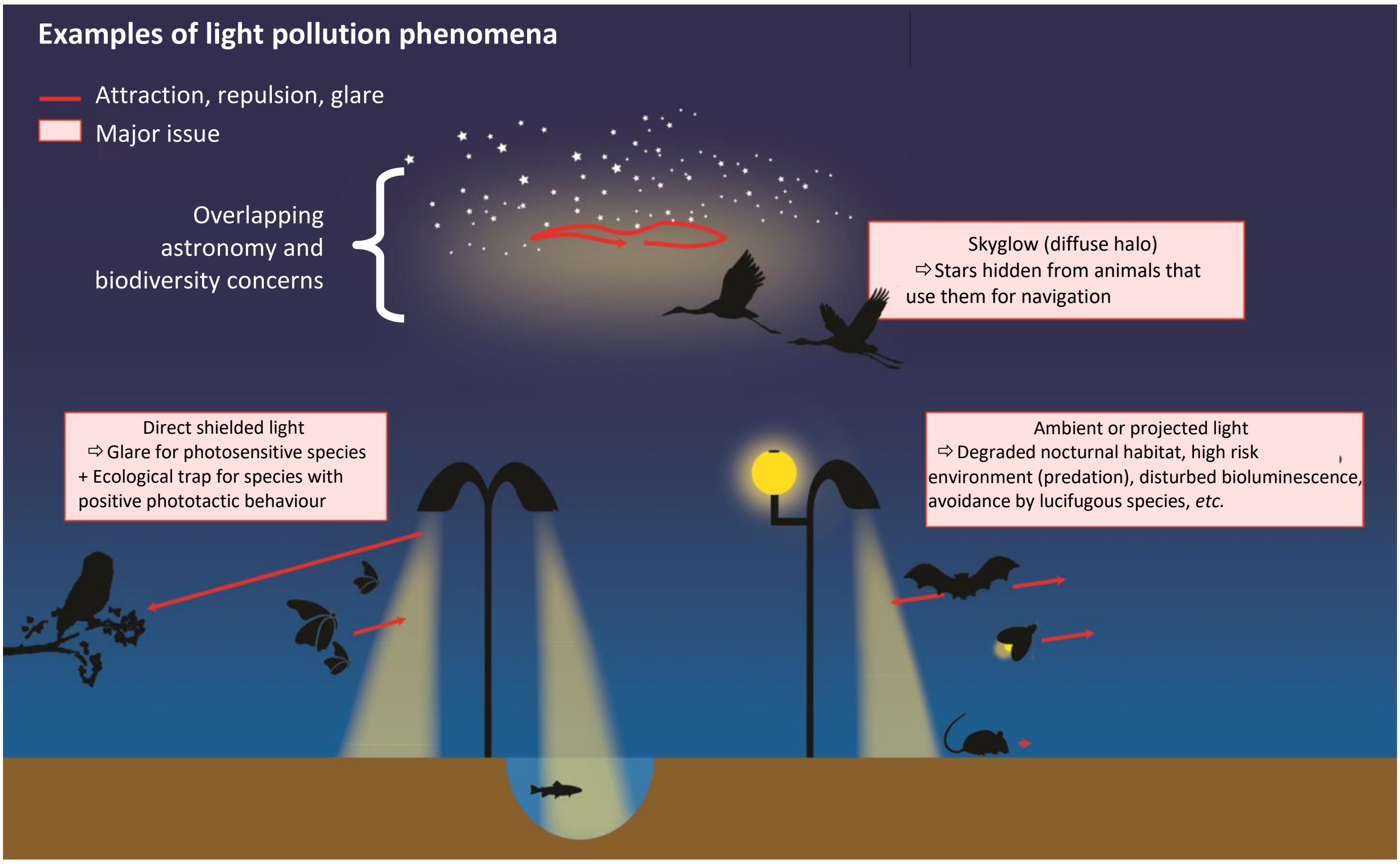


Figure 4: Main light pollution phenomena affecting living organisms. Source: based on Sordello, 2017 [17].

Insects attracted by a stadium projector. © Vincent Vignon

Bat flying around a street light attracting insects. © Romain Sordello

2. Dark Infrastructure: a spatial approach for a nocturnal ecological network

Despite the impacts of artificial light on biodiversity (sometimes even at very low light levels scarcely exceeding that of the full moon), night-time lighting cannot be eliminated everywhere since it fulfils a need in human societies. This means that the issue must be given prior in-depth consideration in order to develop a reasonable and restrained planning strategy. This strategy must ensure that the lighting corresponds precisely to the needs expressed and should question these needs, while taking better account of biodiversity issues and the ecological impact of artificial light.

In particular, to mitigate the disappearance and fragmentation of natural habitats, scientists recommend implementing protection and restoration measures for **ecological networks***. In France, this is the objective of a public policy known as the ***Trame verte et bleue****, mirroring the EU Green and Blue Infrastructure [18].

In view of the effects of light pollution, particularly at landscape level, it appears crucial to preserve and restore an ecological network that will foster nocturnal wildlife, dubbed the **Dark Infrastructure*** [19]. **The Dark Infrastructure can be defined as an ecological network of habitat patches (cores) interconnected by corridors for different environments, identified based on a level of darkness which is sufficient for nocturnal biodiversity.**

The Dark Infrastructure requires global and cross-cutting insights into nocturnal ecological networks at the scale of a given territory through comparison with spatial data on artificial light at night. Light pollution can be quantified and modelled using different complementary data sources (see box below).

Data sources to gain insight into the phenomenon of light pollution

Several data sources can be used:

- public street lighting data provided by the entity managing public lighting;
- different light measurements at ground level;
- radiance data from aerial images at night;
- radiance data from satellite images.

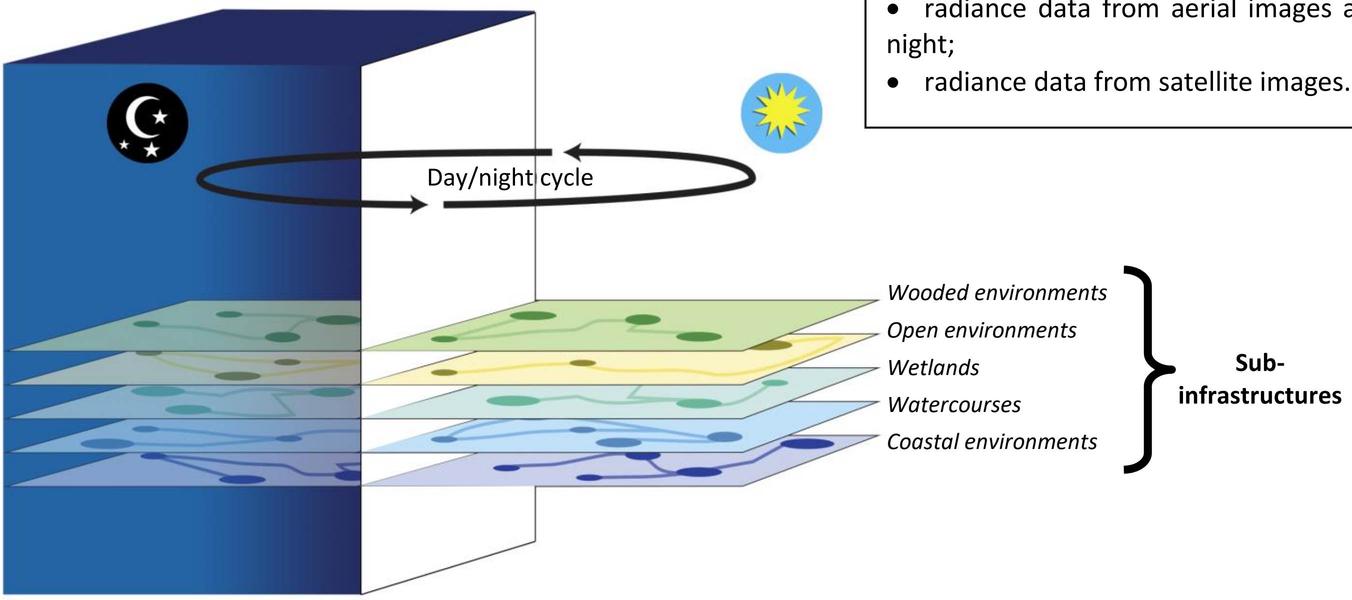


Figure 5: The Dark Infrastructure aims to take into account the temporal dimension (day/night cycle), which is not currently included in the Green and Blue Infrastructure. Source: based on Sordello, 2017

Figures 6 and 7 illustrate the work conducted by the *Parc national des Pyrénées* (PNP - Pyrenees National Park) to model light pollution within the national park and to map its Dark Infrastructure.

Several Dark Infrastructure projects have already been conducted in France as exploratory initiatives by local stakeholders: natural sites (national parks, regional nature parks) and numerous local authorities (Figure 8). To our knowledge, France is pioneering with this nocturnal ecological network initiative which remains largely undeveloped in other countries, with the exception of Geneva [20].

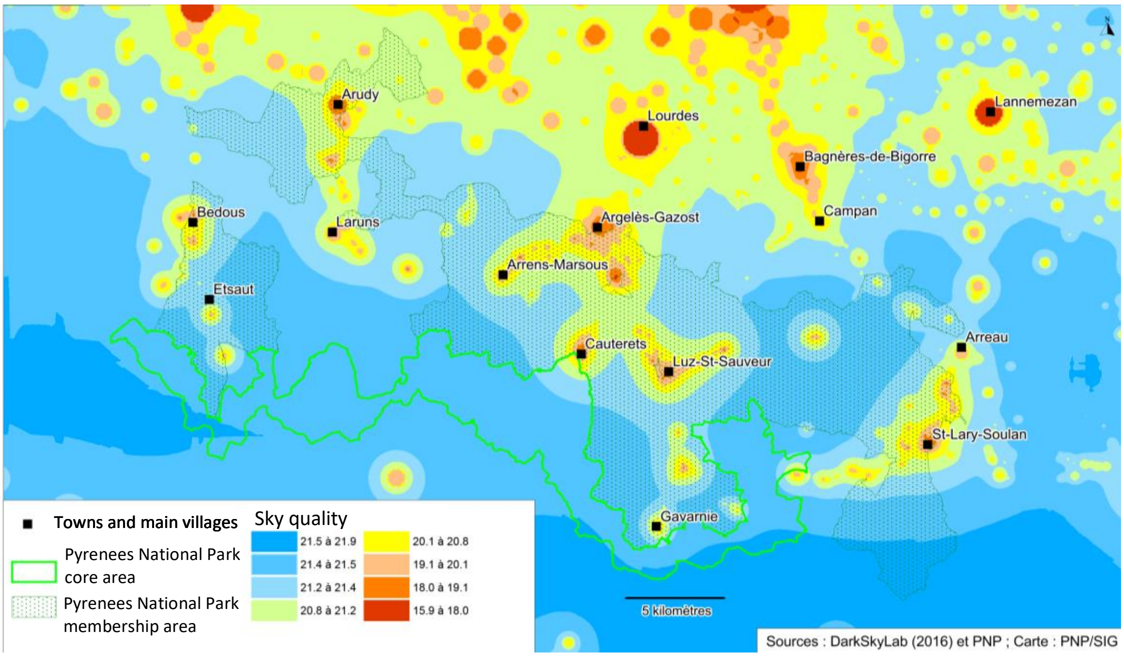


Figure 6: Map of light pollution modelled for the Pyrenees National Park. Source: DarkSkyLab and PNP.

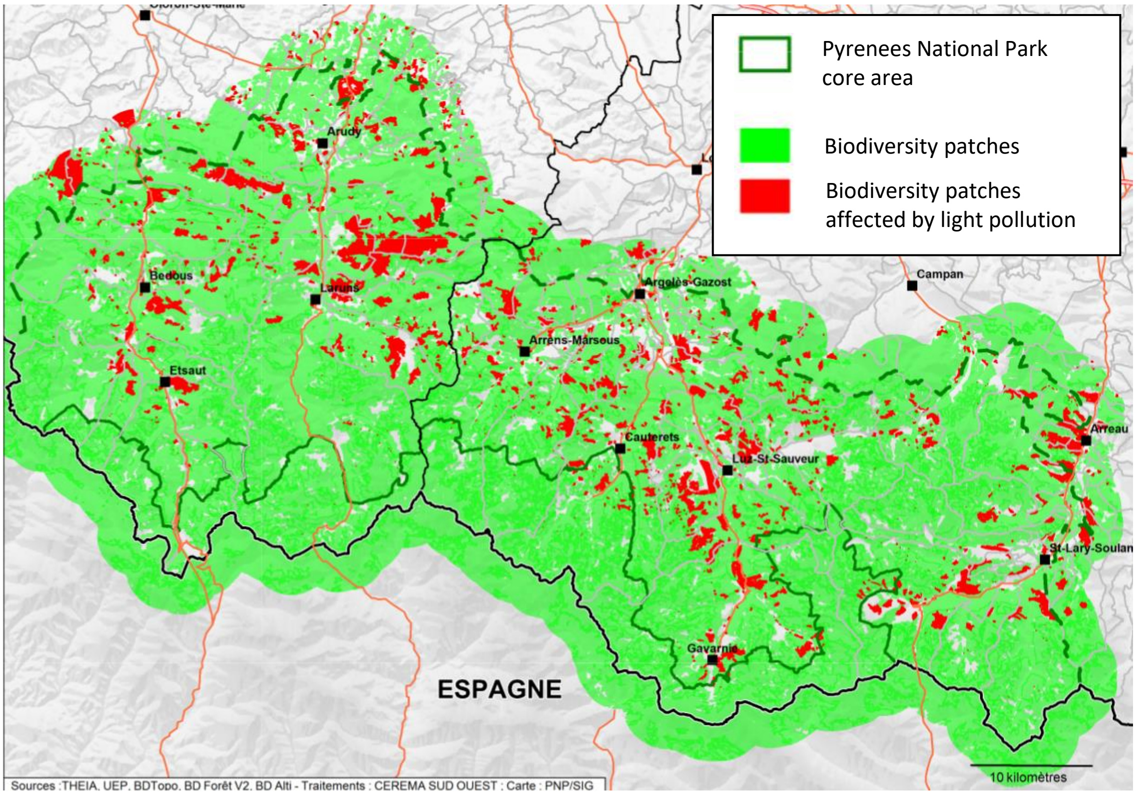
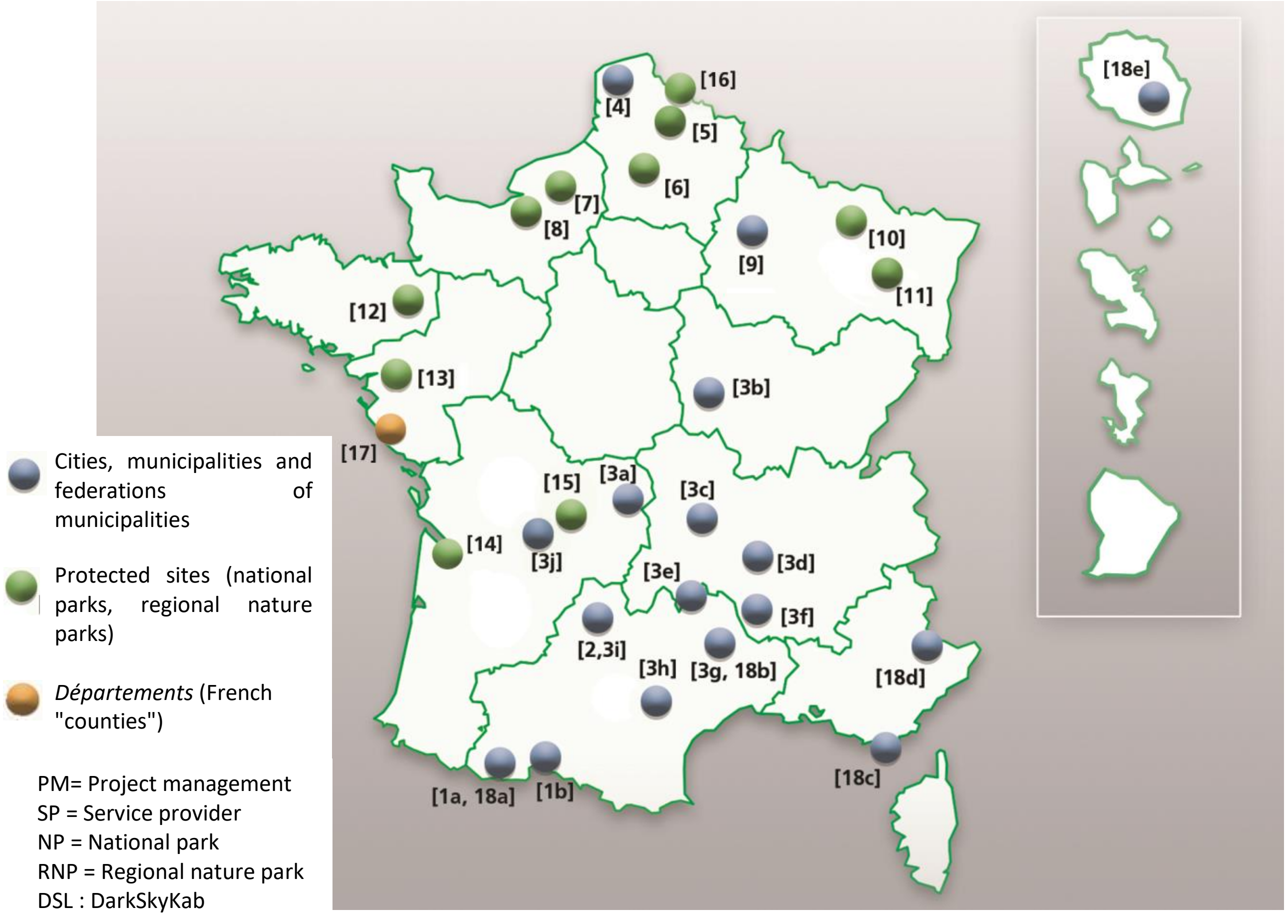


Figure 7: Biodiversity patches affected and unaffected by light pollution. Source: PNP.



[1] Projet "TRAME SOMBRE", 2015-2017
PM: [a] Pyrénées NP et [b] Pyrénées ariégeoises RNP
SP: DSL
[2] Causses du Quercy RNP
Identification de zones de conflits avec la TVB dues à l'éclairage (2012)
[3] PM: IPAMAC ([a] RNP Millevaches en Limousin, [b] RNP Morvan, [c] RNP Livradois-Forez, [d] RNP Pilat, [e] RNP Aubrac, [f] RNP Monts d'Ardèche, [g] Parc national des Cévènnes, [h] RNP Haut-Languedoc, [i] RNP des Causses du Quercy, [j] RNP Périgord-Limousin)
SP: DSL, RENOIR
[4] RNP Caps et Marais d'Opale
SP: TerrOïko, Cerema

[5] PM: Ville de Douai
SP: Auddice
[6] PM: Amiens Métropole
SP: Biotope, Cerema, DSL
[7] PM: Seine-Eure
SP: Biotope, DSL
[8] PM: Lisieux-Normandie
SP: Biotope, DSL
[9] PM: PNR Montagne de Reims
SP: DSL
[10] PM: Metz Métropole
SP: DSL, TerrOïko, Auddice
[11] PM: Vosges centrales (SCOT)
SP: Atelier du territoire, Acere, DSL
[12] PM: Ville de Rennes (SDAL)
SP: Concepto
[13] PM: Nantes Métropole
SP: Cerema

[14] PM: Bordeaux Métropole
SP: DSL, TerrOïko, Auddice
[15] PM: Limoges Métropole
SP: Echo Chiro, DSL
[16] Projet "TRAME NOIRE", 2014-2017
Study on Lille Métropole urban area By Biotope with CEFE/MNHN and Université de Lille 1 (funding FRB/CR NDPC)
[17] PM: Vendée (SyDEV)
SP: Artelia et Luminescence
[18] PM: OFB/National Parks ([a] Pyrénées, [b] Cévennes, [c] Port-Cros, [d] Mercantour, [e] Réunion)
SP: DSL, TerrOïko, Auddice

N.B.: This map only shows the approaches explicitly connected with the Dark Infrastructure as defined in this document. It therefore does not cover all the activities conducted in France to mitigate light pollution and promote nocturnal biodiversity. Furthermore, the map is not necessarily exhaustive; it presents the projects known to the French Resource Centre for the Green and Blue Infrastructure at the time of writing.

To see an up-to-date version of this map, please visit the following address:
http://www.trameverteetbleue.fr/tramenoire

Figure 8: Map of Dark Infrastructure projects

3- Managing artificial light in ecological networks

The first step towards implementing actions in favour of nocturnal wildlife is to identify the Dark Infrastructure. This section presents the various key parameters in night-time lighting that affect the level of light pollution in relation to biodiversity and which should therefore be adjusted to protect or restore the Dark Infrastructure. These parameters can be divided into three categories: technical, temporal and spatial (Figure 9).

It should be noted that in France, regulations on light pollution lay down technical requirements for the management of night-time lighting (see box below).

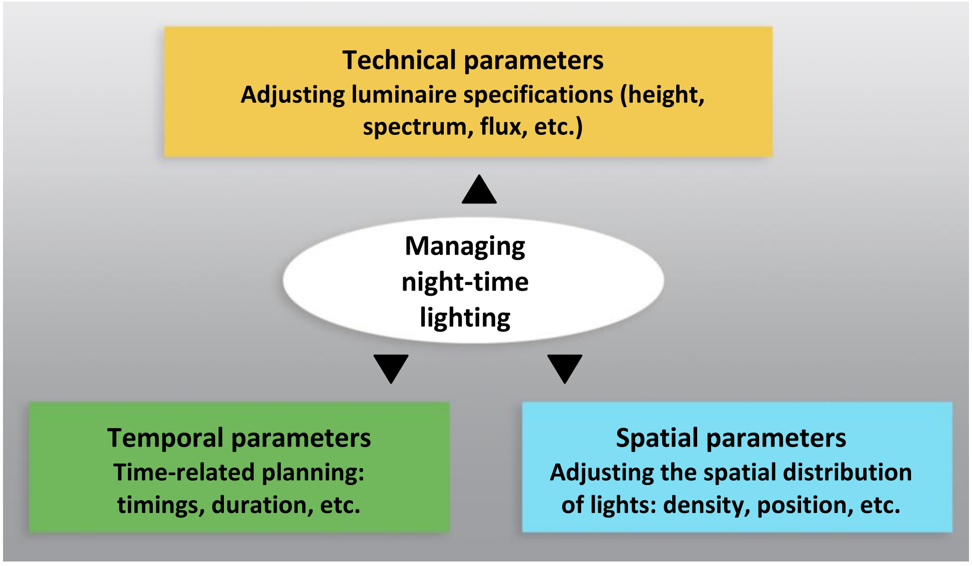


Figure 9: Approaches for reducing light pollution Source: based on Sordello, 2018 [21].

French regulations on light pollution
In France, there is a set of very specific measures for the different light use categories; these are mandatory, independently of the Dark Infrastructure. For example the Ministerial Decree of 27 December 2018 on the prevention, reduction and limitation of light pollution sets out various lighting parameters such as the timings for switching lighting on and off, light levels emitted above the horizontal plane, luminous flux densities and colour temperatures. The decree also includes specific measures for certain protected sites.
For more information (in French): http://bit.ly/2rpNelM

*Greater mouse-eared bat (*Myotis myotis*) in a natural cavity.*
© Philippe Massit / OFB.

1- Spatial organisation of artificial lighting: towards a differentiated management approach to artificial lighting

The first priority is to reduce the number and density of lights as far as possible. All areas do not require the same lighting: **differentiated lighting management** should be implemented. A ranking system for the need for artificial lighting may be established, for instance according to site's protection status (protected areas or other areas of ecological interest). This differentiated management strategy could lead to a **reduction in the density of light sources, or even their complete removal, in ecological networks and specially identified areas.** Luminaire spacing may also be increased to create "dark gaps" for wildlife movements. Finally, a grading system could also be implemented for certain luminaire specifications or their operating times.

On a smaller scale, some sites, such as bridges, cliffs, old buildings, bell towers etc., are particularly sensitive because they are highly sought after by nocturnal fauna. However, these sites are often artificially lit at night. One study shows that illuminated churches house two to three times fewer colonies of bats [22]. When located within an ecological network, these sites should have stricter measures, or even no lighting at all. Some environments are also highly sensitive to light pollution, in particular aquatic environments, as light penetrates water, is reflected by it, radiates into neighbouring environments and forms perpendicular barriers at artificially lit bridges.

Selection of ground surfacing

The ground surface also plays a determining role in the quantity of light emitted skywards according to its capacity to absorb or reflect light. Every material has a reflectance value indicating the extent to which it will reflect light rays. In the case of urban planning, to reduce the impact of light on biodiversity in sensitive areas, it is preferable to select materials with low reflectance for installation under lights in order to reduce upward reflection.

2- Temporal organisation of artificial lighting: optimising duration

Time-based planning involves reducing the lighting duration by targeting the time slots when it is most useful. By scheduling the lighting to be switched on and off in line with human needs, light pollution can be significantly reduced without any loss of comfort.

Adjusting the lighting throughout the night - including in the late evening and early morning - is very important since part-night lighting schemes are insufficient (see below). Indeed, many nocturnal animals appear in reality to be active mainly at dusk and dawn, periods which could be termed **chronotones*** (boundary between night and day, just as the "ecotone" is the boundary area between two ecosystems in space). It is possible that the biological activity of certain species, considered to be either diurnal or nocturnal, which seek to maximise the compromise "see without being seen" (especially by predators), may peak during these transition periods.

Regarding public street lighting, local authorities have developed several types of initiatives: astronomical clocks (to switch lighting on/off based on the time of sunrise/sunset), photocells (to switch lighting on/off based on the ambient light level). So-called "smart" lighting systems are also being developed, which adapt to the users' needs (motion sensors, controlled by smartphone, etc.). It is worth noting that when lighting is switching on and off regularly throughout the night, it can also potentially generate new issues for wildlife through the visual stimulus it creates.

*Tawny owl (*Strix aluco*).*
© Romain sordello.

Part-night lighting

In France, several thousand municipalities switch their public lighting off in the middle of the night. This may be across the whole municipality or part of it, all year round or for part of the year. In certain cases, the lighting is not switched on again in the morning, and may even not be used at all during the summer months. Two studies on bats [23,24] show that the effectiveness of this measure depends primarily on the time window during which the lighting is switched off. The results would probably be similar for other species whose activity peak is in reality at twilight rather than strictly nocturnal (e.g. terrestrial mammals, nocturnal birds of prey). Lighting should thus be switched off as early as possible, to avoid encroaching on the activity period of these species. Part-night lighting is likely to be highly beneficial for certain groups which are active in the middle of the night, as well as for plants and for all species that use the stars for orientation (migrating birds for example). It immediately restores the visibility of the night sky, which also ties up with certain human demands (astronomy, night-time heritage, night-time tourism). Lastly, this measure offers immediate energy savings.

3- Lamp specifications

Quantity of light emitted

Scientific knowledge of the sensitivity thresholds of **flux*** or **illuminance*** remains patchy and results are available for only a few species [25]. Information is also available for plants. In 1936, Matzke observed that leaf-fall from trees in towns was disturbed by artificial lighting at levels as low as 10 lux [26]. A recently published study on bats demonstrates that they avoid street lights by up to 50 m in the case of certain species [27]. Another study shows that even solar powered LED "night lights", which emit light ranging from less than 1 lux to a few lux and which many people install in their gardens, have an impact on insects since they act as attractant traps [28].

Light composition (impact of wavelength)

Light affects different behavioural and physiological processes independently of vision. For instance, it influences biological patterns and hormone regulation. Each wavelength has a relatively precise effect which varies between species groups (Figure 10). According to the current state of knowledge, the wavelengths corresponding to blue, green and red light appear to have the highest impact [84]. In particular, blue attracts nocturnal insects which are often at the base of food webs. Blue is also involved in the disruption of biological clocks (by suppressing the release of **melatonin*** in mammals).

	Ultraviolet (<380nm)	Violet (380-450nm)	Blue (450-500nm)	Green (500-550nm)	Yellow (550-600nm)	Orange (600-650nm)	Red (650-750nm)	Infrared (>750nm)
Plants	■	■	■	■	?	?	■	■
Crustaceans	?	?	?	■	?	?	■	?
Arachnids	?	■	■	■	■	■	■	?
Insects	■	?	■	■	■	?	■	?
Amphibians	■	■	■	■	■	■	■	?
Birds	■	■	■	■	■	■	■	■
Fish	?	?	■	■	■	?	■	?
Mammals (excluding Chiroptera)	■	■	■	?	■	■	■	■
Chiroptera	?	■	■	■	■	■	■	?
Reptiles	?	■	■	■	■	?	?	?

Figure 10 - Wavelength intervals for which at least one type of impact is identified (black boxes) for certain biological groups. Based on Musters et al.*, 2009. Source: Sordello, 2017 [29].*

Lamps emitting a narrow spectrum are therefore recommended. This will automatically decrease the number of species and biological functions affected. Furthermore, harmful wavelengths, in particular blue, should be reduced to a strict minimum. Blue light emissions also have an impact on human health. Orange lights appear to be less harmful both for nocturnal biodiversity and for humans, according to current knowledge.

Gas-discharge lamps (mainly sodium-vapour lamps) produce yellow/orange light and it has been shown that they therefore have a lower impact on certain species. Yet there is currently a major shift towards LED lamps for outdoor - as well as indoor - lighting. LED lamps offer major economic savings and have technical advantages for lighting control: the lamp intensity can be adjusted and they can be used in conjunction with motion sensor systems to best fit lighting requirements. However the LEDs generally sold for outdoor lighting, especially cheaper models, produce relatively "cold", blue-rich light, with a high **colour temperature*** (expressed in Kelvin, K).

If the decision is made to install white LEDs, it is therefore recommended that LEDs with the lowest possible colour temperature be chosen, to reduce harmful effects due to blue wavelengths [90]. Indeed, the lower the colour temperature, the lower the proportion of blue light emitted. It is therefore preferable to install "warm white" LEDs, i.e. 2400 K or less. Nevertheless, warm white LEDs reportedly have as high an impact as cold white LEDs for certain organisms, such as bats and glow worms. Certain manufacturers now offer **orange or amber LEDs (2000 K or less)**.These LEDs have a lower output than white LEDs (their energy efficiency is half that of a 3000 K LED based on current technology) and are slightly more costly, but they would appear to be a good compromise as they have the spectral advantage offered by sodium-vapour lamps for biodiversity (lower impact amber light) and can be operated smoothly via a management system. In Canada, the city of Sherbrooke has converted all its street lighting to amber LEDs.

Sodium vapour lamps.
© Romain sordello

Luminaire orientation

Luminaire orientation determines the proportion of **light emitted skywards and more generally above the horizontal plane; this proportion should be kept to a minimum to reduce skyglow** (Figure 11). It is therefore important to restrict the light to the area to be illuminated, which is generally the ground (a road or pavement). Uplighting, often used to illuminate monuments or even trees, is also very detrimental. Globe lights, which emit a large share of their light skywards, should be avoided.

Figure 12 and the following pages provide an overview of the recommendations made by the French Resource Centre for the Green and Blue Infrastructure.

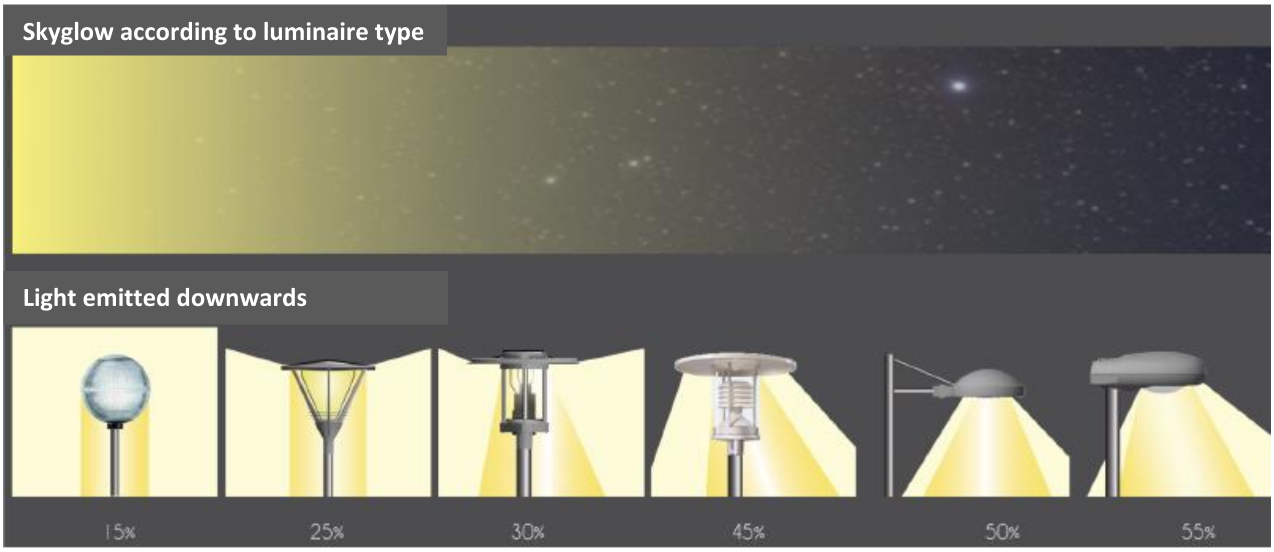


Figure 11: Flux efficacy and light pollution according to luminaire type. Source: Acere.

Finally, it is important to note that the roll-out of LED street lighting entails a risk of seeing an increase in the number of light points due to the “rebound effect”. Indeed, given the low electricity consumption of LEDs, a local council for example may decide to install a greater number of lights, while continuing to make energy savings, however this solution is unsatisfactory in terms of biodiversity. Furthermore, autonomous solar LED lights are easily installed and offer an easy, “free” lighting solution for areas where the installation of wired lighting is impossible or too costly: wall lights, pathway lighting, garden lights, etc.

Overview of recommendations on night-time lighting management in ecological networks

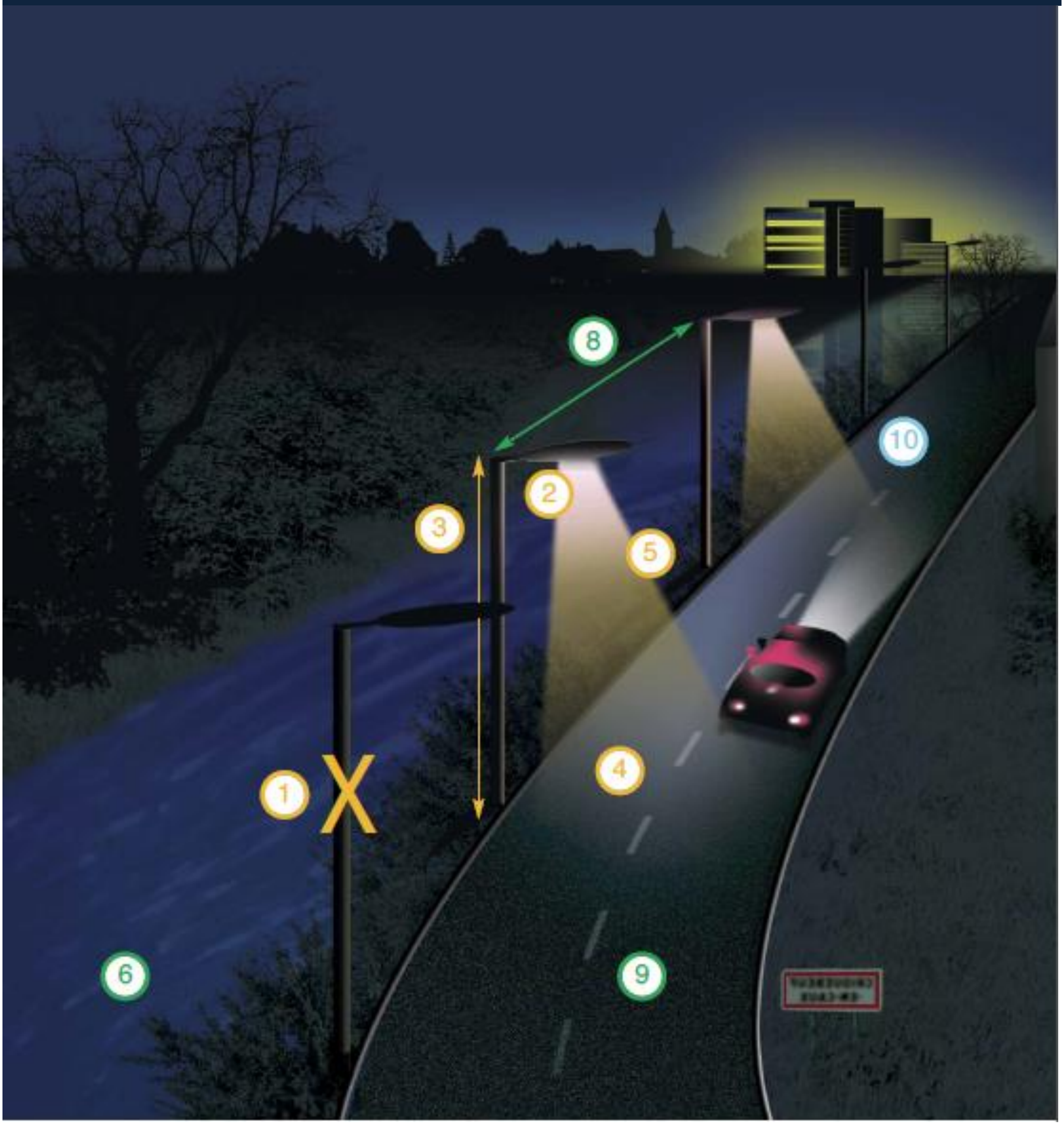


Figure 12: Overview of the different focal areas for managing artificial light at night in ecological networks. Example of illumination of a road at the entrance to a town. Source: based on Sordello, 2018 [46].

Luminaire specifications

1- Avoid installing or remove unnecessary lights
2- Angle of orientation: prevent light from being emitted above the horizontal plane
3- Pole height: as low as possible to reduce detection from a distance by wildlife
4- Restrict lighting exclusively to the surface area to be illuminated
5- Light emitted: emit as little light as possible, at the narrowest spectrum possible and in the amber band, reduce glare to a minimum for wildlife

Spatial organisation of artificial lighting

6- Do not illuminate watercourses
7- Do not illuminate adjacent natural areas
8- Luminaire spacing: leave dark interstitial spaces for wildlife crossing
9- Choose ground surfacing with a low reflectance value under lighting

Temporal dimension

10- Motion sensors
Keep operating time to a minimum: switch-on time, switch-off time, operating time per night, variation during the year

Illustration : Béatrice Saurel / OFB

A proactive approach to maintain and restore darkness should be implemented everywhere. This firstly means adapting lighting, not only with a view to energy efficiency. Within and adjacent to ecological networks, but also generally for all natural areas, this approach consists specifically in:

- avoiding the installation of artificial lighting;
- removing as many lights as possible;
- prioritising passive lighting (reflective strips and markers, reflectors, etc.).

Certain specific human activities may, on an exceptional basis, justify the presence of artificial lighting within ecological networks. The specifications and functioning of these lights must comply with regulations and should meet all the following requirements:

- ensure minimal operating time, reduced to what is strictly necessary for the human activity concerned, using either a timer or motion sensors, and take into account nocturnal biodiversity patterns (daily, seasonal, multiannual);
- not emit any light above the horizontal plane and reduce the “cone” of light cast to decrease luminous flux close to the horizontal plane;
- restrict lighting exclusively to the surface area to be illuminated (e.g. the path);
- not directly illuminate natural environments and biodiversity habitats (aquatic environments, vegetation, trees, cavities, etc.);
- emit as little light as possible;
- choose lamps with the narrowest spectrum possible and in the amber band (low- or high-pressure sodium-vapour lamps or orange/amber LEDs);
- not create glare for wildlife.

These recommendations can be applied both to private and public lighting. These measures can be applied and adjusted outside of ecological networks as part of a differentiated lighting management approach.

Glossary

Chronotone: boundary between day and night, just as the "ecotone" is the boundary area between two ecosystems in space. It is possible that the biological activity of certain nocturnal species may peak during these transition periods.
Colour temperature (in K): indicates the proportion of blue and red in the light spectrum. The warmer the light (high proportion of red), the lower the colour temperature and vice versa. It is expressed in Kelvin (K).
Dark Infrastructure: a series of interconnected biodiversity patches and ecological corridors for different environments identified as being sufficiently dark for nocturnal biodiversity.
Ecological network: an area particularly favourable for biodiversity and for wildlife movements across a given territory, consisting of habitat patches (cores) of high biodiversity value and ecological corridors connecting them.
Green and Blue Infrastructure / *Trame verte et bleue*: a public policy designed to mitigate the fragmentation of natural habitats. It aims to ensure that better account be taken of biodiversity in land-use planning through ecological networks.
Illuminance (in lux): luminous flux relative to a surface area, usually the surface receiving the light.
Luminous flux (in Lumen – lm): amount of light emitted by a light source in all directions in one second (i.e. the sum of the luminous intensities).
Melatonin: primarily known as the central hormone regulating chronobiological rhythms. The secretion of melatonin increases shortly after nightfall. It participates in controlling circadian rhythms and in regulating the day-night cycle.
Phototaxis: phenomenon through which animals and plants control their movement (attraction or repulsion) as a function of light in their environment.
Spectral composition of light: proportion of different wavelengths in emitted light. A light source with wavelengths spread across the entire spectrum visible to the human eye will produce white light, while conversely coloured light will be produced if the wavelengths are close or if certain wavelengths are absent.

Authors

Summary of the following publication: *Sordello R., Paquier F. and Daloz A. 2021. Trame noire, méthodologie d'élaboration et outils pour sa mise en œuvre. Office français de la biodiversité. Collection* Comprendre pour agir. *112 pages* https://bit.ly/2Quy7nv

English translation: Sally Ferguson, Jane Rollet for COMBAVA GIE

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