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# **Impact of outdoor lighting on man and nature**

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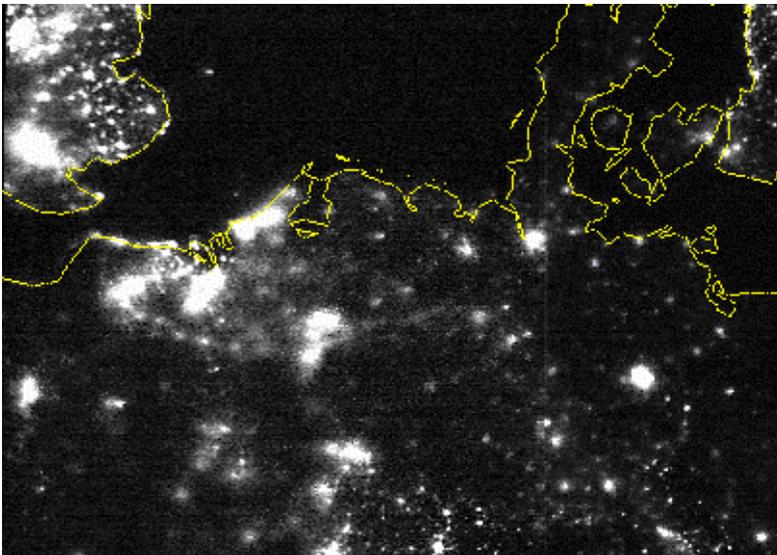
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## The stars

Neither the stars – Muse – nor the wind, the rain  
the fields, the dogs, the horses, the trees  
nor even the tears, the war, the emptiness

But, in the rain and wind, beautiful eyelashes  
And, under the stars, a pair of dark eyes  
– dark stars – such a light of beauty.

Jan Hanlo, Collected poems (in Dutch) 1979



Photograph: International Dark Sky Association

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To the Minister of Housing,  
Spatial Planning and the Environment

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Subject : advisory report 'Impact of outdoor lighting on man and nature'  
Your reference : -  
Our reference : U 2593/MvdB/mr/667-B  
Annexes : 1  
Date : 30 November 2000

Dear Minister,

I hereby present you with a Health Council advisory report on the risks to man and nature of the gradual disappearance of darkness in the evening and at night as a result of urbanization and other contemporary developments in the Netherlands. The advisory report was prepared at my request by the Health Council's Secretariat and was assessed by the Standing Committee on Ecotoxicology and the Standing Committee on Health and the Environment. I subscribe to the considerations, conclusions and recommendations contained herein, including the call for the explicit inclusion of the topic of light nuisance in the government's environmental policy.

Today, I have also presented this advisory report to the Minister of Transport, Public Works and Water Management, and the State Secretary for Agriculture, Nature Management and Fisheries.

Yours sincerely,  
(signed)  
JJ Sixma

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# **Impact of outdoor lighting on man and nature**

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to:

The Minister of Transport, Public Works and Water Management

The State Secretary for Agriculture, Nature Management and Fisheries

The Minister of Housing, Spatial Planning and the Environment

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No. 2000/25E, The Hague, 30 November 2000

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The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is “to advise the government and Parliament on the current level of knowledge with respect to public health issues...” (Section 21, Health Act).

The Health Council receives most requests for advice from the Ministers of Health, Welfare & Sport, Housing, Spatial Planning & the Environment, Social Affairs & Employment, and Agriculture, Nature Preservation & Fisheries. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.

Most Health Council reports are prepared by multidisciplinary committees of Dutch or, sometimes, foreign experts, appointed in a personal capacity. The reports are available to the public.

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## Executive summary

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In this advisory report, the Health Council draws attention to the ongoing loss of darkness in the evening and at night and to the consequences of this loss for landscape quality and the human environment. Modern developments such as urbanization, increased motor traffic, increased greenhouse horticulture, more flexible working hours, a growing demand for outdoor sports facilities and an increasing tendency to floodlight business premises and historic buildings mean that darkness is being eliminated in a growing number of increasingly large areas. For a variety of reasons, many people regret these changes. Annoyance in residential areas and worries about possible harm to plant and animal life also warrant additional attention to this matter in the policy of central government and other regulatory bodies.

### Plant and animal life

Outdoor lighting at night-time can influence the life cycle and behaviour of animals in many ways. The effects vary greatly depending on the animals concerned. Outdoor lighting is often accompanied by other disturbing, barrier-forming factors such as traffic noise. In particular for birds, insects and amphibians, it has been observed that outdoor lighting influences behaviour as animals are disoriented, attracted or repelled by the light, thus increasing the chance of exhaustion and death. For some species with small, isolated populations, this can cause local extinction. In a recent field study it was observed that street lighting affects the density of local populations of black-tailed

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godwit. There are no indications that outdoor lighting has a serious detrimental effect on wild plants.

## Man

Studies have shown that people living in the immediate vicinity of greenhouses and sports fields were annoyed by the illumination of their houses or gardens, the direct view on the light sources or the glow above them. The percentages of people who experience moderate or serious annoyance vary from 5 to 15. In particular the glow above greenhouses is perceived as a nuisance by residents. Walkers in the evening period are annoyed by the direct view of the light from greenhouses. Over the next few years, the number of persons affected will increase due to the growing use of outdoor lighting.

It has been shown in laboratory experiments that a disturbance of the day-night rhythm has negative physical and psychological effects on human beings. However, such disturbances only occur at relatively high light intensities. Although epidemiological research on this matter is inconclusive, it cannot be ruled out that, in combination with other stress factors in the environment, outdoor lighting has a long-term detrimental effect on health due to stress associated with a shortening of the evening and night.

## Loss of darkness as a 'primordial' quality in rural areas

The plans for new urban development locations, industrial estates and various large infrastructural projects such as railways and airports mean that the use of outdoor lighting in the Netherlands will increase continuously in the coming years. Also in rural areas, which now are still relatively dark at night, outdoor lighting is set to increase with the development of housing, business premises and greenhouses, as well as the creation of new facilities for sports and recreation coupled with their intensified use. The disappearance of those still dark areas will promote the loss of diversity as well as the fragmentation of the Dutch nocturnal landscape.

A social science perception survey showed that people attribute importance to nature experiences, including silence and darkness. The Health Council supports the calls of nature conservation organizations to preserve darkness as a 'primordial' quality of the landscape in rural areas, not only for nature itself but also for people, who need the opportunity to wind down in surroundings very different from those of today's hectic 24-hour society (compensation value).

## Further research

If a better picture of the ecological consequences of lighting is to be obtained, a field study over a period of several years is necessary, in which the effects of lighting in combination with other disturbing and fragmenting factors, including traffic noise, are examined. Research into annoyance in the immediate living environment is particularly relevant for the derivation of guidelines for the various applications of outdoor lighting.

The present advisory report underlines that people's perception and appreciation of the landscape quality and the value of darkness and silence as essential elements play an important role in the general discussion on 'light nuisance'. Specific socio-psychological research into people's perceptions is needed to enable the inventory of opinions of the Dutch population on the value of darkness in the context of their views on nature and nature experiences.

## Legislation

Despite the lack of systematic practical knowledge from empirical research on the ecological consequences of nightly outdoor light, there are sufficient indications that support the current 'No unless' policy of the Public Works and Water Management Department on street lighting in nature conservation areas. The need for lighting from a road safety viewpoint must always be carefully balanced against the possible adverse effects on animal life.

The policy of central government with regard to outdoor public lighting should become part of an integrated national approach for protection and improvement of the quality of the natural environment in rural areas and in particular in areas that have a restrictive policy with regard to building, infrastructural works and the like. One possibility is the creation of light abatement areas in analogy to the current noise abatement areas. If 'light nuisance' were explicitly included in the environmental policy as part of the environmental theme 'disturbance', the carry-over to other government bodies could be stimulated

Legislation for reduction of the nuisance in the living environment from lighting at sports facilities and assimilation lighting in greenhouses is already in force or under preparation. Control of the enforcement could, however, be tightened up. Guidelines for dealing with nuisance from floodlighting and illuminated advertisements must still be developed.

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# Introduction

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A major consequence of increasing urbanization and the 24-hour economy is the increased need for lighting. Recreational pursuits continue on into the evening, also because of a lack of space for more facilities. More flexible working hours and the growth in road traffic mean morning and evening rush hours last longer. These developments have resulted in the construction of illuminated roads, car parks and sports fields, illuminated advertising and public buildings, and floodlights around business premises and historical buildings. Private individuals as well as companies are increasingly fitting outdoor lighting as a means of combating crime. Another source of nocturnal outdoor lighting is assimilation lighting in greenhouse horticulture, which is intended to increase yields or accelerate the flowering of plants ('tulips at Christmas').

Satellite photographs show that the amount of outdoor lighting in western countries is increasing annually. The distinction between day and night is becoming blurred: darkness will increasingly become a scarce commodity, as has silence. Astronomers and nature conservation organizations have been trying to get the preservation of darkness as a 'primordial' quality on the political agenda for many years. They point to the annoying consequences for man, the detrimental effect on the perceived value of nature and landscape, and to possibly dramatic consequences, especially for animals.

In the Netherlands, the increasing level of light pollution was pointed out in the early eighties by various organizations concerned with nature and the environment. A number of Council of State appeal cases received publicity in the early eighties in connection with granting permits for assimilation lighting for greenhouse horticulture. Within the scope of this, research has started into the visual nuisance to surrounding residents and

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into possible consequences for wild flora and fauna and for agricultural crops. A study has also been conducted to determine how to limit the radiation of light into the surrounding area (Gri92). Various guidelines have been drawn up or are currently being prepared, with which the government will attempt to reduce the light nuisance for surrounding residents (see NSVV99, Stb98).

In 1995, in a letter to the Directorate-General for Public Works and Water Management, various organizations concerned with nature and the environment expressed criticisms about the illumination of roads in rural areas and nature conservation areas, including along the A50 and the A12 in the Veluwe region. They contended that in terms of the landscape and ecology, the provision of lighting along these roads has a serious detrimental effect on one of the few remaining dark areas in the Netherlands. In their letter, they asked the Directorate-General for Public Works and Water Management to take another critical look at the necessity of lighting along motorways. They also called for a 'no, unless' policy, i.e. no lighting except when its necessity has been demonstrated in connection with road safety, for example. Moreover, decisions to provide lighting should be preceded by a thorough survey of the consequences for the landscape and ecology. This action of organizations concerned with nature and the environment led to a great deal of publicity and even to questions in the Lower House. At the end of 1996, the government accepted a motion of the Lower House to restrict light pollution in nature conservation areas to the minimum and to promote research into the consequences of and alternatives to street lighting. In 1997, the Institute for Forestry and Nature Conservation Research (IBN) was commissioned by the Road and Hydraulic Engineering Department of the Directorate-General for Public Works and Water Management to conduct a comprehensive study of street lighting and its consequences for nature (Mol97a). The results of this study and of field studies, some of which still have to be conducted, provide scientific underpinning for the 'no, unless' policy that has now been adopted by the Directorate-General for Public Works and Water Management. This policy has been worked out in detail in the Public Lighting in Nature Conservation Areas Directive (which came into effect in 1997, CROW97).

This present descriptive advisory report provides a summary of the current state of affairs in research into the unwanted effects of outdoor lighting on man, animals and plants. The key questions are:

- In terms of its seriousness and extent, does any current or shortly anticipated problem justify extra attention in the policy?
  - If so, what are the possibilities for dealing with it, through national policy or more specific policy guidelines, for example?
  - What types of further studies are necessary to underpin any new policy or policy changes?
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## Sources and trends

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### 2.1 Uses of outdoor lighting

#### Street lighting

The paved road network in the Netherlands currently has a length of approximately 116,000 kilometres (CBS99a). According to the Directorate-General for Public Works and Water Management, approximately 85 percent of this is illuminated.\* The municipal authorities illuminate more than 96,000 kilometres and the Directorate-General for Public Works and Water Management approximately 700 kilometres. The other road managers, such as provincial authorities and water authorities illuminate approximately 600 kilometres (RWS98). Most illuminated roads are in the conurbation of Western Holland.

#### Lighting at sports facilities

The demand for outdoor sports in the evening has increased in recent years. The number of lighting masts is increasing rapidly around tennis courts, golf courses, football fields and riding schools, especially at the outskirts of built-up areas.

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\* There is some uncertainty about this estimate. Another study estimated a lower percentage (approximately 62% illuminated; Sch98).

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## Greenhouses

Greenhouse horticulture in the Netherlands takes up a total of approximately 10,000 hectares (CBS99b). Assimilation lighting is used in between 1400 and 1500 hectares of greenhouse horticulture (Bak00).

## Other sources of outdoor lighting

The 24-hour economy has resulted in increasingly more industrial estates, ports, railway yards and airports that are illuminated for longer periods in the evening and during the night. In cities and along railroads the use of illuminated advertising columns is increasing. Facades and company premises are also illuminated for advertising or security reasons. Monuments and buildings with a cultural and historical value are literally placed in the spotlight. An increasing feeling of insecurity is also causing more and more ordinary citizens to illuminate their houses and gardens to combat crime. However, in some situations, lighting appears to attract crime (Schr96).

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## 2.2 Trends

The approach taken in the Fourth Policy Document on Spatial Planning (VROM93) is to restrict urban expansion to existing urban districts and regional overspill areas to avoid the urbanization of rural areas. The 'restrictive policy' applies in eleven still relatively open and green areas that are facing the pressure of urbanization, including the Green Heart of Holland, the range of hills known as the Utrechtse Heuvelrug, and the Veluwe region. In principle, no new buildings should be erected in those areas outside the existing built-up area. Nevertheless, creeping urbanization is occurring. The urban use of space in rural areas, i.e. outside existing built-up areas, increased from approximately 109,000 hectares to 110,000 hectares and in the west of the country the increase was two percent (RPD99) between 1989 and 1993 (the most recent year for which figures are available). This mainly concerns industrial estates and residential accommodation. In the eleven restrictive policy areas, the number of addresses outside the built-up area increased by more than 25 percent. Greenhouse horticulture is also increasing by approximately one percent per year (average growth over seven years). The National Spatial Planning Agency (RPD) reported a striking growth of around 300 hectares in greenhouse horticulture between 1997 and 1998 (RPD99). Most growth occurs in the area around the Rhine, Waal and Meuse rivers, Central Brabant and the hills of Limburg (more than 50 percent with respect to 1980, RPD99).

In connection with urban expansion, the length of the road network has also increased over the past seven years by 16,800 kilometres (CBS99a). The National

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Spatial Planning Agency reported an increase for the whole of the Netherlands of more than one percent in the area of paved road surfaces outside existing built-up areas between 1989 and 1993 (RPD99).

The above figures show that the size of the urbanized area and the associated infrastructure is increasing, not only through population growth but also because each citizen is increasingly taking up more urban space (RPD99). This means that the use of outdoor lighting for roads, squares, car parks, shopping centres, advertising and so forth continues to increase. This increase is not only occurring in and at the edges of built-up areas but also in still relatively dark rural areas.

## **Consequences for plants and animals**

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This chapter provides a summary of the current state of affairs in the research into the biological effect of light in general, and into the consequences for plants and animals of nocturnal outdoor lighting, with the emphasis on street lighting. The summary is largely based on a study of the literature that was conducted by De Molenaar and colleagues (Mol97a).

Only rarely based on field observations, the available knowledge comes largely from laboratory experiments, such as those conducted within the scope of research into increasing production in intensive cattle and plant breeding. The translation of this data into the consequences for population densities of animals in a field situation is therefore a problem. The statements researchers make on this subject are consequently mainly of a qualitative and theoretical nature. Field studies are necessary to further empirically underpin those statements. De Molenaar and colleagues call for field studies into the consequences of street lighting for grassland birds (the black-tailed godwit was selected as a 'guide species'), the movement behaviour of mammals and their use of space, and the impact of street lighting on bats (Mol97b). The black-tailed godwit study has now been completed (Mol00).

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### 3.1 Plants

Plants not only need light for their energy supply (photosynthesis) but also for the induction of flowering.\* The reaction of plants to changing light conditions differs markedly for each species; each species has a characteristic ecological optimum curve, which describes the relationship between light intensity and growth. For example, there are light-favouring species, such as pioneers, and shade-resistant species, such as undergrowth species in a forest.

The consequences of outdoor lighting on plants appear to be limited to (parts of) individual plants in close proximity to the source of light and include delayed loss of foliage, accelerated branch growth and, in the case of plants near street lights, production of a second bloom in the autumn. This therefore concerns species that respond to the length of the day and for which no other restrictive environmental factors apply (Gri92). Presumably, the intensity of most sources of light is too low to affect wild plants and they are also not affected by the nature of the light's composition (Ber92). De Molenaar and colleagues (Mol97a) reached a similar conclusion.

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### 3.2 Animals

Under the influence of light, animals adjust their physiological functions and activities to their environment, that is to say, to the seasonal rhythm and the daytime and night-time rhythm in the environmental conditions that exist. This therefore not only concerns the direct sensory observation of the environment but also neuro-endocrine (hormonal) processes, which play a role in biological rhythms and which are indirectly controlled by light. As mentioned earlier, the knowledge described here has mainly been obtained from laboratory research. The knowledge obtained in the field about the consequences of outdoor lighting for animals is generally very limited and fragmentary.

Lighting may result in:

- improvement in orientation but also in disorientation
- attraction, fixation and repulsion
- disruption of biological rhythms (day-night rhythm, or the biological clock, and seasonal rhythm, or the biological calendar)
- change in habitat quality.

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\* This distinction between short-day and long-day plants is based on this information function of light: short-day plants only flower if the length of the day is shorter than a given maximum and therefore mainly occur in the (sub) tropics. On the other hand, long-day plants flower if the length of the day is longer than a give minimum. These species of plants generally occur in areas at high degrees of latitude.

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A distinction has to be made between luminance (the surface brightness of the source of light), illumination (the lighting up of a horizontal or vertical surface in the area around the source of light) and the spectral composition of the light. For example, the degree of attraction is related to the luminance and wavelength of the light. On the other hand, fixation is determined by both the luminance and the wavelength of the light, as well as the illumination, which creates a sharp contrast with the dark surrounding area beyond the illuminated surface, the so-called 'black wall effect'. The effect of light on the day-night rhythm and seasonal rhythm depends on the duration of the alternation between light and dark and the length of the animal's stay in an illuminated area (illumination).

Figure 1 shows a diagram of the different aspects of lighting and their effect on the physiology, condition and behaviour of animals.

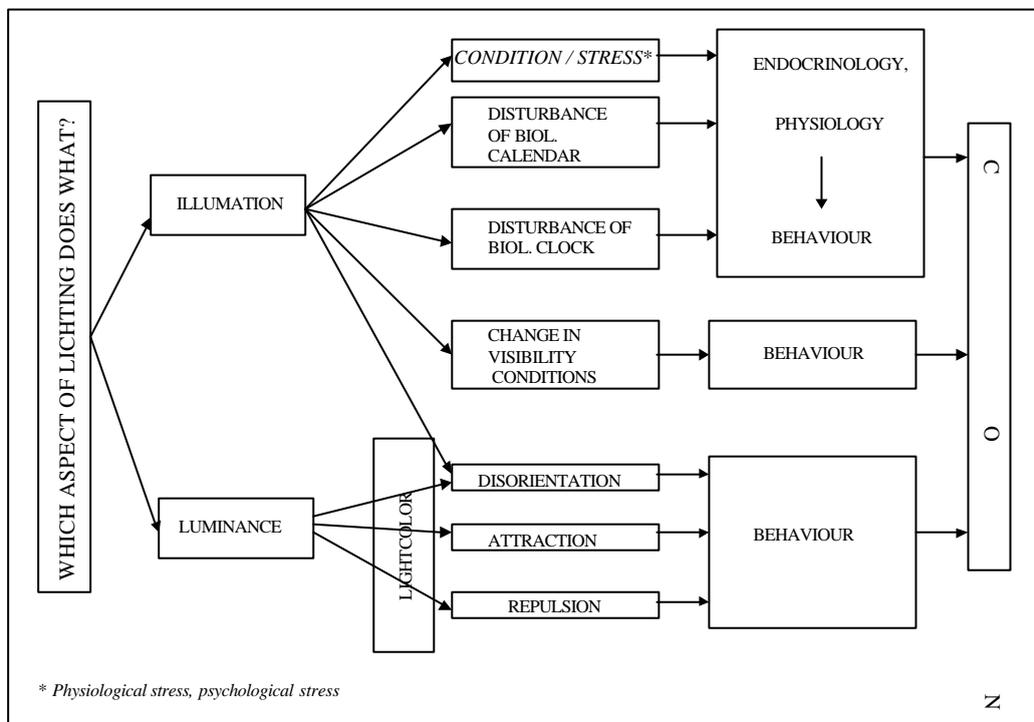


Figure 1 Diagram of relationships between the various aspects of lighting and behaviour, the physiology and the condition of animals (source: Mol97a).

## Orientation

An animal's ability to orientate itself plays an important role in its daily movements between, for example, resting areas and feeding areas and in actually searching for

food. Lighting may improve the orientation of animals that move during darkness, so that they require less energy. On the other hand, disorientation not only leads to higher energy consumption (exhaustion) but also to 'more reckless' behaviour and thereby increases the likelihood of the animal being preyed on or being run over. The same may occur in the seasonal migration (from summer to winter biotope) of migrating birds and amphibians, for example. It is known from observations of amphibians in the field that local populations may be under threat from street lighting in combination with traffic (Bak90). Experimental research has shown that outdoor lighting may disrupt orientation during migration, particularly of young birds and especially in cloudy conditions. German researchers have reported a change in the course of migrating birds through an illuminated greenhouse horticulture area (Abt95a). During nights of bad weather, the researchers counted more migrating birds flying overhead than during nights with good weather. During bad weather, birds were also observed that flew around the greenhouses for some time or even landed.

Lighting can affect orientation both positively and negatively. The outcome at the population level differs for each species of animal and also depends on food supplies and the competitive pressure caused by the presence of other predators.

#### Attraction, fixation and repulsion

Known examples of (direct) attraction are those of insects and migrating toads and salamanders, which are attracted to the light and then aimlessly fly or walk around there, thereby increasing the likelihood of predation or being run over. Collisions with lighthouses are a known example of attraction in the case of birds. Measures have now been taken to reduce the number of bird deaths caused by collisions with lighthouses (Mol97a). Less strong light sources, such as large buildings and airports, can also attract birds. Observations of the attraction of birds to street lighting are very scarce. In the case of insects, indications from field studies show that for moths, amongst other species, the negative consequences of attraction sharply reduce local population densities (Fra88). However, the possibility is not excluded that adaptation is occurring, especially in genetically variable, large populations.

In their turn, concentrations of insects around sources of light attract bats (indirect attraction), which may well consume less energy finding food but are also more likely to be run over (Kie95). Here too, attraction has a positive impact for bats, as long as the food supply is high and not too many competitors are present in the vicinity (Ryd92). Studies of bats in Sweden showed that street lighting is the cause of a shift in species: populations of common species grew, whereas those of rarer species decreased (Ryd92). Bats attract owls and the corpses of animals that have been run over attract buzzards, for example. Fixation especially of nocturnal mammals by the headlights of

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cars increases the impact of attraction and results in additional traffic victims. A relatively large amount of information is available on traffic victims, especially of (breeding) birds. However, no systematic studies have been conducted of the relationship between traffic victims and street lighting.

Repulsion by lighting disrupts the movement behaviour of some animals and reinforces the barrier effect of roads and road traffic. The number of potentially suitable biotopes therefore decreases. The foraging area of some species of bats that are repulsed by lighting therefore decreases. Recent research into the consequences of habitat fragmentation shows that the likelihood of small populations surviving decreases as the distance between other populations increases (Opd91, Opd93). Subpopulations become isolated, which leads to an increased risk of extinction, genetic deterioration, and so forth (see Gil91 for a summary of metapopulation theories and models). Further research into the impact of street lighting on the movement behaviour and use of space of animals should show the degree to which the fragmentation of the nocturnal landscape contributes to population-dynamic consequences of this kind (Ber92).

### Disruption of biological rhythms

Many behavioural and physiological functions of organisms display a daily or annual rhythm (periodicity) that corresponds with the cycles of light, temperature, availability of food, etc., which are related to the alternation of day and night and of the seasons. Biological rhythms of this kind are affected by the length of day (photoperiodicity). The biological clock, a genetically determined internal mechanism for determining the time is responsible for these daily rhythms. This clock requires regular adjustment (synchronization) by means of external stimuli in the light-dark rhythm. Disruption (desynchronization) can lead to a lack of rest or sleep in animals, which has a detrimental effect on their condition and alertness. The likelihood of predation or being run over therefore increases.

The annual rhythm in the length of the day regulates the activities that are related to the seasons. The various phases in the life cycles of animals and the associated seasonal activities, such as procreation, migration and hibernation require hormonal, physiological and anatomical preparation. An internal mechanism, the biological calendar, is responsible for the timing of those preparations.

Example: In September, some birds, such as the black-tailed godwit and the bearded tit, which eat insects in the summer, have to convert their glandular stomach into a gizzard. The gizzard is suitable for eating seeds in their winter habitat in Africa. If they fail to do this in time, they are unable to survive.

Neuro-endocrine processes are responsible for the day-night rhythms and seasonal rhythms in behavioural and physiological functions. These processes are controlled by the epiphysis, an organ in the brain that is particularly sensitive to light. This organ produces the hormone melatonin, which plays a key role in the transfer of external light stimuli to the animal's hormonal system (Mol97a).

Lighting disrupts the day-night rhythm and may therefore disrupt the biological calendar. This may mean that certain activities occur in a less suitable period, resulting in early brooding and offspring being born when the weather and food-supply conditions are not optimal. This can affect the condition of the young and the parents, thereby leading to an increased risk of death and predation.

Not many field observations indicate that outdoor lighting disrupts biological rhythms. It has been observed that robins sing for longer around illuminated tennis courts (Abt95b). High light intensities are required to bring about a shift in the biological clock under laboratory conditions (see also 4.2).

### Habitat quality and population density

Albeit with varying degrees of uncertainty per animal group, the knowledge described above suggests that lighting has a negative impact on wild animals. Depending on the environment and mode of existence of the species, lighting may have consequences for the level of occupation of the (illuminated) habitat and therefore on population density. All the aforementioned factors may play a role in this and consequently, either individually or in combination, may affect habitat quality. Figure 2 outlines the possible link between, on the one hand, road traffic and street lighting and, on the other, the population densities of birds. It is assumed that the reduction in the population density of (summer) birds as a result of traffic noise, as demonstrated in the research conducted by Reijnen (Reij95), was compounded by the impact of lighting.\* According to De Molenaar and colleagues, the diagram should also largely apply to mammals, amphibians, reptiles and insects (Mol97a). This hypothesis has been tested in the black-tailed godwit field study (Mol00). The results of that study are summarized in the next section.

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\* The field study in question showed that road traffic reduces the population densities of summer birds along the roadside by more than 30 percent (to almost 100 percent, depending on the sensitivity of the species concerned). The disturbance caused by noise appears to play a particularly important role (in forest more clearly than in open grassland, because in the latter areas other disturbing factors, including visual factors, may have an impact). However, the impact of lighting was not specifically included in the study.

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### 3.3 A case: street lighting and black-tailed godwits

The study discussed here of the impact of street lighting on a local black-tailed godwit population was conducted in a grassland area along a motorway (A9 between Limmen and Akersloot; Mol00). An initial year without lighting was compared with the following two years in which the motorway was illuminated. To distinguish between the impact of lighting and that of road traffic, a study was also made of an area without road traffic but with street lighting that was switched on simultaneously with the lighting along the A9.\*

It emerged from the study that there was a significant reduction in population density in the first 250 to 300 meters from the road. The repulsion impact of street lighting led to a bunching of nesting locations at a distance of 250 – 300 meters from the lighting. The negative impact on local population density appears to have been somewhat curtailed by the birds' loyalty to the location. The researchers expect that the birds' loyalty to location and the tendency of black-tailed godwits to breed in close proximity to each other will lead to a reduction in bunching and that the distance over which the impact of the lighting extends will increase considerably after a few years.

In an extensive field study, Reijnen discovered road traffic (noise) had a negative impact on the population density of various species of grassland birds (Reij95). No negative impact from traffic noise was observed in the black-tailed godwit study. Any such impact is apparently offset by other factors that determine habitat quality, including grassland management and use. De Molenaar and colleagues suspect that the impact of traffic noise is offset more than the impact of lighting (Mol97a). However, it is difficult to compare the results of the two studies because they were conducted with a different set-up (transversal versus longitudinal). It is striking that the black-tailed godwits that start to nest first, choose a location further from the source of light than the black-tailed godwits that nest later. There are no indications that street lighting affects breeding success or the condition of the parent birds. This suggests an absence of any neuro-endocrine impact, probably because of the light's limited range (the illumination). It is not possible on the basis of the study results to make any comments on how street lighting affects predation on black-tailed godwit clutches (the assumption was that

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\* The study was concerned with the precise locations of the nests discovered in 1998 and 1999, their distance from the lighting, the number of eggs per nest, the size and weight of the eggs, the date on which the first egg per clutch was laid and any losses from clutches. Other environmental factors that determine habitat quality or choice of nesting location were also identified: the weather situation, the dampness and drainage of the plots, the structure of the grass mat, the height of the grass, the fertilization and grazing, as well as all kinds of field work connected with site management (rolling, towing, mowing etc.).

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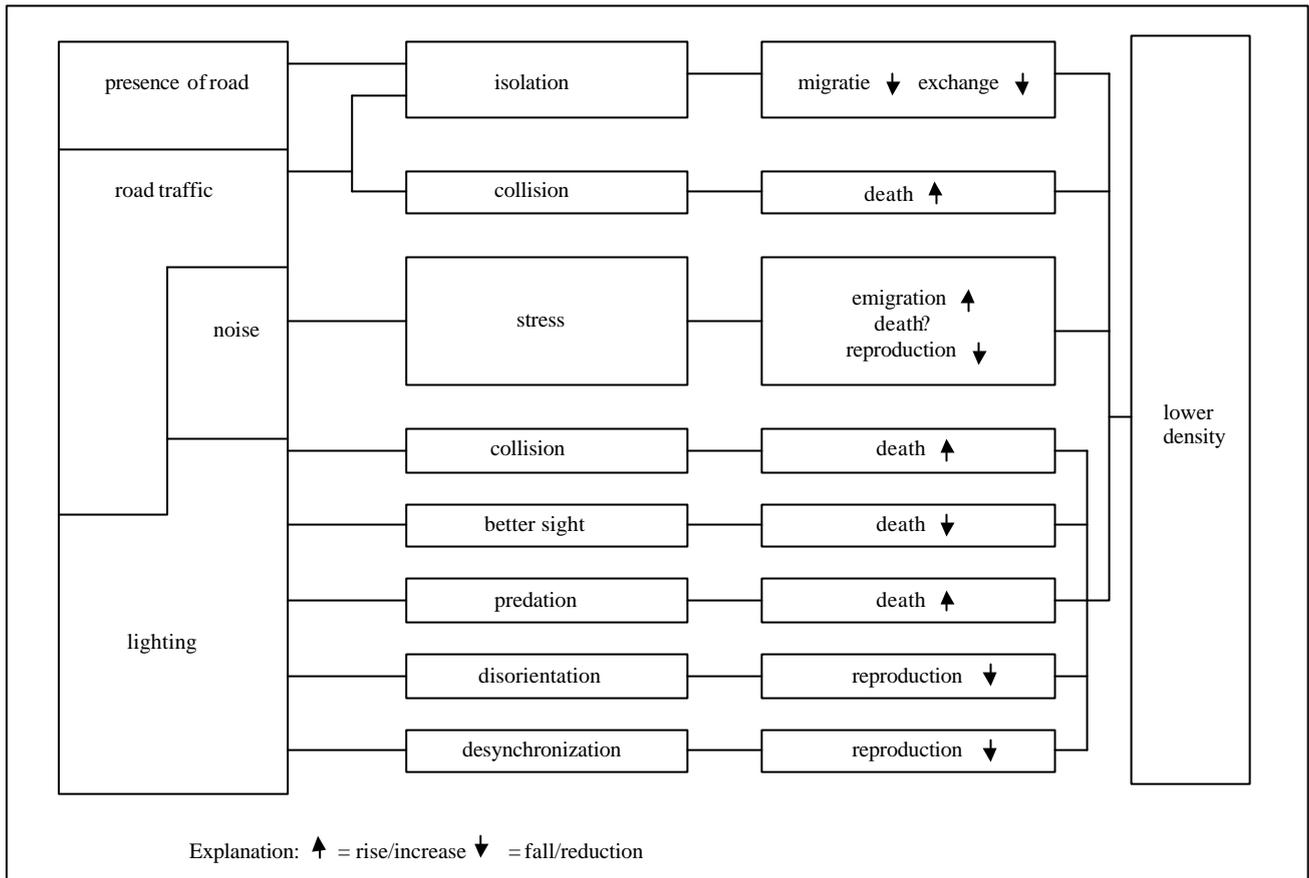


Figure 2 Diagram of hypothetical causal links between, on the one hand, road traffic and street lighting and, on the other, the population densities of birds (source: Mol97a).

lighting could increase the likelihood of predation by attracting predators and improving their orientation while hunting).

The researchers also point out in their conclusions that, owing to the trial set-up of the study, the results only provide an indication. Long-term research could show the degree to which other factors, including site conditions, the use of the site, the black-tailed godwit's loyalty to the location and the natural variation in the size of the population create a distorted impression of the impact of street lighting on the density of the local black-tailed godwit population\*. The occurrence of habituation can also then be studied as can the occurrence of restoration once the lighting has been disconnected.

\* The negative impact of the road may differ from year to year because it may be offset by other factors. Densities may fluctuate considerably as a result of population size: as population size increases, more birds will take up residence in lower-quality areas (see also Reij95).

An important question concerns the degree to which the decline in the local community has consequences for the total black-tailed godwit population in the Netherlands. Reijnen says that a reduction in the quality of the roadside breeding areas of grassland birds will have a detrimental effect on the size and permanency of the grassland bird populations (Reij95). If all of a local population inhabits a disturbed zone, the population is very likely to disappear. High-quality areas that have been disturbed can also no longer serve as a source for populating low-quality areas. This means the numbers in low-quality areas will also decline. Assuming increasing traffic volumes in the west of the Netherlands, Reijnen calculated that road traffic alone will have made 23 percent of grassland areas unsuitable as a breeding area for grassland birds by 2010, owing to noise and possibly lighting. In the case of the black-tailed godwit, this would represent a loss of approximately 3200 breeding pairs (16 percent of the total of 20,000 breeding pairs estimated to exist in the period from 1979 to 1987 in the west of the Netherlands). SOVON (Collaborative Organizations for Bird Research in the Netherlands) has now discovered that the number of black-tailed godwit breeding pairs in the Netherlands has fallen from 87,000 to 58,000 (Teu00). There is a lot of concern about this because a large part of the Western European population breeds in the Netherlands. SOVON researchers assume that changes in grassland management and use are the main reason for the decline. It is difficult to quantify how much street lighting and traffic noise separately or in combination contribute to this negative trend.

## Consequences for man

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Generally very little is known about disturbing factors such as lighting, smells or noise in the environment of man in relation to the occurrence of psychological stress and its consequences on health. Research into disturbances of this kind distinguishes between somatic physiological impacts (disease, death), functional impacts (such as disturbed sleep) and nuisance (the subjective experience of a disturbing factor; VROM95). Functional impacts and subjective experience are difficult to separate in the field and they are both therefore classified as a nuisance.

This section briefly examines (possible) impacts on health as a result of evening and nocturnal lighting. This is followed by a summary of the current state of affairs in research into light nuisance. Finally, the section discusses some more general experiential aspects of the environment and how these are affected by lighting. This is not therefore concerned with the immediate environment but with the experiential value or significance of darkness as a 'primordial' quality of nature and the landscape.

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### 4.1 Impact of outdoor lighting on health

Experimental research with laboratory animals that can be used as a model for man, such as rats, has provided a great deal of knowledge about biological rhythms and the effect of light on the neuro-endocrine system. Light has been demonstrated to control the day-night rhythm in the secretion of melatonin, which in turn affects the sleeping-waking rhythm, the movement rhythm and brain activity (see section 3 and

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Mol97a). Disturbances in the day-night rhythm can have clearly noticeable physical and psychological effects, such as jet-lag and the effects of shift work.

As with other mammals, man also has a genetically determined biological clock and even a biological calendar (seasonal rhythm). Research has shown that under isolated, constant conditions, human beings have a day-night rhythm that is comparable with the rhythm of other mammals (Wev79). The rhythm is also adapted to the specific length of day and night in northern regions, for example. The rhythm is also only affected by exposure to high light intensities (over 2000 lux)\*. This finding formed the basis for using light therapy for people suffering from winter depression. However, still little is known about the mechanism that forms the basis for seasonal affective disorders of this kind and the way light therapy works. (For a summary of the research into light therapy, see Wir93). The 24-hour economy will also result in an increase in shift work. It is hoped that experimental research into influences on the biological clock will provide indications for solving problems experienced by workers when disturbances of the day-night rhythm occur (Foundation for research into light and health (Stichting Onderzoek Licht en Gezondheid; Dam99)). Research over the past ten years into human biorhythms has also examined the role of the seasonal rhythm in relation to the physiology, biochemistry and behaviour of man (Asc81, Lac89).

It seems obvious to assume that a disturbance of the day-night rhythm and seasonal rhythm of man would have a detrimental effect, as it does with other mammals. That effect will generally be less severe in man, as man has not followed the normal day-night rhythm since the invention of artificial light. One possible way that artificial light may affect man's health is through stress. Stress occurs if something is at stake that is important at the time for an individual's well-being in terms of important objectives and values (Laz84). An individual may experience stress, and over time an impact on health, from a disturbance of the environment by artificial light during the evening and night, depending on how much the person concerned considers this to be a nuisance (Pijn91). The combined exposure to other stress factors in the environment may increase this indirect effect of artificial lighting.

In research by the municipal health authority into the effect of the assimilation lighting used in greenhouse horticulture on the residents in the greenhouse horticulture area around Venlo, questionnaires were used to survey the impact on health. Residents in the area reported complaints such as anxiety dreams in children, sleep disturbance, depression and feelings of oppression. None of these health complaints could be related to the light from greenhouses (Gri92, Pijn91). No physiological or biological variables were measured in the surrounding residents. Measurements of this kind would provide a

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\* By way of comparison: a sunny day has a light intensity of 100,000 lux; the figure for a heavily overcast day is 1000 lux and office lighting is 400 to 500 lux.

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more objective indication of the occurrence of stress as a result of a disturbance of the day-night rhythm by light from greenhouses.

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## 4.2 Nuisance caused by outdoor lighting

The research into the nuisance caused by outdoor lighting in the evening and at night for surrounding residents focused mainly on the phenomenon of psychological blinding known as discomfort glare. Glare of this kind creates a nuisance or gives a feeling of unease without affecting visual perception (unlike in the case of physical blinding). There are various kinds of visual nuisance for surrounding residents. Not only residents of houses in the immediate vicinity of the outdoor lighting may experience the illumination of their bedrooms or gardens by the outside lighting as a nuisance. Also people out walking may experience any form of outdoor lighting that is perceivable in addition to the natural light as a nuisance (Ber91, Vos95). In both cases, this may concern either a direct view of the source of light (direct light) or diffuse light (glow). The latter phenomenon mainly occurs when there are clouds that diffuse and reflect the light that radiates upward. The nuisance can therefore extend much further than the immediate vicinity.

Researchers at the Dutch organization for Applied Scientific Research (TNO) have examined two uses of outdoor lighting in terms of the nuisance created for surrounding residents, namely assimilation lighting in greenhouse horticulture (Ber91, Vos95) and tennis court lighting (Ber96a). The research into the nuisance caused by assimilation lighting used in greenhouse horticulture was a follow-up study to the research conducted in the greenhouse horticulture area around Venlo (see section 1; Gri92, Pijn91) and concerned ten locations in the west of the Netherlands (391 surrounding residents).\* The physiological effects were not considered in the TNO research. The researchers use statistical analyses as a basis for attempting to discover linear relationships between an objective exposure level and the percentage of people who are annoyed by various types of nuisances. This should make it possible to use the exposure-effect relationships to determine limits for the percentage of people experiencing annoyance. The percentage will have to be worked out in greater detail in the policy. The research into tennis court lighting included 12 residential areas (120 surrounding residents).\*\*

Questionnaires were used to determine the occurrence of nuisance. People were asked about how often they noticed the lighting (directly or the glow), the perceived strength and the annoyance they experienced. The questionnaire also contained questions on various aspects of perception and behaviour. It covered matters like

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\* commissioned by the Ministry of Housing, Spatial Planning and the Environment.

\*\* commissioned by the Environmental Policy Appeals Consultancy (BAMB).

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difficulty getting to sleep, the closing of curtains, being distracted or irritated, sitting in other rooms, comparisons with the nuisance created by other sources of light, the degree of indifference, or even the feeling of safety that the outdoor lighting gave, and so forth.

### Assimilation lighting

Research into annoyance from assimilation lighting shows that the glow above greenhouses that is visible in residential areas causes the most annoyance: around three percent of residents consider the illumination of their homes or gardens as “annoying” to “very annoying”. Two percent consider the direct view of greenhouse lighting from the home as “annoying” to “very annoying”. Around 10 percent of people experience the visible glow around their homes as “annoying” to “very annoying” (Vos95). The degree of annoyance caused by the glow decreased when the night sky was naturally lighter. Around 15 percent of walkers considered the direct view of the greenhouse lighting as “annoying” to “very annoying”.\* It is striking that the percentage of walkers experiencing annoyance is greater than the percentage of people annoyed by the direct view of the greenhouse lighting from their homes. Walkers apparently prefer walking in the dark during the evening. It is also striking that a third of those questioned did not agree with the following statement in the questionnaire: “It doesn’t really bother me that it’s practically no longer ever completely dark here in the evening and at night”. Nevertheless, only three percent would like to submit a complaint.

TNO researchers subscribe to the conclusion from previous German research that the vertical light intensity, the intensity (in lux) of the vertical light incident, provides an objective measure for the exposure (Ass87, Har84).\*\* However, they failed to find a clear relationship between the degree of exposure and the percentage of people annoyed by the various types of light nuisance. It is therefore impossible to derive nuisance limits from the research data.

### Tennis court lighting

Research into the nuisance caused by tennis court lighting showed that zero to ten percent of the surrounding residents considered the illumination of their homes by the outdoor lighting as “annoying” to “very annoying” (depending on the vertical intensity of the light; Ber96a). Between zero and five percent considered the illumination of their

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\* No questions were asked about the nuisance caused by glare while walking.

\*\* The vertical light intensity in the emission points on the outside wall of the houses (determined by measurement or calculation) varied, from 0.003 to 2 lux, depending on the distance to the greenhouse.

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gardens as “annoying” to “very annoying”.\* In contrast to assimilation lighting, the glow visible above tennis courts caused little, if any, annoyance (the light intensity of the glow above greenhouses is approximately a factor of ten greater). The majority of surrounding residents was fairly indifferent to the fact that it was no longer completely dark in the evening. Some people even saw benefits in the presence of a sports field.

TNO researchers concluded from their results that the nuisance limits recommended by an international committee did not need to be adjusted (for recommended nuisance limits see CIE95 and the general guidelines on light nuisance Part 1, limits set by the Committee on Light Nuisance for lighting at sports facilities, NSVV99; see also 5.2).

### Light nuisance and the general population

The aforementioned research only examined specific types of nuisance among a limited group of people in the immediately surrounding residential area. In a random survey conducted in 1993 of around 4000 inhabitants of the Netherlands that were representative of the country’s entire population, people were asked about the nuisance caused by various disturbing environmental factors, which, besides various sources of outdoor lighting, included noise, smells, vibrations and dust/soot/smoke (VROM95). Outdoor lighting proved to be the least annoying factor in comparison with the others; only four percent of the country’s population experience a serious nuisance caused by light. By way of comparison: 40 percent experience a serious nuisance from noise. The main sources of light nuisance are headlights from road traffic (two percent), followed by street lighting and outdoor lighting, which together account for two percent.

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## 4.3 The value of darkness

The above only discusses the specific nuisance experienced in the immediately surrounding residential area. However, outdoor lighting can also be detrimental to the quality of the residential environment in a more general sense. Rather than the effect the lighting has on the immediately surrounding (urban) residential area, this concerns the effect on darkness considered as a quality of nature and the landscape in rural areas. Government usually measures the spatial quality of rural areas according to diversity or the variety in aspects of the landscape and the degree to which the landscape is open (RPD99). In recent decades, increasing urbanization and the construction of the infrastructure has had a marked detrimental effect on diversity and

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\* Lighting generally appears to cause less of a nuisance if the contrast with the background lighting or the surrounding luminosity is less. However, this impression is difficult to investigate in the Netherlands because the surrounding luminosity in and around urban areas does not vary sufficiently.

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the openness of rural areas (see also 2.2). A levelling out has occurred (RPD99). Outdoor lighting increases this effect, not only at night because of the disappearance of the remaining dark areas but also during the day because of the ubiquitous presence of lighting masts in the landscape.

Together with nature conservation organizations, interest groups of (amateur) astronomers are also calling for dark areas to be maintained. They see darkness as an aesthetic and ethical (intrinsic or independent) value or 'primordial' quality of nature and the landscape; darkness should be included as an extra criterion that should be measured by the government as a factor in the spatial quality of the rural area, in addition to or in combination with the criteria of diversity and openness.

### Perception survey

How much value does the Dutch population attach to darkness, not only for its own sake but also for future generations? As mentioned, it emerged from the nuisance survey discussed in 4.2 that evening walkers like to walk in darkness. However, people were not asked for their opinions about the value or significance of darkness in the context of how they perceive and experience nature. That requires a different approach, comparable with a social-psychological survey of how nature and the landscape are perceived in general (including Ber96b, Ber98). Researchers use questionnaires and in-depth interviews to try to determine what the term nature means to people and why they consider nature important (Ber97, Bui98). City-dwellers generally appear to attach greater value to wild 'primordial nature' untouched by man, whereas people living in the countryside and farmers have a greater affinity with 'crocheted' semi-natural agricultural landscapes. The preference of many people for untouched 'primordial nature' suggests that they attach value to retaining darkness as a 'primordial' quality of nature. This was not examined in the aforementioned social-psychological research. However, an obvious proposal would be that the appreciation of primordial nature goes together with the desire for natural experiences, which consist of elements such as sunlight, wind and also darkness.

### Darkness as compensation value

The view that nature is mainly important as a contrast to daily existence is increasingly gaining ground\*. This therefore relates to compensation values such as silence, peace

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\* Research by Bervaes et. al shows that the Dutch population sees the intangible functions or values of nature as by far the most important (more than 81 percent; Ber97). Bervaes and colleagues interpret intangible functions to be the importance of nature for health (35 percent), the important for future generations (25 percent) and the importance of nature as a value in itself, independent of its use to man, i.e. nature's intrinsic value. Moreover, it emerged that many

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and darkness; nature as *counterbalance* to today's hectic society (Bui98). This viewpoint is also an important starting point in the recently published memorandum by the Ministry of Agriculture, Nature Management and Fisheries (LNV00): '*Natuur, Bos en Landschap in de 21ste eeuw*' entitled '*Natuur voor mensen, mensen voor natuur*') (Nature, forest and landscape in the 21st century, entitled Nature for people, people for nature). State Secretary Faber puts this as follows:

"People have an increasing need to seek out natural surroundings as a means of coping with stress. People want to experience restfulness, space, darkness and silence. This appears to be good for a person's well-being and therefore for human functioning."

She refers with this to the results of a questionnaire survey conducted among the population of the Netherlands in 1999 by Intromart consultants, which was commissioned by the Ministry of Agriculture, Nature Management and Fisheries (Ren99). The survey showed that many people consider the natural environment to be the best place to wind down. Within the scope of this, the results are also relevant of empirical research into the positive impact of nature (natural surroundings) on a person's psychological well-being. It emerges, for example, that recreational activities in a natural environment reduce stress and improve psychological recovery and the ability to concentrate. It also emerged that seeing images of nature, such as a view of greenery from a hospital window or seeing photographs of scenes of nature on the wall made patients recover from an operation with less stress or pain (for a summary, see the references to research into the relationship between nature and psychological wellbeing/health, Ulr93). A future sharp increase is expected in participation in activities such as walking and cycling in natural surroundings as an important means of relaxation (Ber97, Won94).

### Emotional or spiritual value

From time immemorial, writers, poets and philosophers have been inspired by the spectacle of the stars and planets. The value and significance they attach to darkness and the 'existential experience' that go together with the experience of that darkness are best expressed by the relevant quotations from their works. See, for example, the poem of Jan Hanlo at the start of this advisory report. Philosopher Bertrand Russell (Rus00) expresses the significance of existential experiences as follows in his explanation of the philosophy of Spinoza:

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people attach importance to the existence of nature and to the knowledge that they can visit places set aside for nature, even if that nature does not play a major role in their daily lives.

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“There are even moments when it can be consoling to consider that human life, with all its woes and troubles, is an infinitely small part of a life in the universe. Such thoughts may not provide sufficient grounds for a religion but, in a world full of suffering, they can be a help in finding a healthy balance and an antidote to the paralysing power of despair.”

Nature also has an important emotional and spiritual value for many ordinary people: the feelings of fascination and reverence associated with natural processes such as birth, growth and death, and the changing seasons play an important role in this. The fact that such experiences of consolation and gratitude, freedom and insignificance are not only reserved for philosophers is clear from the following quotation from the (in-depth interview) research of Buis and Filius (Bui98):

“You can discover your own insignificance in nature. I see that as very important. You’re not in control of everything. You learn to relativise. [...] The sea can be so powerful. Man can’t exert any influence over it. We don’t generally stop to consider that. That’s what I see as the value of nature.”

The aforementioned LNV memorandum expresses the emotional value of darkness as follows:

“[Nature] offers the much-needed space to return to yourself in silence - not just during the day but in the evening too, when the sparkling stars in the night’s sky add an extra dimension to the peace and quiet around you” (LNV00).

### Aesthetic value

The sight of an unspoiled starry sky is also a valuable, intense experience of nature for many people:

“One of the most beautiful and accessible natural experiences that is completely free and for everyone is the sight of the Milky Way, the veil of stars that appears on a clear night behind the brightest stars and planets and that gives the starry sky an awe-inspiring depth.” (Herman Nunnink in VN, December 1999).

The Society for the Preservation of Nature in the Netherlands regrets that a generation is growing up that has never seen the Milky Way (App99, Bui96).

### Value of darkness for astronomy

In the Netherlands, the Milky Way can only still be seen under optimum weather conditions in relatively sparsely populated areas of Friesland, de Achterhoek and in the

middle of the Veluwe region. However, even in the Veluwe region, the background light level is six times higher than in an area with not diffused lighting. The diffused lighting or glow is the light that is radiated upward and then reflected down again after diffusion in the atmosphere. The light radiated upward may come from sources of light but may also be reflected upward by road surfaces and other surfaces, for example. Measurements and photographs show that the brightness of stars seen in the Netherlands has fallen by a factor of 15 over the past decade (Kop00). It is becoming increasingly difficult in the Netherlands for professional and amateur astronomers to make accurate observations, especially when observing objects with low light intensities (Sch97).

## Policy

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### 5.1 Current policy

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#### 5.1.1 *Street lighting: the 'No, unless' policy of the Directorate-General for Public Works and Water Management*

In the Netherlands, the Directorate-General for Public Works and Water Management is responsible for 20 percent of public lighting along national trunk roads outside built-up areas. When installing lighting along national trunk roads, the Directorate-General follows certain directives that have been laid down in the directives for designing motorways and other non-motorway roads (ROA and RONA). The directives examine issues such as the reason for the lighting, the installation criteria, times of lighting, costs and so forth. The most important reason for illuminating roads is to increase road safety. Street lighting facilitates orientation when driving and makes it easier to see traffic situations, so that car driving becomes less tiring. Lighting also increases safety during roadworks. Traffic intensity during the rush hour (for motorways, more than 1500 vehicles per lane per hour; for major roads, more than 2000 vehicles per hour) provides a general indication for installing street lighting.

In 1997, the Directorate-General for Public Works and Water Management drew up a special directive that provided a supplementary procedure for the installation of street lighting in existing and future forest, nature conservation and recreational areas: the Public Lighting in Nature Conservation Areas Directive (CROW97). The directive's starting point is that important reasons are required, primarily from the point

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of view of road safety, before street lighting may be installed on roads that pass through nature conservation areas. This means a careful survey has to be conducted to determine whether the intended improvement in road safety cannot be achieved using other methods. If this is not possible, the lighting has to be designed so that it creates the minimum disturbance. This is achieved by positioning, for example, and the types of lamps and fittings chosen, and possibly a specific switching regime (switching off or dimming the lights at certain times during the night).

The supplementary survey is intended to determine the number of road accidents during darkness, their cause and the anticipated reduction that will be achieved by installing the new lighting. The survey may reveal various visual problems that make driving difficult for road users, such as the existence of a narrow central reserve or narrow lanes, poor drainage, exits, a lot of cross-roads and junctions, pedestrian crossings and so forth. Sometimes, measures other than lighting can be used to solve the problems. A forecast about future roadworks is also required. If it emerges from the results of the more detailed survey that the proposal for lighting in nature conservation areas is necessary, the road manager has to consult with the regional management of the Ministry of Agriculture, Nature Management and Fisheries. The costs of alternatives are also taken into account in the final decision. The energy costs can often be deducted from these costs because most alternatives to conventional lighting generally involve lower energy consumption.

The directive is intended for all the bodies that are concerned with street lighting. This includes not only central government but also provincial and municipal authorities and other road managers (such as water authorities), as well as organizations concerned with nature and the environment and the designers of street lighting installations.

There were problems in the field with the directive's implementation in the Directorate-General for Public Works and Water Management. An evaluation eighteen months after it came into force showed that the directive had only been followed for half of the decisions concerned with the installation of street lighting along national trunk roads. Its implementation has since been improved in the Directorate-General for Public Works and Water Management. The decision to switch to what is known as orientation lighting was taken after research into road safety, conduct and the experience of road users along a number of (sections of) motorways. Research is underway in Utrecht into the right times for switching lighting on and off (now 11:30 p.m. to 6:00 a.m., whereas organizations concerned with nature and the environment call for the 20:00 p.m. to approximately 6:30 a.m.). It was decided on the basis of the directive that no lighting should be installed along some sections of the motorways that run through nature conservation areas, including the A50 and A12, where they cross the Veluwe region, and the A7 in North Holland. It had already been decided before the directive came into

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force that lighting would be installed along the A9 but a switching regime has now been implemented here too.

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### 5.1.2 *Other regulations*

Besides those for street lighting, regulations also exist, or are being prepared, for lighting at sports facilities and for the assimilation lighting used in greenhouse horticulture. There are currently no directives or limits for reducing the annoyance caused by illuminated advertising and floodlighting.

The Catering, Sports and Recreational Establishments Decree, which came into force in 1998, contains regulations with which organizations must comply to protect the environment (Stb98). The regulations are in the form of Orders in Council, which are an extension of the Environmental Management Act that came into force in 1993. Besides light nuisance, they may also concern other environmental aspects (such as wastewater, smells, noise and vibrations, energy and water consumption). Some regulations include formulations relating to the application of the ALARA (As Low As Reasonably Achievable) principle, which is included in the Environmental Management Act.

To combat the light nuisance caused by the fittings around sports fields, the Decree stipulates that the lighting must be switched off between 23:00 p.m. and 7:00 a.m., if no sport is being played or maintenance work is being performed (page 3 of the Decree). Moreover, annoyance to surrounding residents has to be prevented by the positioning of lighting mast and adjustment of the fittings or by reducing the intensity of the light. NSVV, the Committee on Light Nuisance of the Netherlands foundation for lighting, initially focused on lighting at sports facilities. The Committee's first General Directive on Light Nuisance, published in 1999, contained limits for lighting at sports facilities (NSVV99). The limits are based on the TNO research into lighting nuisance described in section 4.3 (Ber96a) and on the recommendations of an international committee (Commission International de l'Eclairage, CIE; CIE95). The size of the limits for light emissions from a lighting installation was made dependent on the surrounding luminosity, or the prevailing intensity of lighting in the surrounding area. A distinction was made between four types of areas: nature conservation areas, rural areas, urban areas and urban areas in combination with industrial areas. The starting point for working out the light nuisance limits was that no more than 10 percent of people should experience a "serious" nuisance (which is analogous with the maximum permissible noise level of road traffic stipulated in the Noise Abatement Act).

Regulations in the form of an Order in Council exist to limit the nuisance caused by the assimilation lighting used in greenhouse horticulture; the lighting has to be switched off once a day for a specified period of at least four hours during the night, and sufficient protection must be in place on the sides and tops to stop emission into the

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surrounding area during that period. In practice, enforcement inspections vary markedly per local authority (Koo00). Exemptions have also been granted for certain crops, owing to problems with humidity and temperature control in covered greenhouses. In spite of existing regulations, nuisance caused by assimilation lighting in greenhouse horticulture has not been sufficiently reduced. The growth in the area covered by greenhouse horticulture (see 2.2) means that the problem will increase.

From the international point of view, increasing attention is being paid to regulations that place general limits on light nuisance. The lack of exposure-effect relationships makes it difficult to establish standards and to achieve international agreement.

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## **5.2 Sticking points and recommendations**

One sticking point is that the implementation of the ‘no, unless’ policy of the Directorate-General for Public Works and Water Management has not been included in the national policy of other ministries, such as the Ministry of Housing, Spatial Planning and the Environment: ‘light pollution’ is not mentioned in memorandums on the spatial planning policy or in memorandums on the environmental policy. There is also no national encouragement policy based on subsidies.

Another sticking point is that it has not been established for exactly which areas the Directorate-General for Public Works and Water Management Directive is applicable. A map of the Netherlands is attached to the directive showing up-to-date details of areas that are potentially susceptible to ‘light nuisance’. This provides an overview of roads through (potential) forest, nature conservation and recreational areas, including existing and scheduled nature conservation areas relating to the Main Ecological Structure, smaller nature conservation areas outside the Main Ecological Structure that are included in regional plans and zoning plans, forests and plantations that come under the Forestry Act, and public recreational facilities. The map is a snapshot of a planning process that is continually changing. For example, central government is also considering improving the spatial relationship between nature conservation areas by creating green corridors (LNV00). This defragmentation policy cannot be effective if roads with lighting intersect corridors of this kind. Rural areas that are still relatively dark also exist outside the indicated forest, nature conservation and recreational areas. These include the eleven restrictive policy areas referred to in section 2.2.

Integrating the ‘no, unless’ policy into central government’s spatial planning policy, within the scope of the forthcoming Fifth Policy Document on Spatial Planning, would provide provincial and municipal authorities with extra encouragement to implement the policy. This could bring a halt to the gradual increase in outdoor lighting in rural areas. For example, it would be possible to consider establishing dark areas analogous with quiet areas. Dividing the Netherlands into different darkness zones is essential for

providing a basis for policy. Zoning of this kind has to be linked to the intended use or function of a particular area. The aforementioned map of the Directorate-General for Public Works and Water Management showing the areas that are susceptible to 'light nuisance' is a good initial step in this direction. The starting point is that the same stringent requirements need not apply to every location. Obviously, the lighting for, say, sports fields outside built-up areas would be subject to more stringent requirements than those applicable to sports fields inside a built-up area, where background lighting level (or the surrounding luminosity) resulting from other human activities is already high. In the latter case, extreme forms of light nuisance experienced by surrounding residents would have to be prevented. The Committee on Light Nuisance, which has the task of establishing limits for the intensity of outdoor lighting, has already made a start on zoning (see also 5.2).

It is important to have subsidy facilities in place to encourage local government bodies to develop a lighting policy that is concerned with keeping dark areas dark. Although the possibilities for providing subsidies are limited, various provinces are taking initiatives. A few years ago, the Province of North Holland started a trial project to examine the possibility of using new lighting techniques for street lighting. This showed that switching to alternative systems in the quiet hours of the night could provide a useful addition to existing, conventional lighting. These new techniques, including *LEDs* (*light emitting diodes*) and certain fibre-optic techniques are mainly intended to mark the course of the road, without unnecessary light emission, thereby creating less of a nuisance to non-road users and animals in nature conservation areas. An added advantage is the low energy consumption and the possibility of connecting to alternative sources of energy, such as solar energy (for a comprehensive description and the results of the research into the use of alternative lighting systems, see the report on a new direction for street lighting ('Nieuwe richting voor wegverlichting') published by the Province of North Holland, Ano99). The Province of Gelderland is also taking the initiative with LED lighting. However, a great deal of experimental research is still required before large-scale use will be feasible.

Other alternatives include the use of reflecting paint and strips as well as reflecting road studs (cat's eyes). Movement detectors in the form of lamps that come on when there is traffic can provide a good alternative to public lighting for pedestrian paths and bicycle paths (RWS98). The switching regime has already been mentioned above, i.e. light switching or dimming depending on the traffic situation. In quiet situations and at night, lights can be dimmed or switched off altogether. Trials using computer-controlled dynamic public lighting (DYNO) of this kind indicate that the conduct of road users is no different from when the light intensity is reduced to 20 percent during good weather conditions and when there is little traffic (RWS98). The efficiency of lighting can also

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be increased by the choice of fittings and the types of lamps used. Examples of this include:

- sheet-glass lighting: a sheet of glass diffuses light less and focuses it more on the road (first used in the Netherlands along the A27; Directorate-General for Public Works and Water Management, North Brabant division)
- low-pressure sodium lamps: these orange-coloured lamps attract fewer insects and bats; they also cause less nuisance to astronomers.

There is a lack of interest in the lighting policy at the municipal level. However, the Municipality of Wageningen recently took the lead and started a pilot project entitled 'Licht in duisternis, openbare verlichting op maat' (light in darkness, made-to-measure public lighting) in co-operation with the organization *Koninklijke Nederlandse Heidemij Vereniging* and the Society for the Preservation of Nature in the Netherlands.

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A Rationale

B Compilation

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## Annexes

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## **Rationale**

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The Health Council of the Netherlands has the statutory duty (Health Act of 1956, revised in 1997) ‘To inform our Ministers and both houses of the States General about the current level of knowledge relating to issues concerning public health’. This duty extends to describing developments that are important for government policy. The present advisory report is intended as such a description.

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## Compilation

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This advisory report was prepared by MMHE van den Berg, secretary to the Health Council of the Netherlands, following consultations with the following experts:

- J Gorter, Vereniging Natuurmonumenten (Society for the Preservation of Nature in the Netherlands)
- DA Schreuder, chairman of the Committee on Light Nuisance of the Netherlands foundation for lighting (Nederlandse Stichting voor Verlichtingskunde (NSVV))
- J Vos, Dutch Organization for Applied Scientific Research (TNO) Technical Human Biology, Soesterberg
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