LIGHTS OUT!
FOR NATURE

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Humans have radically transformed the physical characteristics of the nighttime hours in ways that would have been unimaginable only a hundred years ago (*Figure 1*, Longcore and Rich 2004). The cost of industrial development, affluence, and mass consumption has been the loss of natural patterns of darkness over vast expanses of the Earth's surface, both on land and at sea (Cinzano et al. 2001).

Those concerned with the nighttime environment, whether scientists or advocates, regulators or lighting manufacturers, in the private or public sector, together face the challenge of restoring the night sky and natural patterns of light and dark in a global economy. We are motivated by an affinity for the night sky (Mizon 2002), respect for our natural heritage, concern for our own health (Stevens and Rea 2001, Pauley 2004), and a desire to protect the night for the other living beings with which we share the planet.

Astronomers were the first to express concern about the widespread proliferation of artificial night lighting, and they rightfully raised the alarm about the degradation of the night sky (Riegel 1973). Concern about the effects of artificial lighting on wildlife and plants has been a relatively recent phenomenon (Verheijen 1985, Upgren 1996, Outen 1998). This is not to say that scientists were not interested in the effects of light on other species. Naturalist William Beebe was fascinated with the ability of ultraviolet lights to attract juvenile fish, as documented in a sketch from an expedition in 1935 (*Figure 2*). But Beebe's observations were not motivated by concern that lights had widespread ecological consequences.

A substantial and growing body of research on the ecological effects of artificial night lighting is now available (see Rich and Longcore 2006). New scientific articles that extend this knowledge are being published at a steady rate (e.g., Oro et al. 2005, Baker and Richardson 2006, Miller 2006). Sufficient information is now available to devise policies to mitigate and avoid the range of profound, adverse consequences on other

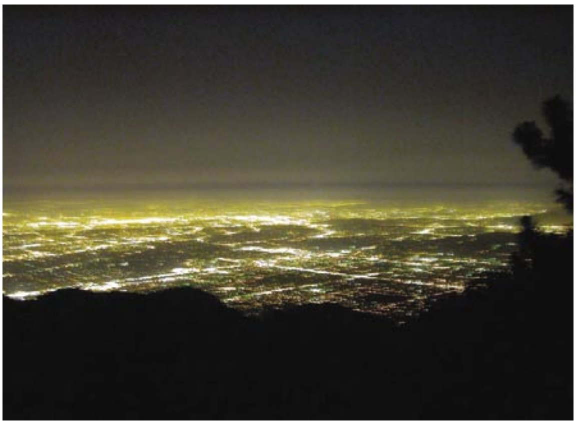

Figure 1. The view of Los Angeles from the Mount Wilson Observatory showing the extent of night lighting.

species caused by artificial light at night.

Urban planners and open space managers can incorporate this knowledge to better protect nature at night. Here we provide examples of three general types of impacts on wildlife: direct mortality, altered reproductive behaviors, and disrupted interactions between species. These examples give an indication of the breadth of this problem and of the opportunities for solutions.

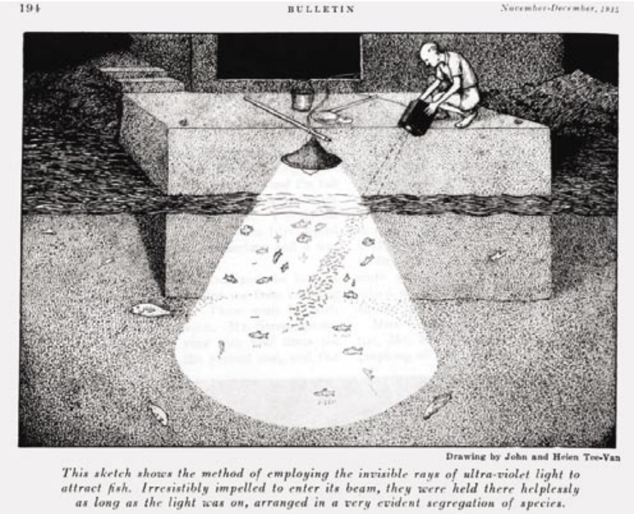

Figure 2. William Beebe shows the attractive effect of different light types on fish on an expedition to Bermuda in 1935. Reprinted from the *Bulletin*, published by the former New York Zoological Society, now known as the Wildlife Conservation Society.

Lights that kill

Anyone with a porch light knows that lights can kill. Many insects are attracted to their deaths at lights; in Germany alone, the estimate of total insect deaths at streetlights in a summer is 100 billion (Eisenbeis 2006).

Migratory birds are attracted to the lights on tall towers when weather conditions are adverse. In North America, an estimated 4–5 million birds are killed per year in collisions with towers, their guy wires, and each other. Most of these are Neotropical migrants, birds that migrate to Central and South America, which are already under severe population stress (Banks 1979, Shire et al. 2000, Longcore et al. 2007). Based on past patterns, we have calculated that two species of federal conservation concern, blackpoll warbler and bay-breasted warbler, suffer losses of over 100,000 individuals each year (Longcore et al. 2007). Over 10,000 individuals of an additional 20 species of conservation concern are killed annually. A change in lighting type would probably eliminate up to 80% of this mortality (Gehring and Kerlinger 2007), and the U.S. Federal Communications Commission is considering such a change based on expert testimony from us, other groups, and the U.S. Fish and Wildlife Service.

Although they are not afforded the same attention as birds, the mortality of insects can be significant. In a study along a forested stream, a single streetlight installed on the bank attracted and killed as many caddisflies as emerged from the stream along an entire 200 meter stretch (Scheibe 1999). This process is described by Professor Gerhard Eisenbeis as the “vacuum cleaner effect,” vividly evoking the image of lights sucking insects out of the surrounding habitat (Eisenbeis 2006).

Beachfront lighting and sky glow threaten the survival of hatchling sea turtles and affect the nest site choice of female turtles (Witherington 1992, Salmon et al. 2000).

Hatchlings are disoriented by lights and fail to make their dash to the ocean and out to sea. This problem was identified first in the 1960s (MacFarlane 1963) and many programs have been put in place to control beachfront lighting (Salmon 2006).

Interference with reproduction

Even when lights do not kill wildlife, they can interrupt important behaviors such as those associated with reproduction. For example, stray light can wash out the visual messages between male and female fireflies (Lloyd 2006).

In a recently published article, two Canadian researchers investigated the effects of intermittent light on the reproductive behavior of northern green frogs (Baker and Richardson 2006). They counted the number of calls by males to attract mates under natural ambient darkness and under the light of a flashlight shined on them. This simulates the effects of a security light on a motion detector or the flash of lights from a passing car. The results show a significant 44% decrease in the number of calls and a 675% increase in the number of moves made by individuals (Baker and Richardson 2006).

Under different circumstances, extra light causes species to expend energy calling at night. In another recent article, current and historic singing records for American robins were used to show that males sing well before dawn only in those locations with high light levels (Miller 2006). Subsequent research on European robins concluded that daytime noise is a more important predictor of nighttime singing, although locations where birds sang at night were on average brighter than areas where birds did not sing at night (Fuller et al. 2007). Our analysis of the data reported by Fuller et al. (2007) suggests a threshold effect where increased illumination allows nocturnal singing in noisy locations; no birds sang at night at any of the darkest 20% of locations, even if the location was noisy during the day.

The effects of lighting can extend to the ocean. Seabirds are attracted to and incinerated at flares at oil platforms, migratory birds are killed running into cruise ships, and lighted squid boats each shine 30,000 Watts into the ocean (Montevecchi 2006). But even sky glow at the level of the full moon could easily disrupt the tightly synchronized spawning of corals. Under normal lunar cycles the release of coral larvae, also known as *planula*, always follows the new moon, presumably to reduce predation on these larvae. This synchronization breaks down in experiments where corals are subjected to perpetual full moon illumination (Jokiel et al. 1985).

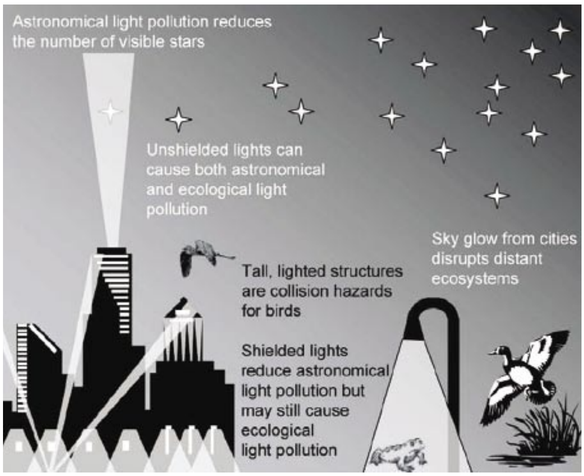

Figure 3. Ecological and astronomical light pollution is caused by lights at night. Figure reprinted from Longcore and Rich (2004).

Predators, prey, and night lights

Lights at night also disrupt ecological interactions. Predator–prey interactions are particularly vulnerable to influence by lighting. In general, additional light benefits the predator, except when the prey are found in groups where individuals warn each other of predators, such as flocks of birds and schools of fish (Longcore and Rich 2004). But examples of lights increasing nocturnal predation are many.

In a study of European storm-petrel nests in caves on an island off the coast of Spain, the birds in the cave illuminated by city lights were killed far more often by gulls than those in the cave facing away from the city (Oro et al. 2005). In addition, bird survival decreased after completion of a major lighting project in the city, declining significantly in the years that followed (Oro et al. 2005). In a separate study of black-vented shearwaters, another seabird, nesting birds were predated far more in the light of the full moon than the dark of the new moon, again by gulls (Keitt et al. 2004).

Young salmon, known as salmon fry, migrate from the streams where they hatch to the ocean. They migrate en masse at night, cued by illumination levels, and this timing is designed to reduce predation. Researchers in the Pacific Northwest documented harbor seals positioning themselves under lights on a bridge to locate and capture the outmigrating fry (Yurk and Trites 2000). When they turned off the lights, predation levels declined at first but then increased as the seals relocated under other lights from the town. They were found eating salmon fry under the lights of a ball field, a sawmill, and other urban glow (Yurk and Trites 2000).

A recent study from Florida showed alteration in the foraging behavior of beach mice under night lighting (Bird et al. 2004). Some species of these small rodents are federally endangered and they are an important part of the coastal dune ecosystem. The research found that beach mice reduced the proportion of bait stations they visited closer to lights. In addition, this pattern was found for both low-pressure sodium vapor lights, which are generally considered to have fewer environmental impacts because they are less attractive to insects, and for yellow "bug lights," which are also promoted as being turtle-friendly and mandated for this reason (Bird et al. 2004). In this example, we see that lights that reduce impacts for one species are not necessarily benign for others.

Nature needs the night

Our question, from this ecological perspective, is whether the international community is up to the challenge of restoring the night. The geographic scope is great, extending throughout the world from urban lights, roadway lights, tower lighting, light-induced fisheries, offshore oil production, and many other sources (Longcore and Rich 2004).

The range of species is also great, extending across all major taxonomic groups and habitats. Any species that evolved with natural patterns of light and dark is potentially susceptible to adverse effects of artificial lighting. Direct glare, sky glow, and steady and intermittent lights from urban to rural environments, both on land and at sea, all alter the nighttime environment, causing both ecological and astronomical light pollution (Longcore and Rich 2004).

Unfortunately, there is no one-size-fits-all solution to mitigate the effects of artificial night lighting on nature. Some species are sensitive to yellow light, others to blue.

As we have seen, turtle-friendly lights still disrupt foraging of endangered beach mice (Bird et al. 2004). Attraction of migratory birds to tall towers can be reduced by using flashing lights (Gauthreaux and Belser 2006), while flashing lights in other contexts would be detrimental. Effective solutions will be place- and habitat-specific, such as a road in Florida where lights that attract turtles were replaced by LED lights embedded in the pavement (*Figure 4*, Salmon 2006).

Our message is simple. Nature needs the night. Substantial progress has been made in understanding the many effects of light on other species and indeed on humans as well. We hope that readers will put this knowledge to work — as researchers, as advocates, as regulators, and as informed citizens.

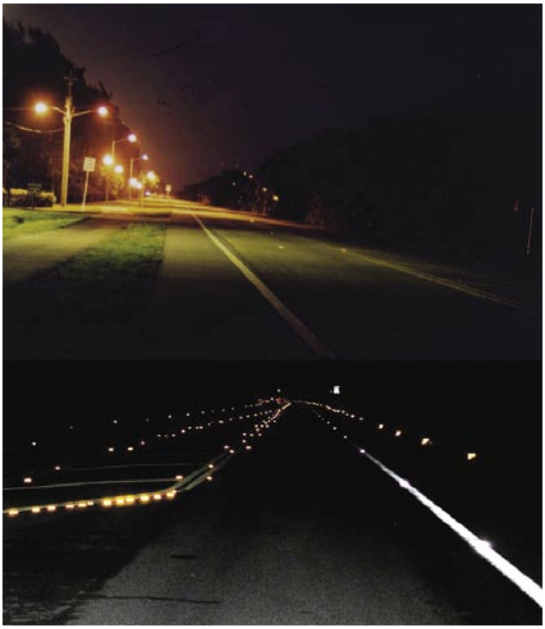

Figure 4. An example of embedded roadway lighting from Boca Raton, Florida. In the top view, the streetlights are visible from the sea turtle nesting beach, while the embedded lights in the lower view are not visible from the beach (Bertolotti and Salmon 2005). Figure reprinted from "Protecting Sea Turtles from Artificial Night Lighting at Florida's Oceanic Beaches" by Michael Salmon. Found in *Ecological Consequences of Artificial Night Lighting* by Catherine Rich and Travis Longcore, eds. Copyright © 2006 Island Press. Reproduced by permission of Island Press, Washington, D.C.

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