Environment, Wil
LED Illumination

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The emergence of LEDs in street lamps and other exterior lighting can have unpredictable impacts, not just for humans but also for plants and animals. But adjusting the LED spectrum could allow humans and wildlife to share the night.

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As we reported last month (OPN, October 2015, p. 34), the widespread adoption of LEDs in municipal street lighting is having some unpleasant side-effects, as human drivers and residents deal with unexpectedly bright, glaring illumination from these new lamps. Yet evidence is increasing that the move toward LEDs in external illumination, driven by a desire to boost efficiency and lower energy costs, could have unanticipated impacts on wildlife populations, too.

At present, scientists don't completely understand how artificial lighting affects wildlife. Studies so far have shown that both brightness and time of illumination have impacts. But the spectrum is also important, although details remain unclear. And the blue-rich spectra of the LEDs, promoted for high energy efficiency, differ vastly from the more orangish high-pressure sodium lamps that have been used in street lamps for decades. LEDs have an advantage, however, that the sodium lamps don't—their emission spectra can potentially be tuned to minimize harmful impacts on humans and wildlife alike.

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Sea turtle hatchlings look for moonlight reflected from the water to find their way to the ocean and escape predators. Artificial exterior lighting can draw them in the wrong direction. iStock

Blue light and baby turtles

As with humans, a key problem for wildlife is that the standard LEDs used for external lighting peak sharply in the blue part of the spectrum. Animal eyes, like human eyes, contain blue-sensitive receptors that help control biological clocks, and excessive blue light can confuse that sensing system. Citing such issues, the International Dark-Sky Association in 2010 urged "a cautious approach and further research before a widespread change" to blue-rich LEDs. Governments around the world largely ignored those cautions, focusing on the blue LEDs' energy and carbon-emission benefits.

Those decisions could further jeopardize the already compromised life cycle of endangered sea turtles. Millions of years of evolution have programmed turtle hatchlings to scurry toward the ocean before coastal predators can catch them. To make their escape, the hatchlings look for moonlight reflected from the water. But street lights or building illumination, even when the lights are high-pressure sodium bulbs in the orange part of the spectrum, can draw the young turtles in the wrong direction.

The onset of blue-rich LEDs in exterior lights could make matters worse, as their color is close to that of moonlight, and the turtles' photo-orientation response at the 450-nanometer blue peak is 10 times stronger than at 600 nm. Moreover, air scattering is much stronger in the blue, adding to potential distractions for the tiny turtles. Florida now specifies that lights near turtle beaches must contain no wavelengths below 560 nm. "The best technology available for sea turtle friendly lighting is a red or amber LED" emitting directly at the longer wavelengths, according to the Florida Fish and Wildlife Conservation Commission.

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Left to right: Examples of cold LED, warm LED, halogen spotlight, LED neutral-warm, HPS, mercury vapor and metal halide lighting.

Andreas Hänel

The penetration of blue light deep into sea water makes other marine life vulnerable as well. Species that synchronize spawning during full moons, for example, could be fooled by the false moonlight color of LEDs. After finding increases in artificial light in protected marine waters, Kevin Gaston and Thomas Davies of the University of Exeter, U.K., urged creating "Marine Dark Sky Parks" to hold back the light.

Bugs, bats, birds and ecosystems

Concern about these and other potential impacts of blue-rich LEDs has spurred a rapid increase in research. The European Union funded a major study by the Loss of the Night Network (www.cost-lonne.eu), and while that work is still in progress, problems are already emerging. "We know there are clear environmental downsides to increasing the blue proportion of lighting," says Gaston, who directs Exeter's environment and sustainability institute and co-edited a May 2015 theme issue of *Philosophical Transactions of the Royal Society B* on the biological impacts of anthropogenic night lighting. "And I am not aware of any environmental upsides."

On land, street lights affect whole ecosystems. "If night lights affect the flowering of plants, it could affect herbivores and the carnivores that eat them," says Gaston. His group has shown that by changing how a plant flowers, artificial light can also change the population of plant-eating aphids. A cascade of such effects could cause differences among insect communities under street lights and between them, even during the day.

Blue attracts moths and many other insects—a vital part of ecosystems—more than other visible light (which is why people use yellow bug lights to avoid them). Biologists have noted that populations of many large moths in Europe and Britain have dropped 75 percent of more in recent years. They suspect that increases in outdoor lighting attract predators and disrupt insect foraging, breeding, and dispersal. Robin Somers-Yeates and colleagues showed that short-wavelength lights attract owlet or nocturid moths, the largest group of moths and butterflies, and recommend using only long-wavelength lights in ecologically sensitive areas to protect moth populations.

Swarms of insects, in turn, draw light-tolerant nighttime predators such as fast-flying *Pipistrellus* bats, common in urban Europe. "As soon as you put on the lights, you create a snack bar for these bats," says Kamiel Spoelstra of the Netherlands Institute of Ecology, who is testing the long-term effects of LED street lamps of various colors in a forest environment. Few bats hunt

Which color? That depends...

One challenge in minimizing the harmful impacts of exterior lighting on wildlife is that they depend on wavelength and vary among different species. Blue and ultraviolet wavelengths appear to be the most harmful wavelengths, but the study of color is still in its infancy. Here are a few impacts that have emerged in recent studies.

Ultraviolet

- Attracts insects
- Visible to birds and reptiles
- Affects circadian rhythm in animals
- Affects photoperiodism in plants

Blue

- Attracts insects and predators
- Repels slow-flying bats
- Affects circadian rhythm
- Decreases melatonin production
- Can be mistaken for moonlight
- Penetrates water most deeply

near unlit lights, and some hunt near red LED lights, but many hunt near greenish or white LED lamps.

Slow-flying bats, however, don't benefit because they "are hard-wired to be light averse," says Gareth Jones of the University of Bristol, U.K. That's probably because light makes them vulnerable to faster-flying predators. Jones's student Emma Stone found that slow-flying mouse-eared *Myotis* bats, important insect-eaters, won't fly in areas with LED illumination levels as low as 3.6 lux—dark twilight. That fragments their environment and reduces the bats' useful habitat. And that worries ecologists, because North American populations of some light-shy bats such as the little brown bat (*Myotis lucifugus*) have already been devastated by white-nose disease. Those light-shy bats are rare at Spoelstra's research site, so he has not been able to see any effect.

Longcore's ideal would be very low blue to reduce wildlife impact, with only enough blue added to raise color temperature to 2700 K if necessary for good color rendering.

Nocturnal animals also don't like lighting, which Spoelstra says has "a very, very strong effect on mice." The rodents clearly avoid light of all colors, with red having the least effect, presumably because their eyes are least sensitive to red light. Lighting also seems to affect one bird common on the site, he says. "In one year with a very cold spring, great tits started breeding five days earlier in nest boxes close to white or green light" than in those close to red lights.

Other effects are more subtle. Bart Kempenaers' group at the Max Planck Institute for Ornithology found that male songbirds started singing at dawn earlier in the year in areas with street lighting. Females started laying eggs earlier. However, the behaviors were not strongly color-dependent when later tested with colored lights. A separate study by Joop Marquenie of NAM in the Netherlands found that red light attracted migrating birds to land on North Sea oil platforms, and they recommended installing green lights to make the platforms less deadly attractive to the birds. Rachel Muheim of Lund

Green

- Attractive to some amphibians
- Affects some bird migration
- Affects some bird egg laying

Yellow

- Low insect attraction
- Can disrupt night foraging

Red

- Interferes with bird magnetic navigation
- May affect plant photoperiodism
- May affect growth of bird gonads
- Little circadian signaling
- Many animals see poorly at night

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University recently suggested that red light may disable birds' internal magnetic sensors, making them lose direction at night.

A very young field

If the results seem spotty, that reflects the newness of the field. "We are still trying to understand basic effects of intensity, spectrum and photoperiod on animals," says Bryant Buchanan of Utica College. Few experiments have used the latest LEDs. When Buchanan recently began testing LEDs, he was "struck by the very small amount of light necessary to evoke changes in nocturnal activity." So far, most research has come from Europe, which has well-funded national studies and testbeds.

A special challenge for LEDs comes from new studies showing that emission spectrum may be more important than light intensity, says Travis Longcore of the University of Southern California, USA, a pioneer in the field. Current color temperature scales are inadequate to quantify LED spectra, which are far from blackbody curves. He urges avoiding "these very cold white LEDs that are the default for outdoor lighting," because of the harsh impact of their strong blue peak.

Yet Longcore likes LEDs because they can be optimized for the application. His ideal would be very low blue to reduce wildlife impact, with only enough blue added to raise color temperature to 2700 K if necessary for good color rendering. That points to a future for LEDs in customizing street light spectra to balance the needs of humans and wildlife, as well as in changing light intensity in time and space to strike a similar balance. OPN

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