Purdue University
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# Does Night Lighting Harm Trees?

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Excessive night lighting is now recognized as a form of pollution with the potential for causing damage to some trees. However, effects of supplemental lighting on trees are complex. Understanding tree response depends on the type of lamps used and the spectrum of radiation emitted, the intensity of that radiation, and the role of light in certain biological processes.

## Light Pollution

Prior to widespread use of outdoor electric lighting, the night sky was a stunning view with several thousand stars visible on a clear moonless night. But, with the increase in lighting to provide safety, security, advertisement, and esthetics, light pollution has grown to be a vexing problem. Today, our earth is wrapped in a luminous fog called skyglow caused by artificial lighting reflecting off airborne water droplets and dust particles that obscure much of the heavens from view. As a consequence, 25% of us can no longer see the Milky Way. Much of the artificial light provided is so bright and inefficiently directed that its use has negative effects.

One of the harmful effects of excessive night lighting is the tremendous waste of energy and the environmental damage associated with producing electricity from mining, drilling, refining, combustion, and waste disposal. For example, it is estimated that 30% of the electricity generated for outdoor illumination is simply squandered by being misdirected into the sky. The International Dark-Sky Association estimates this wasted electricity costs $1.5 billion annually and results in 12 million tons of carbon dioxide in its generation. Many roadways and high-traffic areas are so intensely lit that visibility is actually reduced due to glare and poorly shielded fixtures. Another negative impact is that the annual cycles of growth and reproduction in trees controlled by day length can potentially be altered by supplemental night lighting.

## The Electromagnetic Spectrum

To understand the potential effects of night lighting on trees, it is important to be aware of the nature of the wide spectrum of radiant energy to which trees are exposed. The electromagnetic spectrum refers to all the radiant energy that travels in wave form varying in wavelength from a fraction of a nanometer (nm) to kilometers. For convenience, several segments of the electromagnetic spectrum are grouped together (Fig. 1). All segments of this spectrum have important roles in the functioning of our biosphere. For a consideration of the effects of night lighting, it is the visible and infrared segments that are important. Visible light is 380 to 760 nm along the spectrum. This narrow band of radiation is very important because it is the part our eyes detect making vision possible, and it is also essential for photosynthesis and processes that control growth and development of plants. Collectively, the visible wavelengths produce white light,

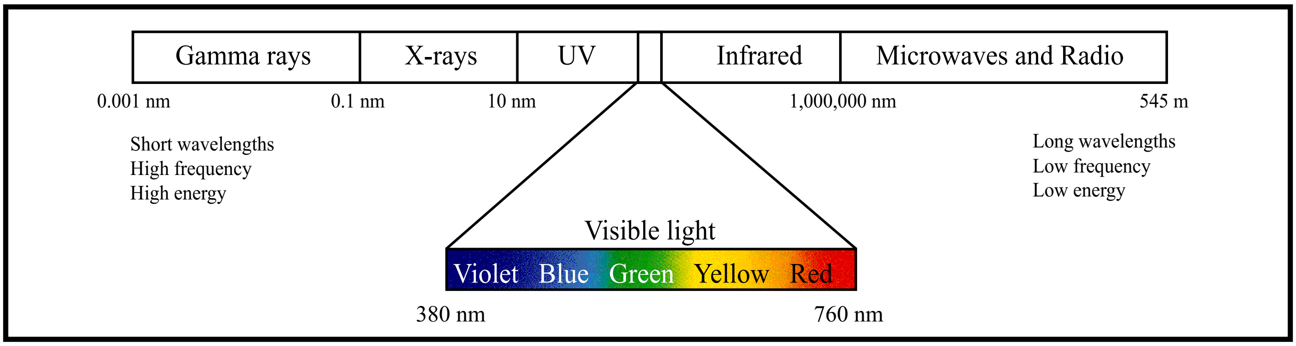


**Figure 1. Electromagnetic spectrum and wavelengths**

but it can be separated into a spectrum of colors. Infrared (760 - 1,000,000 nm) radiation we detect as heat. These are the wavelengths absorbed by increasing levels of so called greenhouse gases in the earth's atmosphere causing air temperature to increase, which results in global warming. Although not visible to our eyes, the infrared wavelengths are as biologically important as the visible part of the electromagnetic spectrum.

## Trees and Electromagnetic Radiation

Trees are dependent for normal growth and development on three aspects of electromagnetic radiation: quality (wavelength or color), intensity (brightness), and duration during a 24 hour period (photoperiod). It doesn't matter to a tree whether the radiation comes from the sun or artificial sources as long as the required wavelength, intensity, and duration are provided. Two important photobiological processes in trees and the wavelengths required are: 1) **Photosynthesis** requiring visible blue (400-450 nm) and red (625-700 nm) and 2) **Photoperiodism** requiring visible red (625-760 nm) and infrared (760-850 nm). The role of light in **photosynthesis** and the conversion of this radiant energy to a chemical form in sugars that trees can use is well known. The role of day length or **photoperiod** in control of vegetative growth and reproductive activities may be less appreciated.

Relatively high light intensity of 1000 microeinsteins per square meter per second ($\mu E/m^2/sec$) is adequate for photosynthesis in most trees (200 $\mu E/m^2/sec$ for shade-adapted trees), but photoperiod responses may be induced with as little as 0.06 to 3 $\mu E/m^2/sec$, only a fraction of that needed for photosynthesis. As a point of reference, indoor lighting sufficient for reading is about 4.6 and full-moon light is about 0.004 $\mu E/m^2/sec$. A 100 watt incandescent bulb provides 5 $\mu E/m^2/sec$ at 5 feet away, and a 150 watt fluorescent cool white bulb provides 17 $\mu E/m^2/sec$ at the same distance.

**Table 1. Sensitivity of woody plants to artificial light**

| High | Intermediate | Low |
|---|---|---|
| *Acer ginnala* (Amur maple) | *Acer nigrum* (Black maple) | *Fagus sylvatica* (European beech) |
| *Acer negundo* (Boxelder) | *Acer palmatum* (Japanese maple) | *Fraxinus americana* (White ash) |
| *Acer platanoides* (Norway maple) | *Acer rubrum* (Red maple) | *Fraxinus nigra* (Black ash) |
| *Betula alleghaniensis* (Yellow birch) | *Acer saccharum* (Sugar maple) | *Fraxinus pennsylvanica* (Green ash) |
| *Betula lenta* (Sweet birch) | *Cercis canadensis* (Redbud) | *Fraxinus quadrangulata* (Blue ash) |
| *Betula nigra* (River birch) | *Cornus sanquinea* (Bloodtwig dogwood) | *Ginkgo biloba* (Ginkgo) |
| *Betula papyrifera* (Paper birch) | *Gleditsia triacanthos* (Honeylocust) | *Ilex opaca* (American holly) |
| *Betula pendula* (European white birch) | *Ostrya virginiana* (Ironwood) | *Liquidamber styraciflua* (Sweetgum) |
| *Betula populifolia* (Gray birch) | *Phellodendron amurense* (Corktree) | *Magnolia grandiflora* (Southern magnolia) |
| *Carpinus caroliniana* (Hornbeam) | *Quercus alba* (White oak) | *Malus sargenti* (Sargent's crabapple) |
| *Catalpa bignonioides* (Southern catalpa) | *Quercus rubra* (Red oak) | *Picea engelmanni* (Engelmann spruce) |
| *Catalpa speciosa* (Northern catalpa) | *Quercus montana* (Rock chestnut oak) | *Picea glauca* (White spruce) |
| *Cornus florida* (Flowering dogwood) | *Quercus stellata* (Post oak) | *Picea glauca densata* (Black Hills spruce) |
| *Cornus sericea* (Redosier dogwood) | *Sophora japonica* (Japanese pagoda tree) | *Picea mariana* (Black spruce) |
| *Fagus grandifolia* (American beech) | *Tilia cordata* (Littleleaf linden) | *Picea pungens* (Colorado blue spruce) |
| *Liriodendron tulipifera* (Tuliptree) | | *Pinus banksiana* (Jack pine) |
| *Platanus hybrida* (London planetree) | | *Pinus flexilis* (Limber pine) |
| *Platanus occidentalis* (Sycamore) | | *Pinus nigra* (Austrian pine) |
| *Populus deltoids* (Cottonwood) | | *Pinus ponderosa* (Ponderosa pine) |
| *Populus tremuloides* (Quaking aspen) | | *Pinus resinosa* (Red pine) |
| *Robinia pseudoacacia* (Black locust) | | *Pinus rigida* (Pitch pine) |
| *Tsuga canadensis* (Hemlock) | | *Pinus strobus* (White pine) |
| *Ulmus americana* (American elm) | | *Pyrus calleryana* (Bradford pear) |
| *Ulmus pumila* (Siberian elm) | | *Quercus palustris* (Pin oak) |
| *Zelkova serrata* (Zelkova) | | *Quercus phellos* (Willow oak) |

*Compiled from Cathey and Campbell (1975) and Hightshoe (1988)*

**Table 2. Wavelength emitted by different types of light sources and their potential effects on photobiological processes in trees**

| Light source | Wavelengths emitted | Potential effect on trees |
|---|---|---|
| Fluorescent | High blue, low red | Low |
| Incandescent | High red and infrared | High |
| Mercury vapor | Violet to blue | Low |
| Metal halide | Green to orange | Low |
| High pressure sodium | High in red to infrared | High |

It has been known since the 1940s that it is the duration of uninterrupted darkness during a 24 hour cycle that governs developmental processes in trees such as dormancy, shoot growth, and flowering. A photo-reversible pigment called phytochome is able to perceive the length of the day and night period depending on whether it absorbs red (625-760 nm) or infrared (760-850 nm) wavelengths of radiation. Even a momentary flash of light during the dark period is sufficient to create the physiological condition induced by a short night or, conversely, a long day.

Trees as well as other plants are classified as short-day, long-day, or day-neutral according to their response to day length. Short-day trees flower and enter dormancy when day length shortens in late summer. Long-day trees flower in early summer and continue vegetative growth until days shorten in the fall. Day-neutral trees are not affected by day length at all. Photoperiod can also influence leaf shape; surface hairiness (pubescence); pigment formation; autumn drop time; and root development, as well as onset and breaking of bud dormancy. Some types of night lighting can alter the natural photoperiod and, consequently, upset these developmental processes.

## Effect of Night Lighting on Trees

It should be clear from the above discussion that most night lighting does not have the intensity to affect photosynthesis, but it might affect trees that are sensitive to day length. Artificial lighting, especially from a source that emits in the red to infrared range of the spectrum, extends the day length and can change flowering patterns, and most importantly, promote continued growth thereby preventing trees from developing dormancy that allows them to survive the rigors of winter weather. Young trees, because of greater vigor and tendency to grow longer naturally, are more subject than older mature trees to cold injury as a result of growth prolonged by artificial illumination.

Continuous lighting, which unfortunately is the most common, is potentially even more damaging than lighting that is turned off late in the evening. The foliage of trees grown in continuous lighting may be larger in size and more susceptible to air pollution and water stress during the growing season because the stomatal pores in leaves remain open for longer periods. There is a good deal of variation in the susceptibility of woody plants to artificial lighting (Table 1). Highly sensitive trees should be avoided in areas where high-intensity lighting rich in red and infrared wavelengths is used.

## Spectra Produced by Different Light Sources and Their Effects on Trees

Different light sources have different emission spectra. One type of lamp gives off more light of certain wavelengths (color) than another type of lamp. For example, fluorescent light is high in blue and low in red wavelengths, whereas light from incandescent bulbs is lacking in the blue part of the visible spectrum, but high in red and infrared. Mercury vapor lamps emit principally violet to blue wavelengths, and metal halides emit in the green to orange range. High pressure sodium (HPS) lamps emit high intensities rich in the red and infrared wavelengths (Table 2).

In the early days of street lighting, the lamps used most commonly were either low-intensity incandescent filaments or higher intensity fluorescent, mercury vapor, or metal halide lamps. These light sources, although attractive to insects, had little effect on plants because they emitted predominately the shorter wavelengths of the visible portion of the electromagnetic spectrum, except for incandescent filaments which emit a relatively balanced spectrum of all wavelengths, but at an intensity too low to affect most trees. In the mid-1960s, high pressure sodium (HPS) lamps were developed, which emit considerable high-intensity light in the red and infrared regions. Increased injury to woody plants has been reported since the widespread introduction of this type of artificial lighting.

## What To Do

When artificial lighting is considered essential, mercury vapor, metal halide, or fluorescent lamps should be used in this order of preference. High-pressure sodium lamps should be avoided and even low-intensity incandescent is best excluded due to its high output of infrared and potential impact on some tree species. Fixtures shielded so that all of the light is directed toward the ground onto pedestrians and vehicular traffic and away from plants should be employed to reduce light pollution and harm to trees (Fig. 2). In all cases, up-lighting and shining light over great horizontal distances should be avoided (Fig. 3). Lights should be turned off or dimmed during off-peak hours to avoid continuous lighting of trees, which has the greatest potential for upsetting normal growth patterns. When planting trees where supplemental night lighting already exists, select those with low sensitivity to light (Table 1).

## For More Information

A significant number of private organizations and government agencies exist today with the objective of preserving the night sky by alerting the public to the problems and providing solutions. For more information contact:

**Indiana Council on Outdoor Lighting Education**, Box 17351, Indianapolis, IN 46217, http://home.att.net/~icole

**Illuminating Engineering Society**, 120 Wall Street, Floor 17, New York, N.Y. 10005, http://www.iesna.org

**International Dark-Sky Association**, 3225 N. First Avenue, Tucson, AZ 85719, http://www.darksky.org

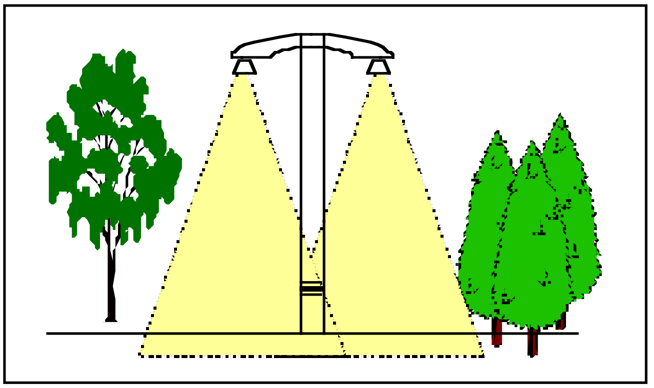

**Figure 2. Best lighting design that with proper choice of lamp type will provide night light and minimize light pollution and effects on trees.**

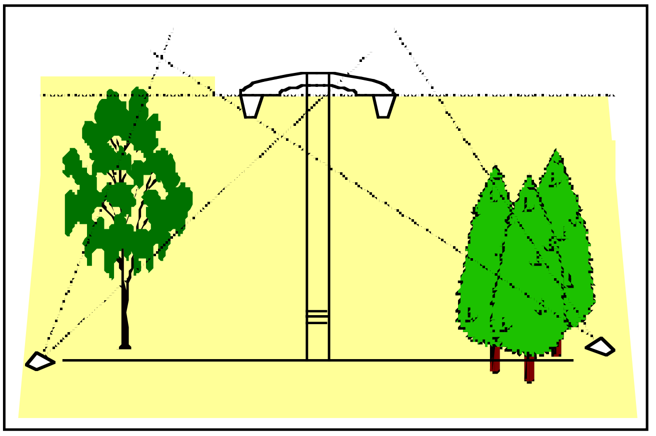

**Figure 3. Poor lighting design using unshielded fixture and upward directed spots. Even with proper selection of lamp type to minimize direct effects on trees, wasteful night sky pollution occurs.**

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