Nature-friendlier lighting of objects of cultural heritage (churches)

Recommendations

LIFE+ Life at Night project
In cooperation with the Slovenian
National Commission for UNESCO

NATURA 2000

LIFE AT NIGHT

Contents

List of acronyms and units

K	kelvin, unit for correlated colour temperature of a lamp (the higher the value of colour temperature the greater the share of the blue part of the spectrum the emitted light contains)
LED	light-emitting diode
MH	metal-halide lamp
IAU	International Astronomical Union
IUCN	International Union for Conservation of Nature
cd/m^2	candela per square metre is the unit for expressing the luminance of surfaces
lx	lux is the unit for measuring illuminance (1lx = 1 lumen per square metre (1 lm/m^2))
	Photopic and scotopic vision – day and night vision

Introduction

This brochure offers a collection of recommendations for nature-friendlier illumination of objects of cultural heritage prepared within the LIFE+ Life at Night project in cooperation with the Slovenian National Commission for UNESCO.

Humans of course require light at night; however, exaggerated and inappropriate illumination may lead to a series of negative consequences that disturb natural processes, cause long-term health risks, hinder astronomical observations and unnecessarily increase energy consumption.

The LIFE+ Life at Night project focused on objects of cultural heritage. Slovenia is known for its many churches scattered all over the country. According to information from the Slovenian Bishops' Conference, there are 2864 Catholic churches in Slovenia. In 2013, 1445 of them were entered in the Slovenian Register of Immovable Cultural Heritage as cultural monuments. Most churches are illuminated. Unlike the case of public lighting and illumination of buildings, for which it is prohibited to use lamps that emit light above the horizontal plane, cultural monuments may be illuminated from the ground up. Such illumination causes a lot of light pollution.

The key purpose of this project was to contribute to long-term reduction of negative impacts caused by illumination of churches and other objects of cultural heritage and thus improve the conservation status and biodiversity of nocturnal animals. Our goal was to find proper technical solutions for nature-friendlier and more energy-efficient illumination for objects of cultural heritage. We developed a lamp to improve the existing lighting of 21 pilot churches. The results of three years' research by biologists have shown that improved lighting reduced the negative impact of illumination on moths and bats. With the improved lighting, we also managed to reduce energy consumption by 40% to 90% depending on the energy consumption of original lighting at an individual church. However, reducing energy consumption is by far not the most important criterion of improvement. It is more important that negative impacts of illumination at night on environment, people and animals be reduced.

Some objects in this brochure are not named because their lighting will be improved in the near future. Recommendations represent an upgrade of the Decree on Limit Values due to Light Pollution of Environment (OG RS, No 81/2007; hereinafter: Decree) governing the illumination of cultural monuments by taking into consideration the latest findings of biologists. We hope that the new findings will be used both in Slovenia, in the EU and worldwide.

Light pollution is destroying the nocturnal image of nature

We live on a planet where the astounding beauty and variety of nature inspire us and enrich our lives. To many, contact with nature represents an opportunity to get in contact with oneself and loved ones. We live in a world of paradoxes, and most of humanity wishes for more rapid development mostly measured in the length of new roads, surface of cultivated areas, number of shopping centres, in energy infrastructure and in material goods with a questionable service life.

Due to anthropogenic release of greenhouse gases, the average temperature of the environment increases. Glaciers are melting, snow is becoming increasingly rare in winter, and during summers, temperatures are reaching record levels. The increased thermal energy of oceans results in more intense weather phenomena which will affect the majority of the world's population in coming decades. Previously ordinary weather phenomena such as droughts, storms and winds are becoming ever more extreme and destructive.

In the shadow of global warming, nature is undergoing degradation which is no less important than the releasing of greenhouse gases. Biodiversity is reducing extremely rapidly and so is the share of natural environment. The living environment of plants and animals is shrinking and fragmenting due to construction and ever more intense agriculture. The International Union for Conservation of Nature (IUCN) is warning that the extinction of animal and plant species has never been as rapid as it is now, and it is increasing annually.

Unlike many other European countries, Slovenia still has a small percentage of land where its inhabitants can enjoy nature in its pristine state. Unfortunately, this applies only during the day. When it gets dark, the sky takes on an orange colour and stars are "washed out" and we are left with only a faded version of the natural starry sky.
In Europe too, light pollution has "washed out" the stars from the sky. The night sky above most beautiful natural

Cerknica from Slivnica.

parks has become light polluted. There is not a single piece of land in Europe where one can enjoy a natural starry sky as it was for instance 100 years ago, even from big but modestly illuminated cities. When it is cloudy, sky brightness in the urban environment can increase even tenfold (Kyba et al. 2011). When snow falls, the reflection of light from snow causes additional increases in light pollution.

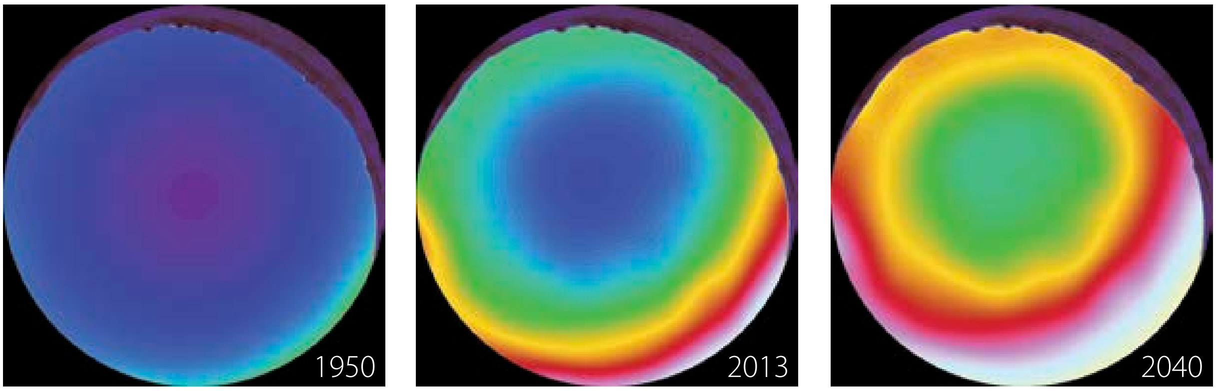
Maribor from Pohorje.
Even on mountain summits we cannot experience nature in its pristine state at night because light pollution is spreading through clouds.

The Horsehead Nebula in the constellation of Orion.
In the declaration for the 2009 International Year of Astronomy, UNESCO wrote: "The sky is our common and universal heritage and is a part of the human environment."

The disappearance of the natural environment is a subject of increasing international awareness. In cooperation with UNESCO and in the presence of numerous international organizations, the StarLight Declaration was adopted in La Palma in 2007, calling for the preservation of the night sky as a world heritage site and affirming the right of all the people of our world to admire and explore the starry sky.

The rapid increase of light pollution

Measurements point to a rapid increase in light pollution ranging from 2% to 8% annually depending on the location. Both satellite images and measurements of light pollution performed by several thousand amateur astronomers and environmentalists confirm this increase. This rapidly increasing exponential curve is worrying us deeply. If nothing is done, it is quite possible that in a few decades the brightness of the night sky will be more than twenty times greater than it is today. This means that the sky above natural parks which are usually the darkest areas would only show a few brightest stars. And in the darkest nights we would be able to read at night without the help of artificial lighting.



Simulation of light pollution at Matajur Mountain on the border between Slovenia and Italy, based on a photograph recorded by a fisheye camera in 2013, and an assumption of 5% annual growth rate of light pollution. We have assumed that the sky over Matajur was almost naturally dark in 1950. Then numerous settlements had no public lighting. Lighting was rare and of low power. Light sources were inefficient. In order to simulate the conditions from 1950, we apply 5% annual increase in light pollution. If the trend over the last 60 years continues, we expect that in 2040 only a few of the brightest stars will be visible in the sky. Simulation was made with the Sky Quality Camera software.

The influence on the environment of illuminating objects of cultural heritage

We estimate that in developed countries, external lighting of objects of cultural heritage causes 5% to 20% of total light pollution. Since the majority of these objects are illuminated from the ground up, they are especially strong sources of light pollution. Very often, 60% to 80% of the entire light flux misses the façade and is emitted into the sky and the surroundings.

Light unnecessarily emitted into the sky and the surroundings.

Slovenia is known for numerous churches on top of hills, outside settlements and within the natural environment. Since they are surrounded by forests or meadows, their influence on nocturnal animals is great. In such cases, nature-friendlier lighting is therefore so much more important. Environmentalists do not use the term "nature-friendly" lighting since unfortunately no lighting is nature-friendly. All artificial lighting increases the brightness of the natural environment and has a negative impact on the lives of animals. Thus, "nature-friendlier" lighting seems a more suitable expression.

Legislation governing light pollution in Slovenia and in other countries

Of all countries, Slovenia has the most advanced legislation on light pollution for objects of cultural heritage. In the Decree on Limit Values due to Light Pollution of Environment (OG RS, No 81/2007), the following sections are important:

Article 4
(Illumination with environment-friendly luminaires)

(1) For lighting, only luminaires with 0% of light emission above the horizontal may be used.

…

Article 10
(Illumination of façades)

(1) Those illuminating façades must ensure that the luminance of the illuminated part of the façade calculated as the average value of the entire illuminated façade surface does not exceed 1 cd/m².
(2) Façade luminance is established by luminance measurements in at least 10 points of the illuminated façade equally distributed across the entire illuminated façade surface. Measurements of façade luminance are performed at the distance of a maximum of 50 m away from the illuminated façade or, if possible, from behind the luminaires that illuminate the façade, whereas the luminance meter should be placed not more than 2 m above the ground.
(3) The façade of the building can be illuminated in a manner laid down in the first paragraph of this article only if the building is in the area of a settlement with public lighting and the illuminated wall of the building is not more than 240 m away from the external edge of the closest illuminated public surface, measured horizontally, where the illuminated public surface is considered to be a public surface with an average illuminance of more than 3 lx.

Article 11
(Illumination of cultural monuments)

(1) Those illuminating façades must ensure that the luminance of the illuminated part of the cultural monument calculated as the average value of the entire illuminated surface of the cultural monument does not exceed 1 cd/m².
(2) Luminance of the cultural monument is established by luminance measurements at a minimum 10 points of the illuminated part of the cultural monument equally distributed across the entire illuminated surface. Measurements of cultural monument luminance are performed at the distance of a maximum of 50 m away from the cultural monument or, if possible, from behind the luminaires that illuminate the cultural monument, where the luminance meter should be placed not more than 2 m above the ground.

(3) If it is technically impossible to illuminate the cultural monument with luminaires meeting the requirements from Article 4 of this Decree, light flux should be directed in such a way that the external edge of the illuminated surface of cultural monument is at least 1 m below the lower part of the roof or 1m beneath the top of the monument for monuments without roofs. No more than 10% of light flux may go past the façade of the cultural monument.

Article 12
(Protection of endangered species)

If according to regulations governing the preservation of nature the habitat of endangered species in the illuminated building or object from Article 10 or 11 of this Decree is protected, the surfaces of such an object or building where flight openings of endangered species are located should not be illuminated.

Article 28
(Adjustment of existing luminaires)

(6) The existing illumination of cultural monuments shall be adjusted by 31 December 2013.

The Decree was adopted in 2007 when disputed white LED light sources had not yet begun to be marketed. White light did not then represent a serious environmental problem. The environmentalists also managed to negotiate with the relevant Ministry for the Environment that all lamps should be limited to the enhanced yellow part of the spectrum. Unfortunately this provision was left out of the Decree. Limitation on the spectrum is the most important serious shortcoming of the Decree. Even though the deadline on the harmonization of lighting of cultural monuments with the Decree expired at the end of 2013, it is not reasonable to hurry since it is crucial to find a technically and economically most suitable solution which is also as nature-friendly as possible.

In Italy, the majority of regions have legislation on reducing light pollution. Luminance of façades and cultural monuments is limited to 1 cd/m^2. For illumination of roads and streets in the surroundings of cultural monuments only lamps may be used that do not emit light above the horizontal. One of the newest regional laws in Friuli – Venezia Giulia already includes limitations on the blue part of the spectrum since it limits the colour temperature of luminaires to a maximum of 3300 K (Legge Regionale 18/06/2007, N. 015).

Legislation in Chile limits the share of blue light to less than 15% of emitted light in the spectral band under 500 nm. Such is also the recommendation by the International Astronomical Union (IAU) concerning the protection of sky from light pollution. Numerous countries have general legislation addressing light pollution but without executive acts (Croatia, Czech Republic). Among other things, the French legislation requires that façades should not be illuminated after 1.00 hours. In numerous countries with no legislation on light pollution, lighting of façades is switched off after 1.00 hours as well.

Legislation protecting animal species and their habitats

Light pollution is one of the factors endangering nocturnal animals and their biodiversity.

The relevant ministry for the environment recognised this fact and decided to include protection of endangered species in article 12 of the Decree. Conserving biodiversity in the broadest sense of the term is of great public importance; thus all plants, animals and their habitats are under special state protection. As a result of numerous regulations, nocturnal animals are protected as well.

The framework Nature Conservation Act (OG RS, No 96/2004) prohibits the degradation of the living conditions of plants and animals to a point that a species is endangered. This act also determines that, when encroaching on nature, ways, methods and technical appliances should be used which contribute to a favourable conservation status of a species. Since each outdoor lamp kills numerous insects, it is important to use lighting with the smallest possible impact on insects.

The Decree on Ecologically Important Areas (OG RS, No 48/2004) protects the habitats of living plant and animal species that importantly contribute to the conservation of biodiversity.

The protection of wild animal species is more thoroughly governed by the Decree of Protected Wild Animal Species (OG RS, No 46/2004) which among other things prohibits disturbance to animals. Article 4 defines disturbance as "any action because of which an animal at the place of disturbance stops nesting, wintering, reproducing, hibernating, breeding, using its space during migration or satisfying other living needs". If flight openings for bats are also illuminated in places where bats give birth, the light may have a negative impact on the entire colony – this is considered a disturbance.

A study accompanying the Life at Night project confirmed that lesser horseshoe bats prefer to roost in churches that are not illuminated and have appropriate flight openings (Herzog 2013). They may even completely abandon a newly illuminated roost (Downs et al. 2003). The list of endangered animal species in Slovenia based on the Decree of Protected Wild Animal Species includes all 28 bat species and 54 moth species.

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The conservation of biodiversity in Slovenia is not only important for our country but also for the European Union and all the people of our planet. With the Decree on Special Protection Areas (Natura 2000 sites) (OG RS, No 49/2004), Slovenia protects species and habitat types, the conservation of which is also in the interest of the European Union.

Light pollution of an inappropriately illuminated smaller country church

A smaller country church.
The photograph was taken in clear weather with somewhat increased air humidity as is usual at night. The photo clearly shows light beams that miss the belfry and illuminate the sky.

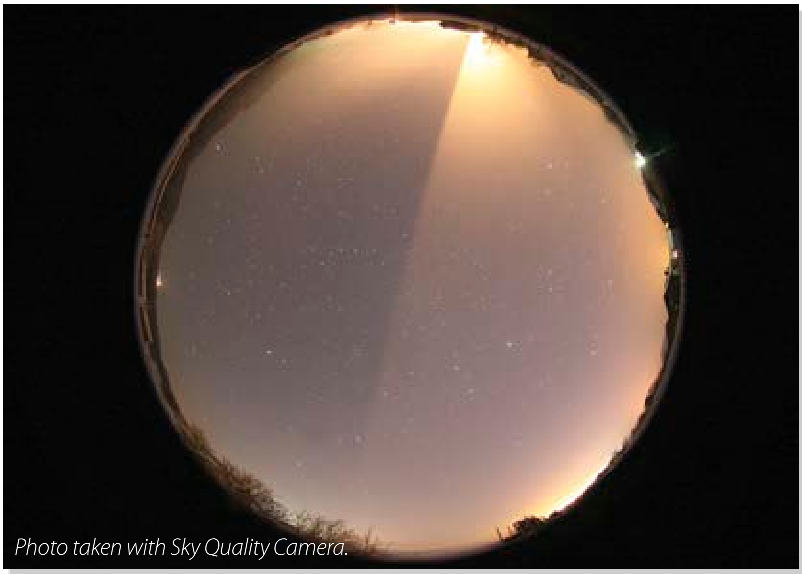
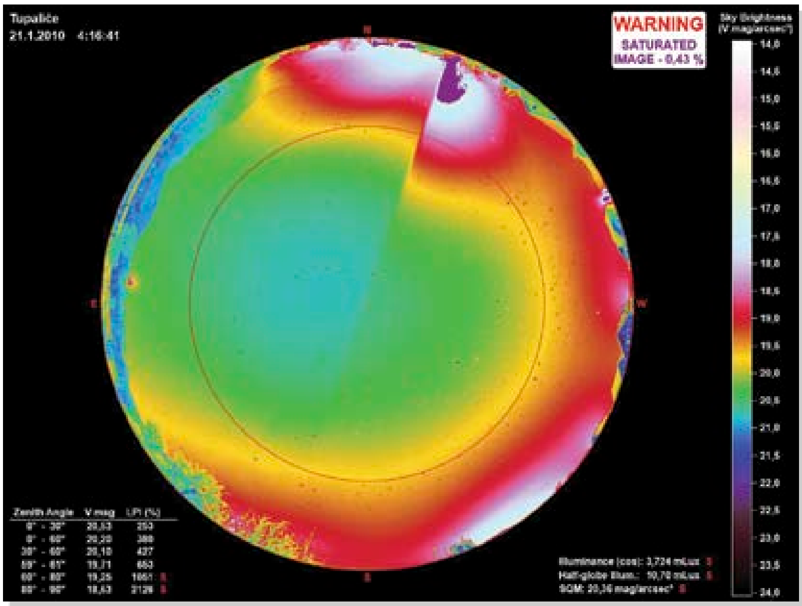


Photo taken with Sky Quality Camera.

The photo taken with a Sky Quality Camera (fisheye) was taken a few hundred metres away from the church. It captures all 360 degrees of the sky. This is the standard method for measuring light pollution of the sky at a certain point. Software was used to analyse the levels of sky brightness. The results show a light polluted horizon and the sky surrounding the church where light beams spread in all directions. The belfry cuts the light beam from one of the reflectors and causes one half of the sky to be approximately 50% more illuminated (light polluted) than the other half. Even though this phenomenon is local, we should not forget that light spreads through the atmosphere more than 200 km away from the source and that light pollution at a certain location is the sum of all radiation in a circle with radius of 200 km. Improving the standard of lighting at only one site results in a measurable decrease in light pollution at a distance of several kilometres.



Analysis of sky brightness.

White LED lamps pose a great threat to nature at night

Only a few years ago, LED lamps became sufficiently effective for exterior lighting. Recently, LED lamps have often been used for exterior lighting that emits white light with a high percentage of blue colour (a colour temperature of 4200 K) – hereinafter, white LED lamps. The technology has been improving and will probably dominate indoor and outdoor lighting in a few years.

The majority of LED lamps for domestic use have a colour temperature of 2700 K. Such a lamp emits little blue colour and shines in yellow-white light. Such, for instance, is a normal bulb with a filament and an emphasis on warm colours. In domestic applications, we use lamps with 2700 K or even 2500 K. This is not only more comfortable in the evening but also less harmful to health.

For people and animals, light interrupts melatonin (also known as sleep hormone) production at night. When it gets dark, organisms start to synthesise melatonin and its production peaks in the middle of the night. Red coloured light has almost no influence on interrupting melatonin production while blue interrupts it even at low illumination levels. Cajochen et al. (2005) have shown that even an illumination of 5 photopic lux with a wavelength of 460 nm causes significantly greater melatonin suppression after 40 minutes.

Scattering of light in the atmosphere by molecules and very small particles is described by the Rayleigh law, which states that scattering is inversely proportional to the fourth power of the wavelength. If we assume that an extremely violet light that the eye detects has a wavelength of 390 nm and an extremely red colour has a wavelength of 780 nm, the ratio of wavelengths between the two extremes is exactly one to two. Thus, the Rayleigh scattering of the extremely violet colour is 16 times greater than the scattering of the extremely red colour (Figure 1). Of course, luminaires do not emit light in the extreme part of the visual spectrum, but bluish luminaires, emitting light close to the violet part of the spectrum, will cause far more light pollution than yellowish ones. A white LED lamp at 4000 K causes approximately up to 3 times (300%) more light pollution than a yellow high-pressure sodium lamp (2100 K) for scotopic (night) vision.

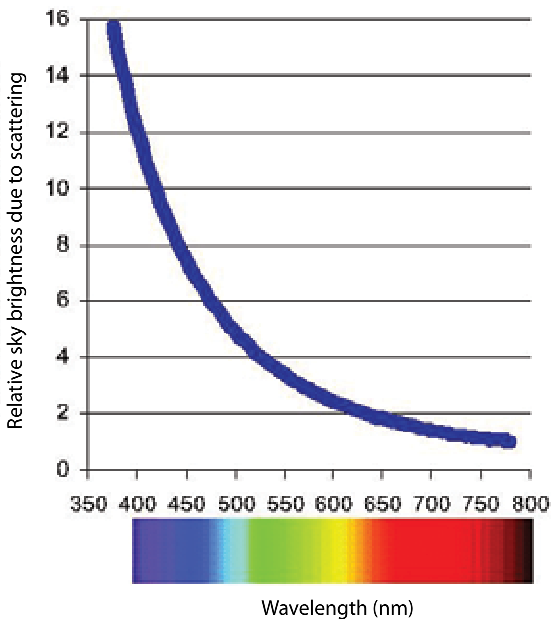


Figure 1: The scattering of the extremely violet colour is sixteen times greater than the scattering of the extremely red colour (2^4 or 2 x 2 x 2 x 2).

In the evening, people prefer to choose luminaires with warm colour; thus, there is no reason for the lighting of streets and cultural monuments to be in cold colours. Unfortunately this has been going on for some years now – white LED lamps with 4000 K are becoming a standard in outdoor lighting. Even though white LED lamps are somewhat more efficient, this criterion should not prevail if we know that white LED lamps cause harm to the environment – the more light pollution there is and the more intense it gets, the greater the interruption to melatonin synthesis and other negative impacts on animals. For the majority of animal species, this influence cannot be estimated.

The impact of artificial light on people and animals

One of the most serious consequences of light pollution is its negative impact on people's health.

Over long years of evolution, living beings have adapted to the rhythmic exchange of light and darkness. The circadian rhythm (day-night rhythm) helps to balance body temperature and blood pressure, and is instrumental in the secretion of hormones and in other physiological processes (Španinger & Fink 2007). It also balances the amount of melatonin which an organism synthesizes in darkness. Melatonin is a strong antioxidant which intensely regenerates the organism and prevents the occurrence of carcinogenic changes such as breast and prostate cancer. The functioning of this hormone is especially important if we are aware of the number of harmful substances that our body ingests with food and the air that we breathe, and takes in through the skin when we use body care products. If during the night we are exposed to light, melatonin production is reduced or even interrupted. Before we go to sleep, we should avoid light, especially the blue-white light of computer screens and mobile phones. When exposed to light during the night for a longer period of time, the organism's biorhythm may collapse and the protecting melatonin function may decrease. The results of a study on the health of nurses involving almost 80,000 people confirm that repeated night-shift work over a period of more than 15 years for at least three nights a month increases the risk of breast cancer (Schernhammer et al. 2003).
The majority of highly developed animals produce melatonin. Research abounds on the influence of light on melatonin and development of cancer cells in small mammals such as rats (Dauchy et al. 1997). The role of melatonin has not yet been sufficiently researched for other groups of animals.

Even if the influence of artificial light on animals has not yet been sufficiently researched, a precautionary principle should be applied. Lighting should be used at night with an emphasis on the yellow part of the spectrum and with as little blue colour as possible.

Apart from physiological processes, artificial light also changes animal behaviour and reduces the quality and range of animal habitats. At night, it influences a wide variety of organisms. It has adverse effects both on diurnal and nocturnal animals: it changes the circadian rhythm, causes imbalance between predators and prey and disturbs animals on their migration paths (Rich & Longcore 2006). Nocturnal animals are especially endangered – as are many animal species: 30% of vertebrates and more than 60% of invertebrates (Hölker et al. 2010). Some nocturnal animals are attracted by light, and some are repelled by it. Light sources disturb animals that orientate themselves with reference to celestial bodies. Animals attracted by light tend to swarm around lamps where they are much more exposed to predators. Those caught in light beams get exhausted and run out of time for important activities such as feeding, reproduction and migration. Those avoiding light are losing their habitats, since a great part of Earth's terrain is illuminated. There are several ongoing research projects studying the influence of light on nocturnal animals. There is now even a special branch of biology, called scotobiology, studying the lives of animals at night.

Birds often migrate at night. They can be disturbed by tall illuminated structures such as buildings, chimneys, masts, oil rigs, lighthouses, light beams from façade surfaces and tall advertising boards. These light sources cause disorientation so that the birds get caught in light beams, start circling around lamps and may even tire or die due to exhaustion or injuries. This may especially be a problem in foggy or cloudy weather when light beams become much more visible. An example of good practice can be found in the USA. According to the American Bird Conservancy, the state of Minnesota has adopted a regulation requiring that all public buildings (more than 5,000) switch off their lighting after midnight during the times of spring and autumn bird migration. A similar decision was adopted in Chicago within a voluntary "Lights Out" programme where lights of tall buildings are shielded for 5 months each year. It was estimated that this programme annually saves the lives of 10,000 birds and leads to considerable savings in electricity.

Light also influences sea turtles. Naturally, turtle hatchlings head towards the sea which is the brightest part of the horizon. If the shore is illuminated, the hatchlings do not head towards the sea but towards the light on the shore. On their way away from the sea they fall prey to road traffic, become dehydrated or are taken by predators (Rich & Longcore 2006).
Even the darkest areas in Europe are twice as bright as the natural environment without the influence of artificial lighting. This can have serious consequences for the survival of endangered animal species. The International Union for Conservation of Nature (IUCN) placed light pollution on the list of factors influencing endangered animal species (IUCN, Red list).

Consider the case of the ongoing extinction of the largest beetle living in Slovenia, the great silver water beetle (Hydrophilus piceus). According to the study collection of the Slovenian Museum of Natural History, these beetles used to inhabit Ljubljansko Barje in vast numbers. Unfortunately, today, great silver water beetles are rare and endangered, even though their habitats seem intact. According to biologist Dr. Tomi Trilar from the Slovenian Museum of Natural History, the street lighting and the lighting of industrial zones in Ljubljana have exterminated this animal species.
Abundant research work is being done worldwide on the influence of light on nocturnal animals. This publication presents the results of scientific research on the influence of light on moths and bats within the Life at Night project.

Research within the Life at Night project on the influence of church illumination on moths and bats

The goal of the LIFE+ Life at Night project was to develop a new lamp for the illumination of objects of cultural heritage with the smallest possible impact on moths and bats. We developed two types of new lamps which we call:

1. Yellow-white lamp
   This was a metal-halide (MH) lamp with a colour temperature of 3000 K. It had an integrated filter which blocked the emission in the greater part of blue spectrum with wavelengths shorter than 480 nm. The lamp did not emit UV light. A mask was mounted on the lamp with a silhouette of the church, preventing the light from being emitted into the sky.
2. Blue-white lamp
   This was a metal-halide lamp with a colour temperature of 4200 K. It had an integrated filter only for UV light. It differed from the yellow-white lamp in that it also emitted light in the blue part of the spectrum. A mask was mounted on the lamp with a silhouette of the church, preventing the light from being emitted into the sky..

Both types of lamps had masks which were made based on photographs of the church façades, making it possible to illuminate only the church façades. The share of light missing the façades was less than 10%. Since the surroundings of the churches were not illuminated, we anticipated that, due to the masks, fewer moths would be attracted. Where the influence of light on bats was studied, the masks also shaded the openings of bat roosts. The original lighting (prior to replacement) varied significantly and varied from integrated high-pressure sodium lamps to metal-halide lamps with a greater share of light emission in the blue part of the spectrum. The amount of emitted UV light also varied. The majority of original lamps emitted UV light.

For the experiment, 21 project churches were selected (Figure 2). Since we only intended to study the influence of illumination without additional factors of distraction, intensively illuminated churches were selected in a natural environment outside settlements. For each area three churches (triplets) were selected which are similar in geographical aspect. In each triplet, lighting was replaced every year. Each of the 21 churches thus had original illumination, yellow-white illumination and blue-white illumination for one year respectively. Cyclic replacement of lighting made it possible to exclude all factors resulting from various climatic conditions throughout the year.

Map of locations of project churches (LIFE+ Life at Night)

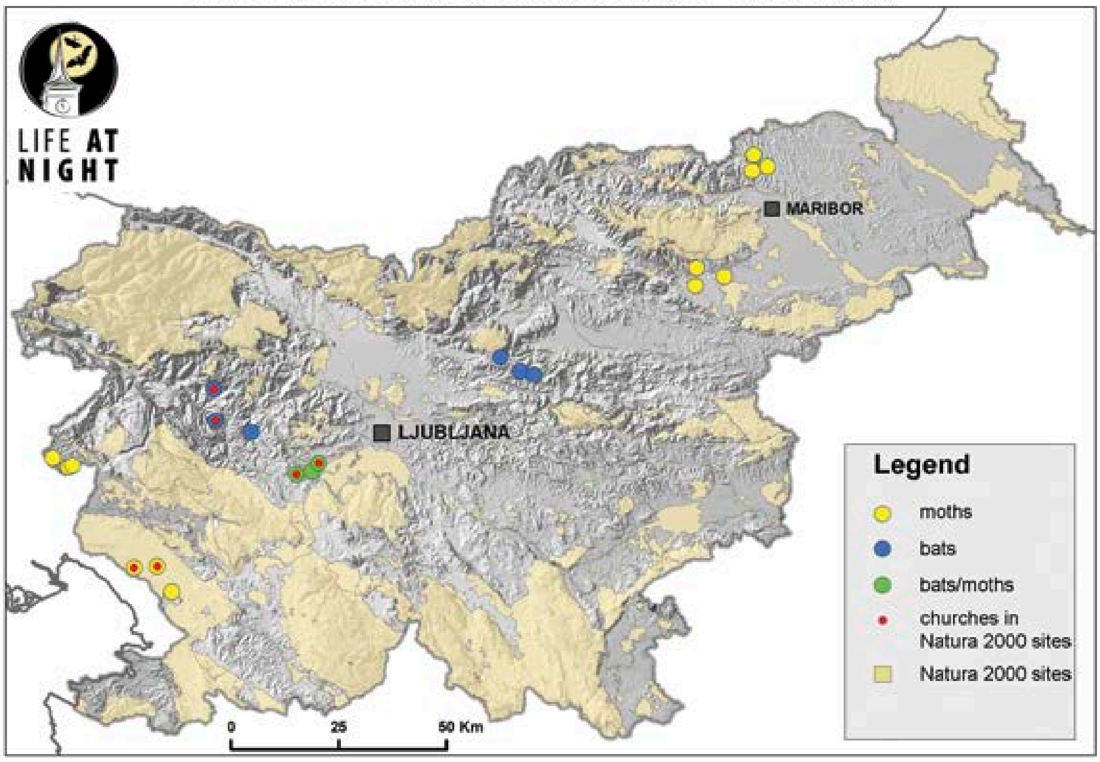


Figure 2: The map of selected churches in the LIFE+ Life at Night project, 6 of which are located within 5 Natura 2000 sites.

A team of biologists studied the influence of various types of lighting (original, yellow-white and blue-white lamps) on moths and bats for three years. Biologists visited the churches from spring till autumn, always during new Moon, when the Moon did not disturb the observations.

The following chapters present the research results. For a more comprehensible presentation, lighting types are presented in three colours:

RED marks the results connected with the original lighting which was used prior to the onset of our project.

BLUE marks the results connected with improved lighting emitting blue-white light (approx. 4200 K).

YELLOW marks the results connected with improved lighting emitting yellow-white light (approx. 2700 K).

The influence of lighting on moths

Rudi Verovnik, PhD

Small emperor moth (Saturnia pavonia).

A great part of our planet is illuminated at night and the share of light pollution increases by approximately 6% per year (Cinzano et al. 2001, Hölker et al. 2010). This increase is accompanied by changes in the sizes of moth populations. A decline in the number of moths, which importantly contribute to biotic diversity, has already been observed in Great Britain (Conrad et al. 2006), the Netherlands (Groenendijk & Ellis 2010) and in Scandinavia (Mattila et al. 2006). The decline in moth populations is probably a result of a combination of factors, mostly the loss of habitat and anthropogenic climate changes (Fox 2012). One of the key factors accelerating the extinction is also light pollution, caused mostly by public lighting (Frank 1988, Conrad et al. 2006, Groenendijk & Ellis 2010, Fox 2012). Moths play an important role in the food chain, and they are also important pollinators. Thus, a decrease in their numbers threatens the entire ecosystem (Fox 2012).

It is a known fact that moths are more attracted by lamps emitting a greater share of shorter-wavelength light, especially ultraviolet (UV) light (Rydell 1992, Eisenbeis 2006, van Langevelde et al. 2011, Barghini et al. 2012). Entomologists also take advantage of this fact when researching moth fauna (Nowinszky 2003). Artificial light disturbs the natural behaviour of moths, especially in their search for food, distribution, reproduction and in other interactions between members of the same species (Altermatt 2006, Frank 2006). Their mortality has increased, since artificial light additionally exposes them to predators, mostly bats (Rydell 1992, Svensson & Rydell 1998). More exact research of the influence of various types of light on moths has so far been scarce; however, the results point to a phenomenon that is not general. Van Langevelde et al. (2011) found that, statistically, lamps emitting a greater share of UV or shorter-wavelength light attract significantly larger moths, most probably because their eyes are larger and more sensitive and because of greater animal mobility. Among large moths, owlet moths (Noctuidea) are more sensitive to shorter-wavelength light than geometer moths (Geometridea) (Somers-Yeates et al. 2013).

Our research focused on lighting of cultural monuments, notably churches, which contribute considerably to light pollution in Slovenia. Churches are often in exposed locations outside urban areas. We expected that these illuminated objects would attract a great number of moths. Slovenia is one of the 'hot spots' when it comes to biodiversity of moths. 3200 nocturnally active and 183 diurnally active species live here. However, we estimate the number of species ranges from 3500 to 3700 (Gomboc & Lasan 2006). Based on this research, we can indirectly estimate the influence of artificial lighting of cultural monuments on the entire biodiversity of terrestrial habitats in Slovenia.

Research of moths within the LIFE+ Life at Night project

Our research included five church triplets from various geographic and biographic areas ranging from the Primorska region to the Štajerska region (see the map above). In addition, the research also included the mountain hut at Sabotin, which had previously never been illuminated, in order to test whether long term illumination of selected churches has already contributed to the reduction of the diversity of moth species.

The survey was carried out six times a year from mid-May to mid-September; that is during the period when most moth species are active. Due to standardization, each census survey lasted 45 minutes and the surveys at all churches of a triplet were carried out during the same night. Work was divided into moth counts from the sample façade surface of 10 m in length and 3 m height as well as an inventory of moths from the entire premises. While on the scale of the entire premises, only the presence of species was documented, and the number of specimens was also measured on the sample façade surface. In parallel to this, we also counted insects and moths caught on sticky panels under reflectors at the church in Skopo (Kras/Karst triplet).

Findings

On all objects we documented 611 species of moths in total, which is 20% of all moth species living in Slovenia. The church in Koritno stands out with regard to biodiversity, as well as the test object at Sabotin. Both study sites are located in a wooded landscape with well preserved natural habitats. Churches with fewer observed species (Gornje Cerovno, Šmarje, Velika Ligojna) are mostly located in settlements and surrounded by houses and public lighting.

Area	Location	No. of species
Mariborsko Pohorje	Koritno	216
Goriška Brda	Sabotin	213
Kras	Skopo	186
Goriška Brda	Fojana	151
Goriška Brda	Dolnje Cerovo	124
Slovenske Gorice	Zgornja Kungota	124
Slovenske Gorice	Šober	113
Mariborsko Pohorje	Zgornja Ložnica	110
Mariborsko Pohorje	Malahorna	104
Ljubljansko barje	Stara Vrhnika	95
Slovenske Gorice	Gradiška	84
Kras	Veliki Dol	78
Ljubljansko barje	Zaplana	63
Ljubljansko barje	Velika Ligojna	56
Kras	Šmarje	25
Goriška Brda	Gornje Cerovo	25

When comparing different types of illumination, sample façade surfaces under adapted yellow-white illumination yielded on average 3.9 times fewer species (Figure 1a) and 5.8 times fewer specimens (Figure 1b) than in the case of the original illumination. On the scale of entire sites yellow-white illumination yielded 3.6 fewer species than the original illumination. When comparing both illumination regimes, sample façade surfaces under yellow-white illumination yielded 30% fewer species and 40% fewer specimens than under blue-white illumination.

Figure 1: Comparison of the average number of moths in relation to different types of illumination.

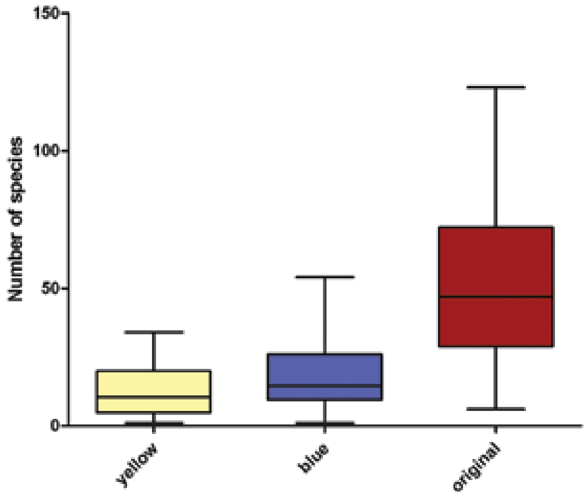


Figure 1a: Comparison of the average number of species of moths observed on sampling plots in relation to different types of illumination.

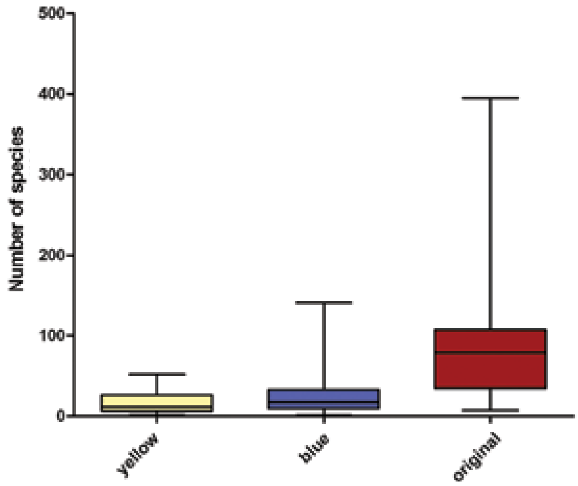


Figure 1b: Comparison of the average number of specimens of moths observed on sampling plots in relation to different types of illumination.

The reduction in the observed number of specimens and species results from the combination of three improvements:

- reduced intensity of illumination,
- reduced share of light with shorter wavelengths, especially in the blue and ultraviolet part of the spectrum and
- limited amount of light illuminating the surroundings of sites due to proper shielding of lamps.

For the first two improvements, we measured the luminance of façades and spectral compositions of lamps. We can confirm that the reduced intensity of illumination as well as the reduced share of ultraviolet light resulted in less light pollution. Thus, the emergence of moths at project churches has dropped significantly (Figure 1).

Figure 2: Correlation between the number of specimens at sample façade surfaces, the share of emitted UV light and the intensity of illumination.

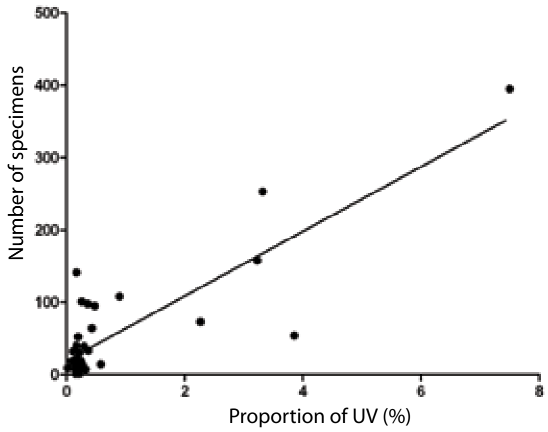


Figure 2a: Correlation between the number of specimens on a sample façade surface and the share of emitted UV light.

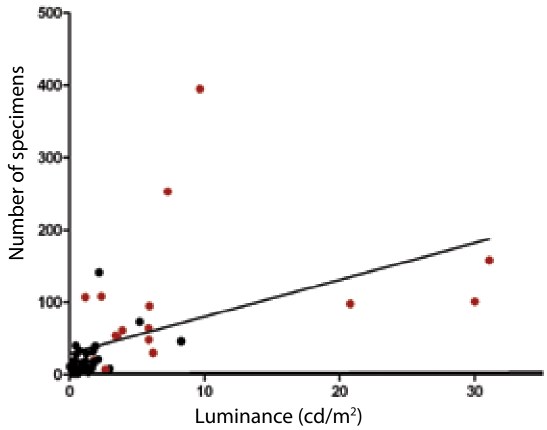


Figure 2b: Correlation between the number of specimens on a sample façade surface and the intensity of illumination. Red points represent sample façade surfaces with original illumination.

During research, we also monitored other factors which could influence the number of attracted moths. Among these factors, we established a positive correlation with the increasing temperature and a negative correlation with increasing wind power. As a factor of habitat, the numbers of moths documented at test sites were compared with the share of wooded and urban areas in the vicinity of project churches and confirmed that predominantly wooded areas contribute to greater biotic diversity, whereas biodiversity diminishes within the urban context.

The research with sticky panels resulted in much greater differences in the abundance of insects (as a whole) and moths in particular. Under yellow-white illumination 21 times fewer insects adhered to the sticky panels than under the original illumination; whereas under blue-white illumination, 5.8 times fewer insects adhered to the sticky panel than under the original illumination (Figure 3).

Work with sticky plates

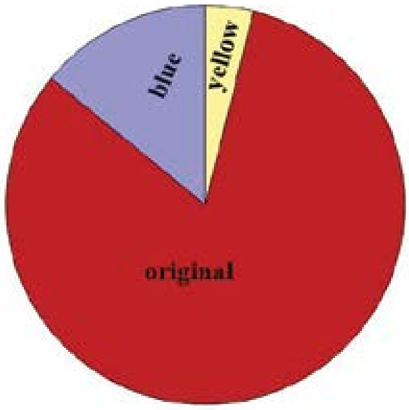


Figure 3: Comparison of shares for numbers of insects caught on sticky panels in relation to different types of illumination (Skopo).

Conclusions

Our research encompassed an important part of the moth fauna in Slovenia, thus confirming that the selection of project churches and areas was appropriate. Among the observed species, 13 are listed as endangered in the Red List of Endangered Plant and Animal Species in Slovenia, mostly categorized as endangered species (En) (OG RS 2002). At three sites, we also noticed the Jersey tiger moth (Callimorpha quadripunctaria) which is one of species from the Habitats Directive for which Natura 2000 areas should be established. This gives additional weight to our results, since we have shown that artificial illumination of cultural monuments has a negative impact on a large number of moth species, including some already endangered species.

Jersey tiger moth (Callimorpha quadripunctaria). The species, from the list of the Habitats Directive, was observed at three sample sites.

The influence of light pollution can be significantly reduced by using adapted illumination with reduced intensity of illumination, no emission in the ultraviolet and blue part of the spectrum, and the minimum amount of light passing the illuminated structure into the surroundings. These changes yielded extraordinary results, since, with adapted illumination of churches, up to four times fewer moth species and six times fewer moth specimens emerged. The difference between yellow-white and blue-white adapted illumination is also evident, making it reasonable to use yellow-white lamps for illuminating church façades in the long term. A key recommendation of this project is that lighting of cultural monuments should be omitted as much as possible, especially when they are located outside urban areas. Another important recommendation is that after 23.00 hours, lighting should be switched off in order to attract fewer moths. Insects which are already trapped in light beams should have the chance eventually to escape.

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The influence of external lighting on bats

Maja Zagmajster, PhD

Lesser horseshoe bats

Bats are one of the most endangered groups of mammals. 35 bat species are found in continental Europe (Dietz et al. 2009), 28 of which live in Slovenia (Presetnik et al. 2009). European bats feed almost exclusively on insects and other arthropods. Due to lack of such prey in the winter, bats spend this time in a deep sleep (hibernation). Towards the end of the spring, females gather in roosts to form larger groups called nursery colonies, where they give birth and take care of their juveniles. Each female usually has one juvenile (though in some species females can have twins) which becomes independent by the end of summer. Bats mate in the autumn, however, and fertilization and fetus development start only in the following spring. They roost in underground caves, tree holes, crevices in rock walls and behind tree bark. Many species also inhabit various parts of buildings such as cellars, crevices behind panels, attics, etc. They can migrate between roosts (even up to 100 km or more away), and they can travel long distances each night to feeding grounds.

Changing or destroying bats' natural habitat or disturbing and chasing them from their roosts are the main negative factors for their conservation. Artificial light at night also has negative influences on bats (Patriarca and Debernardi 2010). Light pollution was listed among ten main factors that endanger biodiversity (Hölker et al. 2010).

Influences of night lighting on bats

At night, artificial light sources attract numerous insects which then attract predators – including bats. Some bat species have started to successfully exploit this source of food and in some areas even prefer to hunt around street lamps rather than in their natural habitat (Rydell 2006). Yet, many other bat species tend to avoid lamps. In research conducted in Great Britain, lights were set up on known flight paths of lesser horseshoe bats (Rhinolophus hipposideros) and as a consequence, bats stopped using these flight paths. Bat species from the genus of mouse-eared bats (Myotis spp.) avoided lamps as well, while pipistrelle bats (Pipistrellus pipistrellus) started to come to the light to feed (Stone et al. 2009, 2012). After street lighting was introduced to some mountain valleys in Switzerland, pipistrelle bats started spreading to these valleys, while lesser horseshoe bats started disappearing (Arlettaz et al. 2000). As artificial illumination negatively influences the abundance and biodiversity of insects, in the long run, this negatively affects all bat species.

Buildings are important shelters for numerous bat species. As many as 24 European species are at least partially bound to living in castles and churches (Marnell and Presetnik 2010). Buildings are inhabited by nursery colonies and their protection is crucial for preserving bats in certain areas or in the larger regions. In this way, the combined protection of cultural and natural heritage is necessary to protect both. Slovenia has over 130 buildings (among them 112 churches and 11 castles) which are included in the Natura 2000 network because of their importance for bats.

In Slovenia, lesser horseshoe bats (left) and Alpine long-eared bats (right) are mostly found in the attics of buildings, especially churches, in the summer.

In Slovenia, lesser horseshoe bats (left) and Alpine long-eared bats (right) are mostly found in the attics of buildings, especially churches, in the summer.

To preserve bat roosts in buildings, it is first necessary to preserve the appropriately sized flight openings. Maintenance and renovation works should be done at times when bats are not present. An important negative factor is also exterior lighting. The time when bats emerge from their roosts is related to the intensity of light outside (Fure 2012) and differs among different species (Jones and Rydell 1994). If bats emerge too early, they can be exposed to predators, and if they emerge too late, they may miss the evening peak of insect activity in their feeding habitats (Jones and Rydell 1994, Duverge et al. 2000). Illumination of flight openings and their surroundings disturbs bats and gives them false information on the natural intensity of light. Bats tend to emerge later from illuminated roosts or can even completely abandon their newly illuminated roost (Downs et al. 2003, Reiter and Zahn 2006, Boldogh et al. 2007). If emerging from their roosts too late, bats may miss the evening peak of insect activity, which then has an impact on their nourishment and consequently on the growth and survival of juveniles. Juveniles in illuminated roosts presumably grow more slowly than in roosts that are not illuminated. These differences were observed in Geoffroy's bats (Myotis emarginatus) and in lesser mouse-eared bats (Myotis oxygnathus) in Hungary (Boldogh et al. 2007).

Research on bats within the Life at Night project

In the Life at Night project we studied the influence of different types of illumination of churches on lesser horseshoe bats (Rhinolophus hipposideros). These are the smallest species of horseshoe bats in Slovenia, with their nursery colonies almost exclusively in buildings, mostly in church attics and belfries (Presetnik et al. 2009). They are one of the most endangered bat species, also listed in Appendix 2 of the Habitat Directive. According to the latter, Natura 2000 sites had to be designated, where habitats of lesser horseshoe bats have to be preserved. A large proportion of buildings is included in the Natura 2000 network due to their importance for lesser horseshoe bats.

As a part of the Life At Night project, a diploma thesis was undertaken by Klara Hercog to conclude her undergraduate study in biology at the University of Ljubljana (Hercog 2013). In the Posavje region in central Slovenia, she studied the characteristics of churches and their surroundings, with the aim of establishing what influences the choice of roost by lesser horseshoe bats. This research was especially interested in evaluating the influence of external illumination on the presence of lesser horseshoe bats.

The main project activities were directed toward evaluating the influence of different types of illumination at selected churches on bats. This project included churches that had nursery colonies of the species and which had been illuminated already before the project. At each church, different illumination was installed every year (original, blue-white and yellow-white). In the first year, bats were monitored at six churches: one triplet was near Vrhnika (Stara Vrhnika, Zaplana, Velika Ligojna) and the other triplet near Cerkno (Trebenče, Otalež, Ledinica). In 2012 and 2013, we included the third triplet of churches near Trojane (Šentgotard, Čemšenik, Špitalič) in our observations. Ten observations were carried out at each church with two- or one-week intervals from the end of May till the end of August. During the day, bats were counted inside the church, and in the evenings, their emergence from the roosts was observed. On each evening, all churches of the same triplet were observed simultaneously, with events for each flight opening recorded separately. In churches near Vrhnika, the growth of juveniles was monitored as well. Several additional observations at illuminated and non-illuminated churches were done by biology students, contributing to a better understanding of the project results.

Findings

When comparing churches with and without lesser horseshoe bats in the area of Posavje (Hercog, 2013), it became evident that lesser horseshoe bats preferentially inhabit churches with large enough and non-illuminated flight openings (Figure 1). Another important factor was the vicinity of woods, which is the main feeding ground for this species.

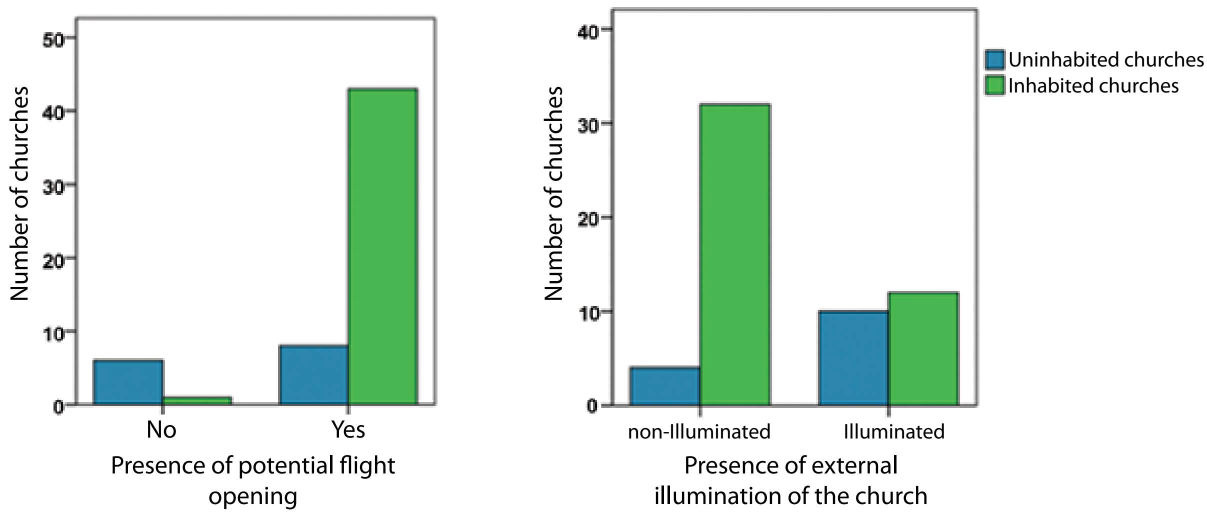

Figure 1. Number of churches with and without lesser horseshoe bats according to the presence of a potential flight opening (left) and according to the presence of outdoor illumination (right). The data are from 2011, when 58 out of 90 churches were inspected in the Posavje region in central Slovenia (Hercog, 2013).

Responses of lesser horseshoe bats to different types of illumination within the three year period were not the same at all churches. At some churches, we did not notice obvious differences due to changed illumination. This can be explained by the fact that changes were not so marked – it could be, that by coincidence flight openings had been located at the "darker side" of the church and were not illuminated so strongly even with original illumination. Yet, in some other cases, when flight openings were more strongly illuminated, bats could fly quickly into the nearby vegetation and perhaps were not so much influenced by the illumination. The size of the flight openings and their surroundings can influence the emergence behaviour of bats (Duverge et al. 2000).

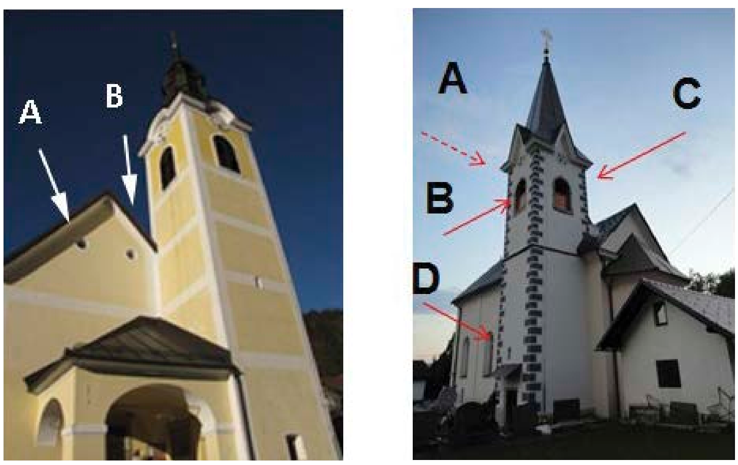

Figure 2. The church in Špitalič (left) and in Zaplana (right) with marked flight openings.

At some churches we confirmed a positive influence of improved illumination on lesser horseshoe bats. At the church in Špitalič, flight openings were strongly illuminated under original illumination. Measurements at two main flight openings (Figure 2) yielded on average 8.3 lux. Under improved illumination, measurements showed only 1.16 lux. This change had a significant influence on the emergence of bats (Figure 3). Under adapted illumination, bats emerged sooner and the median bat* emerged 20 minutes earlier. Emergence time has shortened significantly – under original illumination, it could lasted also than 2 hours, whereas under adapted illumination, bats mostly emerged in less than 40 minutes (Figure 3).

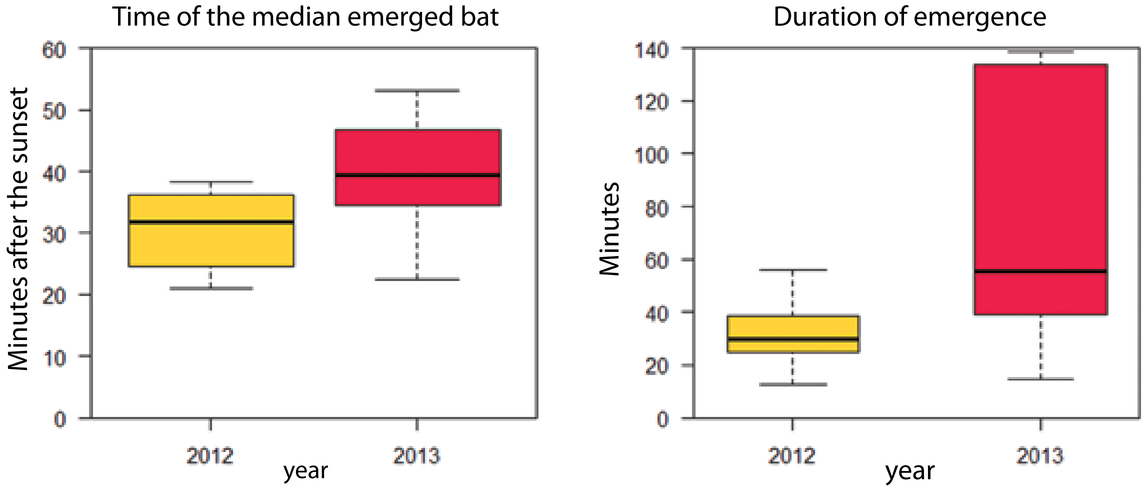

Figure 3. Difference in emergence time of median bat (left) and duration of emergence (right) of the lesser horseshoe bats from the church in Špitalič in 2012 and 2013, with adapted (in yellow) and original (in red) illumination.

The positive influence of adapted illumination was observed in church belfries. At the church in Zaplana, we noticed that under original illumination, over 60% of bats emerged from the opening that was not directly illuminated, while hardly any bats were observed emerging from the openings on the illuminated side of the belfry (Figure 4). This ratio changed considerably under adapted illumination, when flight openings were not illuminated. From previously fully illuminated and now properly shaded openings the proportion of emerged bats increased to up to 50% of all bats.

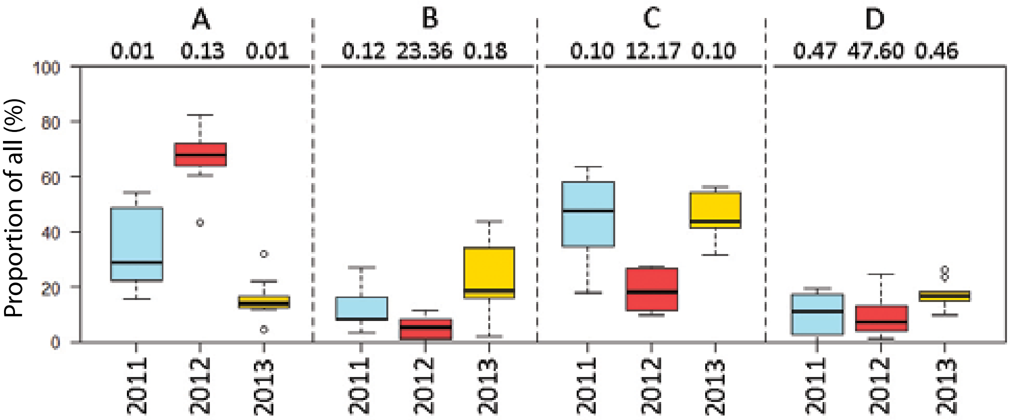

Figure 4: The proportion of bat emergences from different flight openings (Figure 2, from A to D) at the church in Zaplana for every year according to original illumination (2012) and two adapted illumination regimes (2011 – blue-white, 2013 – yellow-white). Illumination intensity in lux measured at each flight opening for every year is given under the designations of flight openings.

The growth of juveniles was observed at the churches of the Vrhnika triplet. We noticed differences in the time of birth and development of juveniles, but they cannot unambiguously be attributed to changing of illumination. The differences could be related to differences in microclimatic conditions in roosts that influence juvenile growth (Reiter 2004). Even though our case does not confirm the findings of Boldogh et al. (2007), who have noticed significant changes in juveniles' growth in other bat species, this does not mean that illumination at some other church would not have a negative impact on the growth of lesser horseshoe bat juveniles.

** When we know the number of emerged bats, we can determine the median bat: i.e. the bat before and after which the same number of bats emerged.*

Conclusions

In this project we demonstrated that lesser horseshoe bats preferentially inhabit churches with appropriate big flight openings and without external illumination, which are located near the woods. The response of lesser horseshoe bats to changing illumination was not observed everywhere, which can be explained with reference to particularities of individual churches and the positions of flight openings according to the luminaires. We discovered a positive influence of changed illumination on evening emergence behaviour of lesser horseshoe bats. They emerged sooner from less illuminated flight openings and in less time or they emerged in greater numbers through shaded flight openings rather than through brightly illuminated flight openings.

We can confirm that improved lighting with less intensity and shaded flight openings is more appropriate for lesser horseshoe bats than exaggerated original illumination. It is also stipulated in the national legislation (Decree on Limit Values due to Light Pollution of Environment) that it is not permitted to illuminate bat flight openings from roosts. However, we need to be aware that even nature-friendlier illumination is still a compromise, and that the absence of illumination is without doubt the best solution to protect endangered species.

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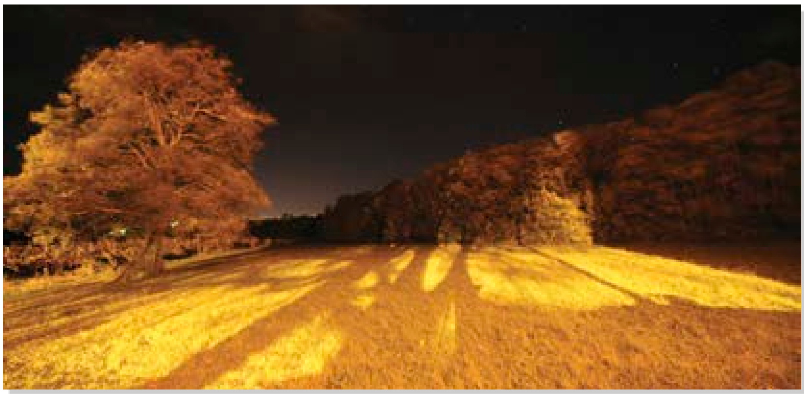
Recommendations for nature-friendlier illumination of objects of cultural heritage



Over-illuminated façade.
Over-illumination causes a great amount of reflection which illuminates distant surroundings.

We recommend that objects of cultural heritage not be illuminated. If this is not possible, they should be illuminated according to the Decree on Limit Values due to Light Pollution of Environment. To these requirements we add the newest findings and recommendations of biologists and environmentalists.

This church is easily visible even though its average façade luminance is only 0.4 cd/m².

1. Façade luminance

The Decree requires that the average façade luminance be less than 1 cd/m². This limit value is the same in Slovenia as in Italy where strict legislation limits façade luminance. In smaller towns in less illuminated areas, 0.2 cd/m² suffices. Limitation of façade luminance is crucial if we wish to reduce energy consumption and the negative impact on nocturnal animals. Half the luminance means half the energy consumption. The human eye can adapt to all levels of brightness. If brightness is increased or reduced by the factor of two, we hardly notice any difference since the curve of eye sensitivity to brightness is logarithmic.

City Hall at the Grand Place in Brussels. Despite the fact that Belgium is the most light-polluted country in the EU, the façade luminance of the greater part of this side of the building (without illuminated windows and lamps) is under 1 cd/m².

2. Illumination with 0% emission into the sky

If possible, the facades of objects of cultural heritage should be illuminated in such a way that no light shines into the sky. In such case illumination should be made from top down. Thus, the majority of reflected light falls on the ground and is also used to illuminate the surroundings of the object.

3. The share of light that can miss the façade

If objects of cultural heritage have the status of cultural monuments, the Institute for the Protection of Cultural Heritage of Slovenia does not allow any changes to the façade. That is why the illumination of cultural monuments is an exception and can be carried out from the ground up. The share of light that misses the façade and shines into the sky is an extremely important factor and has to be less than 10%. With technically demanding projectors (similar to slide projectors) it is possible to ensure that even less than 1% of light misses the façade and shines into the sky. Within the Life at Night project we developed a cost-effective technology of shielded reflectors. The shielding includes a mask with the shape of the silhouette of an individual object. With such shielded reflectors, the share of lost light that passes the facade is less than 2%. The masks significantly reduce the light beam that would light the sky. Light pollution caused by the illumination of the object is reduced by a factor of 5. The smaller light beam attracts fewer insects and makes it possible to shade flight openings for bats.

A shielded luminaire with an MH bulb with 3000 K and additional filter that blocks UV and blue light.

The Church of St. Martin and Urh in Zaplana with shaded flight openings. Masks make it possible to shade the flight openings for bats in the belfry and above the doors.

The Church of St. Urban at Šober above Maribor.
After shielded lamps had been mounted, light pollution above the church was reduced significantly and one could again enjoy observing the splendour of the Milky Way. This location is popular for romantic dates and after lighting reconstruction, Šober with the starry sky above has become even more magical.

4. Lamps directed upwards close to the wall (»wall washing«)

Wall washing is environmentally the most debatable way of illumination since a large amount of light is reflected into the sky. Lamps are placed right against the wall illuminating it at a low angle. Since the majority of light is reflected into the sky and not towards the observer he/she considers the wall to be darker than it actually is. The area of the façade right next to the lamp is as much as 100 times brighter than the area of the façade away from the lamp (depending on the lamp's optics). Such illumination makes it technically difficult or almost impossible to ensure that less than 10% of light will miss the façade and shine into the sky.

Lamps that are mounted right at the wall increase the shadows on the façade, which are a result of the uneven wall surface. This may distort the image of the façade.

Lamps mounted right against the façade cause shadows which do not give the feeling of authenticity of the object.

Palazzo Vecchio in Florence.
The building is illuminated from the side so it has no shades or exaggerated emphases. The appearance of the palace is more natural. Façade luminance is low, under 1 cd/m^2, giving one the feeling of monumentality and drama.

5. Light spectrum

Due to a large share of blue light, white light (4000 K) strongly pollutes the sky and attracts insects. The following lamps should be used: amber LED or white LED with filter that blocks blue light under 500 nm. If possible, red light should be filtered above 650 nm since our eye can hardly detect wavelengths of red longer than that. If no filters are used, the colour temperature of light should not exceed 2700 K. Some laws governing the protection of night sky (Chile, Spain) have a criterion that all outdoor lighting should emit less than 15% of light in wavelengths shorter than 500 nm. As we have already mentioned, the regional legislation in Friuli – Venezia Giulia limits the colour temperature of luminaires to a maximum of 3300 K.

We usually wish to display objects of cultural heritage as buildings which have lasted for centuries and have a historic value. If we illuminate them with blue-white colour, they will lose the look of authenticity.

Illuminated 14th century church at Šmarna gora.
The church, illuminated with a blue-violet light, looks unnatural and blue light strongly influences insects, thus reducing their biodiversity.

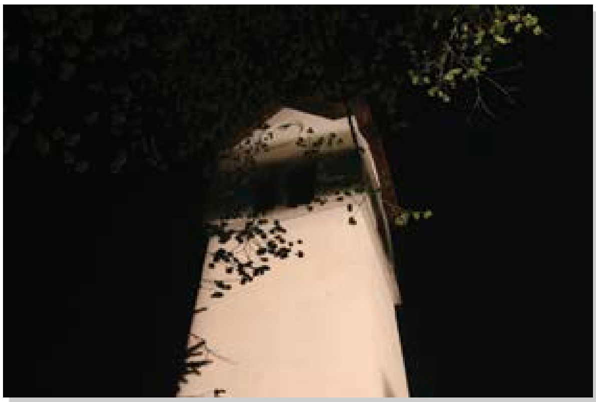
This lamp was developed within the Life at Night project. The Moon is visible in the background. The colour of the light beam shows that the lamp emphasizes the green and yellow part of the spectrum where eye sensitivity is greatest in photopic (colour) vision. At the luminance of 1 cd/m^2, our eye mostly detects in a photopic manner.

Smolenice, Slovakia.
A representation of amber LED at the international conference "Light pollution – Theory, Modelling and Measurements" in 2013: The amber LED creates a magical feeling and a warm ambiance which all conference participants found appealing. It is important that lighting is very discreet. We recommend an illumination of less than one lux.

6. What should not be lit

If an object is inhabited by a colony of bats, surfaces with flight openings are not allowed to be illuminated. If these surfaces are illuminated at the time, lamps directed towards the walls with flight openings should be switched off. In protected natural areas and in Natura 2000 sites, objects of cultural heritage should not be illuminated.

If the church is in an isolated place far from the settlements, it should not be illuminated. Nobody will admire objects of cultural heritage from a distance of a few kilometres. Because of the considerable distance, the observer cannot discern whether the illuminated object at the distance is a church or only an unshielded lamp. We should not illuminate the façades facing away from settlements or towards forests, since nobody admires them from there.



Shaded flight openings for bats in the belfry.
Shading is enabled by the mask attached to a nature-friendly lamp and specially tailored to the façade of the building.

In several rich countries, e.g. Switzerland (Basel), Germany (Berlin), numerous objects of cultural heritage (museums and churches) are not illuminated. In this manner, the historical authenticity of the area is emphasised. Some centuries ago, larger cities had public lighting; however, it was incomparably weaker than today's lighting. Levels of illumination then were lower and the luminaires emphasised the yellow part of the spectrum (candles, oil lamps, gas lighting). When renovating objects of cultural heritage, one should bear in mind the authenticity of the period nocturnal ambiance.

7. Lighting the environment surrounding objects of cultural heritage

Lamps with 0% emission into the sky should be used in order to reduce glare and prevent emission above the horizontal. Lamps should emit warm yellowish light of less than 2700 K. We should especially bear in mind that lamps are mounted in a way that they do not shine into the eyes of visitors.

Unshielded lamps can cause strong glare, especially for elderly people. Due to the natural process of ageing, the eye lens becomes cloudy, which, among other things, results in glare. The surroundings of churches should be made pleasant, and be a place where people like to visit in the evening also. Cemeteries need not be illuminated, since they are usually illuminated by hundreds of candles.

Entry into the church with unshielded lamps on short poles shining into people's eyes from the direct vicinity. We should use fully shielded lamps even if the legislation does not require it.

An example of a stylish lamp for the illumination of the vicinity of objects of cultural heritage. The bulb is placed in the upper part. The luminaire has no side glasses since these scatter light above the horizontal.

Access road to the cultural monument. This is an example of senseless and harmful investment: unbearable glare, light shiningabove the horizontal, and high maintenance costs. Also, the lawn around the luminaires will require manual mowing.

8. Lighting should be switched off

Energy-efficient lighting of façades should also be switched off after 23.00 hours. By doing so, people's health is preserved, and biodiversity and the night sky benefit.

The Church of St. Helen at Javor in Kozjansko.
This church is not illuminated. The genuine historic landscape is conjured up by the light from the interior of the church. Above the church, one can see a bright shooting star crossing the winter part of the Milky Way. If the church were illuminated, the stars and the shooting star could not be seen.

The Church of St. Ana in Prevorje.
Lighting here is switched off when the pupils open the dome of the school observatory 30 metres away from the church. Only then can they adore the millions of stars of the Milky Way.

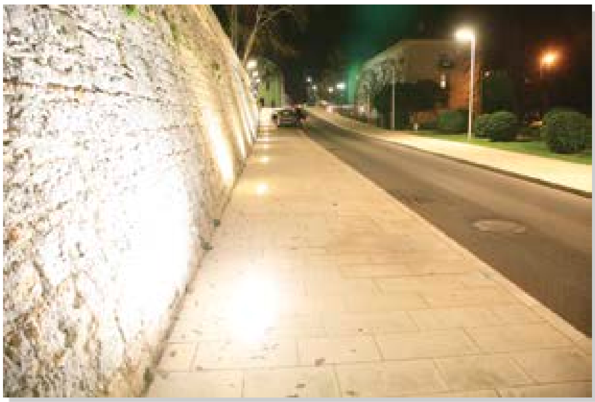
9. Lighting of overhangs

We should avoid illuminating overhangs. Light attracts insects which are prey to spiders. Even in city centres where there are fewer insects, we can notice mould like cobwebs on façades. Cleaning of cobwebs is challenging and expensive.


Cobwebs on façades.

10. Ground-recessed lamps

In Slovenia, ground-recessed lamps are prohibited. They glare, blind and cause discomfort. They emit almost 100% of light into the sky and are very harmful to the environment. Since they are exposed to water, they are often damaged. We propose that the EU bans the production, import and sale of ground-recessed lamps.

A ground-recessed luminaire, and an example of illumination with ground-recessed lights.

11. Reducing energy consumption and installing timers

Churches used to be illuminated with 400 W reflectors. If we accept a lower brightness of façades and apply the newest technology, it is possible to illuminate one side of a façade of an average sized church with approximately 30 W. Moderate and technologically advanced lighting of cultural monuments can cut costs considerably. Let us not limit ourselves merely to low energy consumption - timers should be employed as well so as to switch off the lighting at night. If LED lamps are switched on only during the first half of the night, less energy will be consumed and the service life of luminaries will be doubled, for instance from 12 to 24 years. Apart from that, something good can be done for nature at night.

The book of Moses states: "God separated the light from the darkness." Let this wisdom guide us to think that night too has its purpose. During the night we should switch off lighting because nobody is admiring sites of cultural heritage at two in the morning. We should allow nature to live its own life at night.

12. Consult nature and culture protection experts

Prior to renovation of lighting, the building manager should consult nature and culture protection experts. In Slovenia, these are the Institute of the Republic of Slovenia for Nature Conservation and the Institute for the Protection of Cultural Heritage of Slovenia.

It is possible that bats roost in the building. Renovation should be carried out in such a way that the bat habitat is preserved. If the building is inhabited by bats, and because this is a Natura 2000 site, nature conservation approval is required for renovation.

Cultural heritage protection approval is required if the building is of cultural heritage, protected by regulations from the field of cultural heritage protection.

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Brochure prepared by:
Andrej Mohar, Maja Zagmajster, Rudi Verovnik, Barbara Bolta Skaberne

Contribution on the influence of lighting on moths: Rudi Verovnik
Contribution on the influence of external lighting on bats: Maja Zagmajster

Authors of photographs:
Andrej Mohar (also on the front page),
Jurij Stare (p. 2, Nebula),
Peter Mlakar (p. 10), Rudi Verovnik (p. 13),
Lea Likozar (p. 14), Simon Zidar (p. 15),
Maja Zagmajster (p. 16),
Primož Kuk (p. 21, above right)

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Teslova 30, SI-1000 Ljubljana, Slovenia
+386 1 477 66 53
info@temnonebo.si
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