

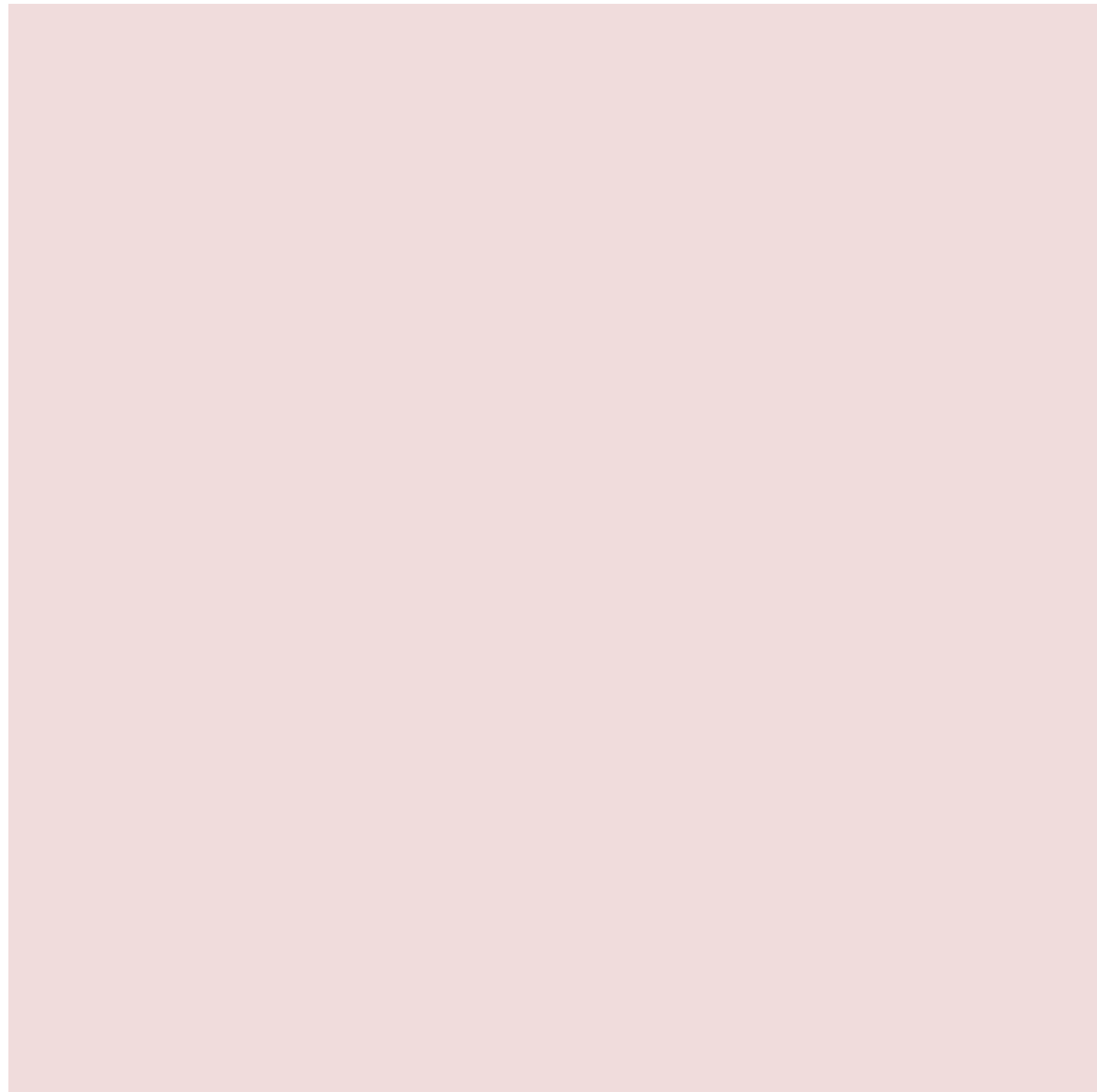


# What is the ecological impact of light pollution?

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*Light pollution is a phenomenon associated with the use of artificial lighting by humans. In fact, it alters the natural cycles of light and alters the illumination of the environment. Through this article, we will consider the origin and extent of light pollution, its impacts on living organisms and ecosystems, as well as the biological mechanisms involved.*

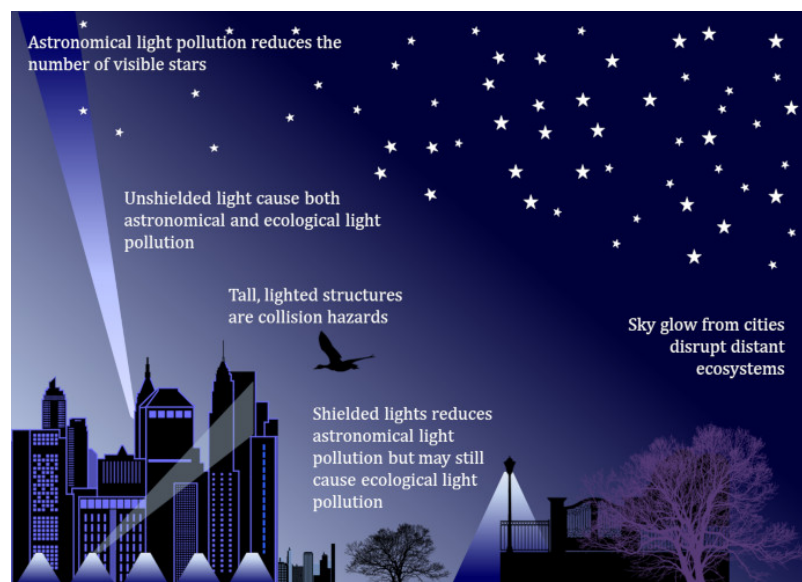
## 1. Light pollution around the world

## 1.1. What is light pollution?

Light pollution is a phenomenon of anthropogenic origin associated with the development of urbanization and human activities and which involves artificial light. From the astronomer's point of view and according to a qualitative approach, light pollution refers to artificial light that degrades the quality of the night sky, masks the light of stars and other celestial bodies and limits their study. The astronomer speaks of "astronomical light pollution". According to a quantitative approach, the *International Astronomical Union* indicates that, for a clearly defined geographical region, light pollution occurs when the artificial light propagated in the night sky is greater than 10% of its natural luminosity at night.

From the ecologist's point of view, light pollution refers to artificial light that degrades the cycles of natural light (day/night cycle and seasons), modifies the nocturnal component of the environment, i.e. the illumination of the environment, and consequently impacts behaviour, the biological rhythms and physiological functions of living organisms, as well as ecosystems. Assemblages formed by an association of living beings (or biocenosis) and its biological, geological, soil, hydrological, climatic, etc. environment (the biotope). An ecosystem is characterized by interactions between living species and their surrounding environment, material and energy flows between each of the ecosystem components that allow their life and a dynamic balance over time between sustainability and evolution. Ecologists work in ecology. The job of an ecologist is to study the relationships between organisms and the surrounding world. Should not be confused with the ecologist, who campaigns to protect ecology. Ecologists speak of "ecological light pollution" [1].

## 1.2. Sources



*Figure 1. Sources of light pollution: sources of light pollution include illuminated buildings and structures, public and road lighting, emergency lighting and vehicle lighting. Pollution from these sources alters natural light cycles, degrades the quality of the night sky and modifies the night component of the environment. [Source: Figure modified from Rich & Longcore, 2006. See ref. [1]]*

An artificial light source is, theoretically, dedicated to a specific purpose. Unfortunately, in practice, it produces an irremediable flow of light directed towards the sky, which is diffused by atmospheric particles and water vapour. At the scale of a luminaire, the diffusion of artificial light forms a "halo of light". At the scale of an agglomeration, the sum of the luminous halos forms a "agglomeration halo". Therefore, any human construction equipped with an artificial lighting source is likely to generate light pollution (Figure 1, [1]). This is particularly the case for:

Public and road lighting, which, in the context of road prevention and anti-crime, is used at luminous intensities that often exceed the minimum requirements.

Lighting in industrial and commercial buildings, which are frequently over-lit to attract customers and create an attractive and consumer-friendly environment.

Lighting of car parks and sports centres.

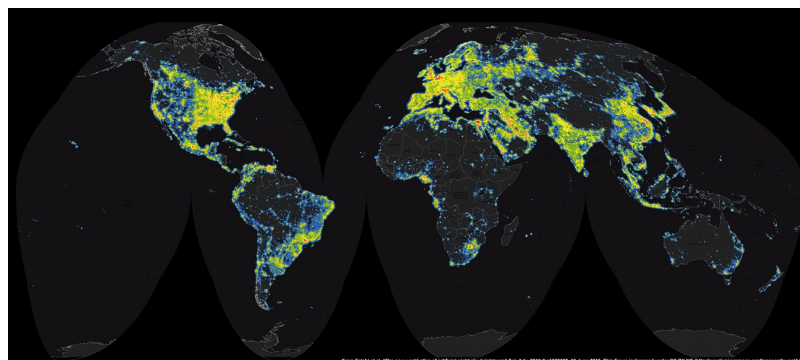
The exterior and interior lighting of homes that are not regulated by any regulations.

Vehicle lighting.

In addition, when the lighting is of poor technical quality, when the lighting devices are switched on at unnecessary times of the night or when they are poorly maintained or not maintained, light pollution is amplified.

Finally, weather conditions can influence the extent of light pollution by increasing the diffusion of light into the atmosphere. In urban areas, for example, heavy cloud cover can increase the intensity of light pollution by a factor of 10. These same conditions vary the reflection factors of the illuminated surfaces and therefore the amount of light reflected towards the sky. In dry weather, the reflection factor of artificial surfaces in urban areas is between 0.1 and 0.2, i.e. 10 to 20% of the light received is reflected. For a snow-covered surface, the reflection factor is 0.8.

### 1.3. A global phenomenon



*Figure 2. World map of light pollution: this map was developed from satellite surveys of the years 2013/2014. Light pollution levels are expressed as a function of the ratio of artificial brightness to natural brightness of the night sky and are represented by different colours. Ratio: 0.1-0.3 - blue; 1-2 - green; 2-5 - yellow; 5-10 - red; greater than 10 - white. [Source: Map from Falchi et al., 2016. See ref. 2] (CC BY-NA 4.0); [Light pollution Atlas](#)]*

The first world atlas on light pollution was published in 2001 and updated in 2016 [2]. This latest version is based on satellite surveys from 2013/2014 and on the definition of the International Astronomical Union: for a clearly defined geographical region, light pollution occurs when the artificial light propagated in the night sky is greater than 10% of its natural luminosity at night (Figure 2).

For the years 2013/2014, light pollution impacts 22.5% of the world's land surface, 46.9% of the surface area of the United States, 88.4% of the surface area of the European Union and 100% of the surface area of France. As a result, 83.2% of the world population, including 99.7% of the population of the United States, 99.8% of the population of the European Union and 100% of the French population, are affected by light pollution. Finally, 35.9% of the world's population is no longer able to observe the Milky Way at night and 13.9% of the world's population is exposed to light pollution such that the visual system cannot adapt to night vision. In reality, the visual system is permanently in day vision [2].

At present, scientists consider that light pollution is one of the fastest growing forms of pollution in the world, growing by an average of 6% per year, and by 10% in European countries [3].

Thus, light pollution is not a local phenomenon. Its scope is global and continues to grow. It already impacts some of the world's protected areas, particularly regional and national nature parks. A large part of the world's ecosystems, i.e. a large part of the world's fauna and flora, is therefore affected.

## 2. Impacts of light pollution on living organisms

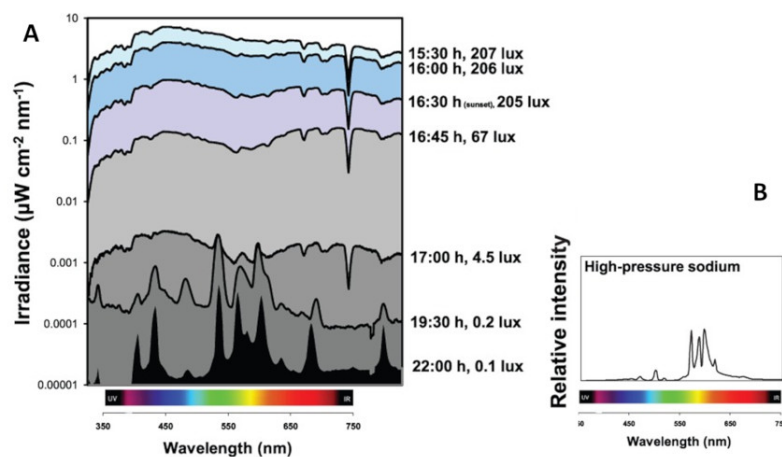


Figure 3. Evolution of the light spectrum during the day: these measurements of the electromagnetic spectrum were made near a small town in Cornwall (United Kingdom) and at various times during a winter day (A). Until 17:00, the measured spectrum corresponds to that of sunlight. Only the light intensity decreases over the hours. From 7.30 pm to at least 10 pm, the spectrum measured corresponds to that of artificial lighting using mainly high-pressure sodium lamps (B). [Source: Figure modified from Gaston et al., 2013. See ref. [4]]

Natural light and its cycles are essential for living organisms (see focus [Light cycles and living organisms](#)). However, light pollution modifies the illumination of the environment, i.e. its intensity and spectral characteristics, and masks the cycles of natural light (Figure 3, [4]). It is therefore likely to modify the behaviour, physiological functions and biological rhythms of individuals. In the long term, this pollution could threaten the balance of ecosystems [1].

## 2.1. Changed behaviours

From a behavioural point of view, light pollution leads to attraction/repulsion and orientation/disorientation responses. For example, in small nocturnal mammals, exposure to artificial light causes a repulsive response, i.e. individuals move away from the light source. This behaviour, due to the increased illumination of the environment, probably reflects an increased perception of the risk of being driven out by a predator. On the contrary, in nocturnal insects and migratory birds, organisms that use starlight to move in the dark, exposure to light pollution causes an attractive response, i.e. individuals approach the light source. However, this response can cause disorientation for individuals. Even more problematic, individuals, when approaching artificial lighting, can collide with large lighted structures or dehydrate or even burn themselves in contact with lamps [1].

Light pollution can also affect musculoskeletal and eating habits. This is observed in small nocturnal mammals, which, exposed to light pollution, limit their movements and their search for food, at the risk of seeing their physical condition deteriorate. Thus, in the bushy Darwin's eared mouse (*Phyllotis darwini*), individuals exposed to increased environmental illumination reduce their food intake by 15%, provide 40% of the food collected in their shelter, and lose 4.4 g of body weight per night [1].

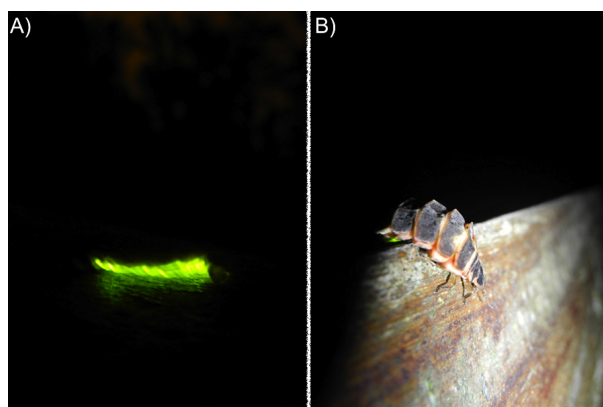


Figure 4. Light pollution and visual communication. To communicate between congeners, glow worms and fireflies emit light signals. In the absence of light pollution, flashes emitted by a glow-worm female can attract a male up to 45 metres (A). In the presence of strong illumination, the visibility of these flashes is reduced, which compromises communication (B). Here a glow worm (*Lampyris noctiluca*) with and without artificial light. [Source: By NN (FR-64129) [FAL], via Wikimedia Commons]

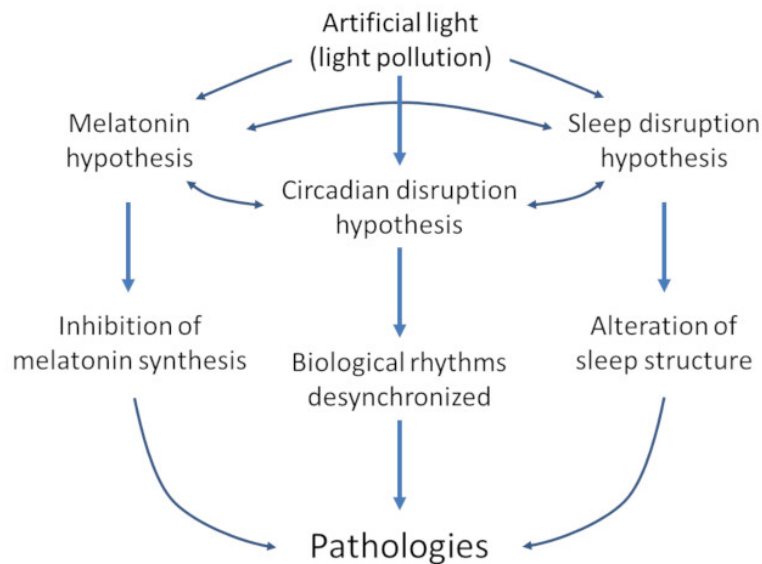
Finally, light pollution can affect the effectiveness of visual communications and reproductive behaviour. Bioluminescent species, i.e. species capable of producing and emitting their own light, are particularly affected, such as fireflies and glow worms

that use light signals to attract their partners. Indeed, when ambient illumination is high, the visibility of these signals is reduced and communications between individuals, and therefore reproduction, can be impaired (Figure 4). This is also the case for non-bioluminescent species. Thus, in amphibians, strong illuminations can inhibit bridal songs. Individuals are then less selective in their choice of partner in order to accelerate mating speed and limit the risk of predation. However, the success of a reproduction depends, among other things, on the proper selection of the partner [1].

## 2.2. Physiological functions and biological rhythms: hypotheses

The impact of light pollution on the biological rhythms and physiological functions of wildlife is still unknown. Most of the current data come from studies in birds. Thus, day birds exposed to light pollution start their activity and singing earlier. In addition, seasonal rhythms are also disrupted as birds exposed to light pollution begin their breeding cycle and moult earlier in the year. A study conducted in 2013 shows that the synthesis of a photosensitive hormone, melatonin, is partially inhibited in birds exposed to light pollution. However, this hormone ensures the synchronization of the body's different biological rhythms, in birds and mammals alike. It could therefore be involved in the observed lags [5].

In rodents studied in the laboratory, biological rhythms are also modified by light pollution. In addition, light pollution in these animals has been associated with metabolic disorders (glucose intolerance, body weight gain), the genesis of apathetic and depressive behaviours, altered thermoregulation and decreased immune response. In 2016, a study carried out in a small nocturnal primate, the murine microceb (*Microcebus murinus*), showed that an inhibition of melatonin synthesis could be involved here too [6].



*Figure 5. Three non-exclusive hypotheses explain how light pollution can alter human health: (1) "Circadian disruption hypothesis": light pollution desynchronizes the main internal clock with respect to the day/night cycle; (2) "Melatonin hypothesis": light pollution reduces melatonin synthesis and secretion; (3) "Sleep disruption hypothesis": light pollution alters sleep structure. In the long term, all these modifications and alterations lead to the genesis of pathologies.*

In humans, clinical and epidemiological studies conducted in urban areas and on night work show that light pollution, by altering the day/night cycle, represents a risk to human health [7]. Three mechanisms are advanced to explain how light pollution can affect human health (Figure 5):

*The "Circadian disruption hypothesis":* by stimulating the main internal clock, light pollution desynchronizes it with respect to the day/night cycle.

*Melatonin hypothesis:* Light pollution reduces the production and secretion of melatonin. However, melatonin deficiency is accompanied by an alteration of biological rhythms and the loss of its anti-inflammatory, antioxidant, immunostimulant, neuro-protective, cardio-protective and anti-oncotic properties.

*Sleep disruption hypothesis:* light pollution, by desynchronizing the main internal clock, could modify the structure of sleep, or



even reduce its total duration. However, both the quality and quantity of sleep have been associated with the maintenance of internal homeostasis and are a guarantee of good health.

These three mechanisms are not mutually exclusive. On the contrary, they are probably closely associated and in the long term, by altering the body's homeostasis, could lead to the genesis of pathologies in humans. In wildlife, it is likely that the same mechanisms are at work.

## 3. Light pollution and ecosystems

### 3.1. Unbalanced ecosystems?

At the ecosystem level, light pollution can cause a number of imbalances. In particular, it can modify inter/intra-species competitions, prey/predator balances and the organization of species communities. Indeed, light pollution, by modifying the lighting environment, creates a new ecological niche. However, the strong illumination that characterizes this niche attracts some nocturnal species and repels others. Thus, fast flying bats are able to take advantage of the aggregation of nocturnal insects with streetlights. In particular, for Nilsson's Serotin (*Eptesicus nilssonii*), caloric intake is 0.5 kJ/min in peri-urban areas and near streetlights, compared to 0.2 kJ/min in wooded areas. On the other hand, slow-flying bats, which are unsuited to escape from nocturnal raptors, are unable to take advantage of insect aggregations near streetlights. The result is interspecific competition for food, which is at the expense of slow-flying bats. This competition could explain why the number of individuals of fast flying bat species has increased in recent years in Europe while the number of slow-flying species has decreased [\[1\]](#).

In addition, this ecological niche also favours the vision of diurnal species, which can then orient themselves, move around and search for food. These species "colonize", so to speak, nocturnal habitats exposed to artificial light, compete with nocturnal predators and modify the prey/predator balance. Such behaviours have been observed in spiders, day reptiles and day birds that take advantage of the aggregation of nocturnal insects around streetlights to hunt and the desertion of some nocturnal species to fill a vacant environment. In the opinion of some authors, this desertion from enlightened environments could encourage the colonization of invasive species.

Finally, a study conducted in peri-urban areas showed that artificial lighting changes the composition of terrestrial invertebrate communities. The number of terrestrial invertebrates present directly under artificial lighting is significantly higher than that of invertebrates present at a distance from such lighting and the composition of terrestrial invertebrate communities is significantly different between the two environments. Under the lighting, the communities are mainly composed of predatory and scavenger invertebrates, spiders, carabids, woodlice, ants and amphipods. If carried out on a large scale, such changes could alter the balance and functioning of ecosystems [\[8\]](#).

### 3.2. Impacts on habitat and species selection

Light pollution could also contribute to habitat fragmentation. The example of nocturnal insects is a perfect illustration of this. Indeed, an artificial light source can attract nocturnal insects within a radius of 400 to 700 metres. However, in urban areas, streetlights are only 30 to 50 metres apart. Illuminated traffic lanes are therefore real artificial barriers that stand on people's routes. Considering the attraction that artificial light exerts on nocturnal insects, these barriers therefore limit their movements and fragment their habitat [\[1\]](#).

Light pollution could also threaten photosensitive species or individuals, i.e. those with low light tolerance. Light pollution could therefore act as a selection factor and modify the diversity of natural populations. However, it should be recalled that 28% of vertebrates and 64.4% of invertebrates are partially or exclusively active at night, i. e. just as many species that are not or only slightly adapted to the strong illuminations of their environment.

Finally, aquatic organisms and plants, which are sensitive to light like animals, are also threatened by light pollution [\[9\]](#).

In conclusion, light pollution is a phenomenon that is not well known but very real and whose extent is constantly increasing. However, this pollution, by altering the natural cycles of light and the illumination of the environment, is likely to modify the behaviour, physiological functions and biological rhythms of living beings. At the individual level, light pollution can affect orientation and modify locomotor, eating, reproductive and communication behaviour between individuals. At the population and ecosystem level, light pollution acts as a selection factor, modifies inter-species competition, prey/predator balances and fragments habitat. Its impact on ecological communities is therefore real. It is also important to limit and reduce light pollution in order to protect the night sky and biodiversity.

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