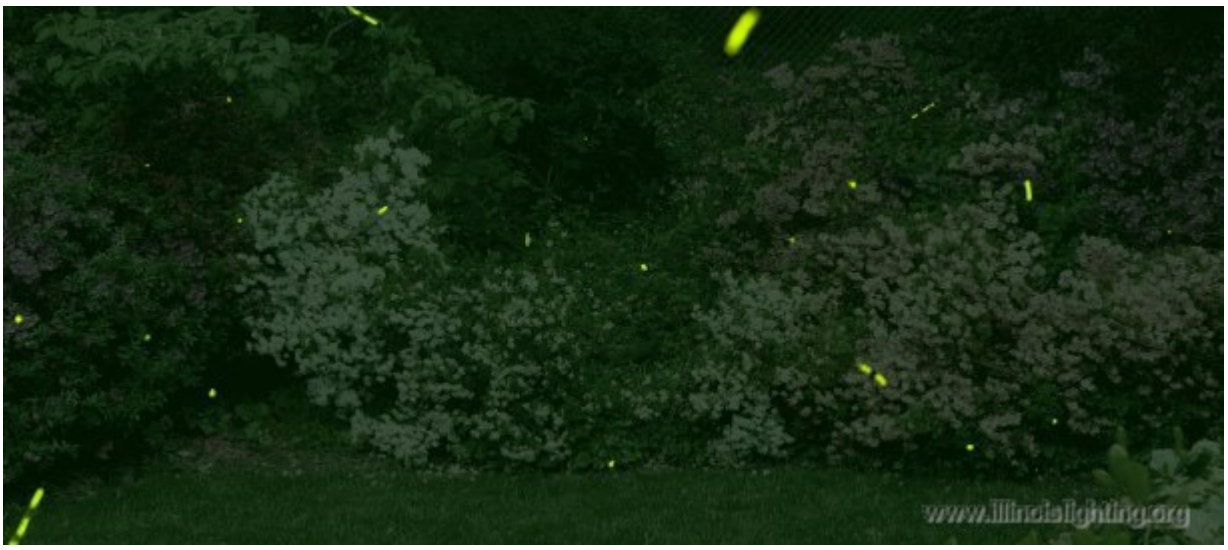
Fireflies and Lightbulbs:
Does Manmade Light Impact Ecosystems?

A reprint of the Illinois Coalition for Responsible Outdoor Lighting website page at http://www.illinoislighting.org/fireflies.html



A number of people have noted to us that they think they're seeing fewer fireflies on summer nights than they used to, and they are interested in whether the steady increase in manmade light pervading their towns is causing harm to the charming little insects. The correlation seems obvious; here we have a family of insects which locate their mates by using a fairly faint light at night, and it makes sense that introducing brighter artificial light into the system could upset that process.

But, can we definitively connect a decline in the number of fireflies[1] with an increase in artificial illumination? This may be easier said than done. To make connections between environmental factors and biological response which "hold water," we need to do some analysis which meets scientific standards, and which provides telling evidence. For example, on our firefly question, we need to determine if their activity and/or populations are changing, examine whether artificial light affects their behavior and/or biology, and examine other factors (besides light) which might be triggering changes. (On that last topic, for instance, fireflies -- which are a family of beetles -- spend the larval part of their lifecycle -- two years out of three, for some Illinois species -- in the soil and leaf mold. During that "grub" stage, they eat slugs and other invertebrates, not grass roots. But the insecticides dumped on lawns to kill other beetle grubs readily kill firefly larvae, too; perhaps that is one reason why lightning bugs are no longer common in some neighborhoods.)

Gathering definitive evidence on the causes of ecological changes is not a simple matter -- but that is by no means saying that it is impossible to achieve a practical understanding of cause and effect. This scientific gathering of evidence can be done in two basic ways: studying living things in their natural ecosystems, and studying them in the lab. The first faces the problem that in the external environment, there is potentially

an almost unlimited number of variables; as in the firefly question we just noted, might the population change be caused by the change in illumination, by a change in pesticide application practice, or by some combination of factors? In the laboratory, on the other hand, we can control most all the variables -- making sure, for instance, that only the nighttime illumination varies -- but then we've taken our organism so far out of its natural environment that we don't know whether, with that paradigm change, altering the selected variable a will generate precisely the same result it would "out in the wild."


Photo courtesy U.S. Nat'l Park Service

Sometimes, practical conclusions can be reached through simple field observation and testing. For example, it had been noted for many years that sea turtle hatchlings[2] on some beaches had started heading inland, rather then into the water, as they emerged at night from nests on sandy beaches (to fatal results). Some observers noted that this effect was most prevalent where there were artificial light installations inland, such as along beachfront roadways; it seemed evident that the hatchlings were being confused by the lights. From that observation, tests were made by shutting off lights, or shielding them so they were not visible from the hatching areas, and that was found to solve the problem. Subsequently, experimentation has shown that sea turtle hatchlings are attracted to light in the blue and green wavelengths which are also prevalent in moonlight and starlight reflecting off the ocean surface; however, the problem of disorientation caused by manmade lights was both demonstrated and solved through simple observation. (Not to imply that thousands of hatchling sea turtles don't still die each year along coastal beaches in the S.E. U.S. each year because of interference from manmade light.)

In other instances, behavioral changes in animals related to the introduction of manmade light into their environment may be evident, but it is less clear as to whether the effects are harmful, benign, or helpful. One such case is with songbirds,[3] which have been documented to begin their "dawn chorus" of singing earlier in areas where manmade light blurs the beginning of natural dawn. Unlike with the sea turtles' hatching, and fairly immediate deaths from dehydration, predation, or being run over by cars when our lights keep them from finding the ocean, the ultimate effects of the behavior changes which our lights are causing on the birds are not immediately obvious. Changes in breeding success and other behaviors may take numerous generations to have blatantly obvious effects on population levels; negative shifts may not be noted until they snowball to a point where it is too late to counteract them.

What is needed is a tremendous amount of new research, studying how manmade light affects living organisms of all phyla. Such research needs to be conducted in both manners noted earlier -- environmental studies carried out in the field, and controlled variable experimentation in the laboratory. We also need to accept the obvious fact that for billions of years, the sun has illuminated the daytime landscapes on our planet, and the only substantial ambient light at night has been provided by the moon and stars; it is only in the last split-second of time that broad landscapes have become illuminated more brightly at night (speaking in geologic time, of the past few decades that have witnessed the explosion in manmade outdoor illumination which we address on other pages of this website). Rather than being illogical to suggest that this manmade environmental change affects organisms and ecosystems, it would be fallacious to hypothesize that most living things wouldn't be affected by such a major alteration to their surroundings.

THREATENED SYSTEMS

In studying how artificial light at night affects organisms and ecosystems, there are several main parameters where light plays a key role, where we can search for cause and effect:

- Photoperiodism on a 24-hour cycle is the backbone of the physiology of many organisms (including humans); internal clocks which regulate numerous biological functions such as growth, metabolism, immune system response, reproduction and more are set by exposure to a cycle of light and dark environment. Amid rising concern that exposure to too much artificial light during the natural dark of night may be causing or exacerbating a host of human diseases,[4] it is important to remember that other animals can fall victim to the same disorders (indeed, many of the telling experiments in this area are conducted on other animal species). Behavior is also, obviously, variable on a light/dark schedule. On a seasonal timetable, the shift in the balance between light and dark hours during the 24-hour periods (seasonal photoperiodism) regulates a wide variety of biological activity in organisms, including sprouting, flowering & fruiting in plants, and mating, migration, and hibernation in animals.

- Avoidance and Attraction are common responses by animals to artificial light at night; the causes for these responses are often not obvious nor well understood. Some species of bats[5] are an example of animals which avoid areas illuminated by artificial light at night. Attraction to artificial light at night is epitomized by flying insects,[6] which die by the billions around streetlights and area lights every summer. While the common idea that night-flying insects mistake artificial lights for the moon, and steer into them by mistake, may hold some truth, we really don't know why many insects are attracted to our lights; for instance, ultraviolet light (common in the output from many streetlamps) is strongly attractive to many species, while the moon's albedo in ultraviolet is low -- there aren't any notable natural sources of ultraviolet light at night. Avoidance or attraction of one species or group can affect a wider ecosystem; if pollinators never get to the plants needing pollinating, or prey cannot be found by predators, misplacing even one species can have broad ecological effects.

- The Lunar Cycle (phase of the moon) has been credited with affecting human health and behavior, but such folk wisdom does not stand up to statistical analysis. On the other hand, many nocturnal animals (including some fish, mammals, insects and other invertebrates) do have behavioral and physiological ties to the changing levels of moonlight at night through the lunar month. Moonlight is faint enough that it is easily swamped out by artificial outdoor lighting; in such situations, the timing cues of the lunar month are lost.

SUMMARY

We cannot with certainty say that manmade lighting is creating an untenable environment for the firefly. Nor can we necessarily make that claim for each of the thousands of other species which share the environment with the firefly; the simple reason being that very little work has been done to study the effects our lighting is having on the natural world around us. But neither can we claim that our light is having no effects, or even just no serious negative effects (on the firefly or any other species); such a claim could only be made from ignorance of the fundamental role which the natural cycle of light and dark plays in the natural world. No naturalist of any stature would understate the importance of the night in every ecosystem; even if we humans tend to sleep at night, the natural world remains as active at night as during daylight. And replacing that night with an artificial twilight most certainly does affect biological processes.

We must also not make the mistake of imagining that the "natural world" is off in a preserve somewhere far away, and that our "manmade space" around our towns and cities is somehow exempt from the laws of nature. "Natural" systems are everywhere; not just including the fireflies (formerly) in our yards, but within our very selves. And the effects from the lights in our towns not only permeate their landscapes, but also carry far, far beyond the town boundaries.

Unfortunately, we are not likely to see a massive program instituted to study nocturnal biology (scotobiology), and identify how manmade light is affecting thousands of different species of living things. So, we are faced with two choices: Pretend that our lighting creates no ecologically damaging effects, or own up that our lighting must be causing ecological effects, and then obey the precautionary principle which says that since some of those effects are likely to cause serious harm, we should act pro-actively now -- even before the last species has undergone rigorous study.

Pro-active solutions wouldn't be to turn out every last light; they would simply be to follow the practices we propose elsewhere on this website: focus outdoor lighting application onto the specific areas where it is needed; use only the minimal amounts needed; illuminate only at times of activity. Pay special attention to the spectral qualities[7] of the light we introduce to the outdoor environment, because light color plays a critical role in determining its environmental effects. At present, we are so distant from achieving any of those practices that the environmental impact of our outdoor lighting is most certainly many times higher than it needs to be. And, as we explain on other pages, the benefits of better lighting practice will go far beyond ecological conservation;

we'll also have safer, more effective lighting for our nocturnal activity, consume far less energy, and regain the stars in our nighttime skies.

[1] Resources on fireflies: Boston Museum of Science Firefly Watch;
https://www.mos.org/fireflywatch/
"Scientists See Fewer Fireflies", *Washington Post*, 2008;
http://www.washingtonpost.com/wp-dyn/content/article/2008/08/30/AR2008083002097.html
"Fireflies", Minnesota Department of Natural Resources;
http://www.dnr.state.mn.us/volunteer/julaug02/fireflies.html
Seasonal Rhythms -- Fireflies, Howard Hughes Medical Institute;
http://www.hhmi.org/biointeractive/clocks/summer/fireflies.html
"Summer flings: firefly courtship, sex, and death". *Natural History* magazine, 2003;
http://findarticles.com/p/articles/mi_m1134/is_6_112/ai_105371466/?tag=content;col1

[2] Resources on sea turtles: "Artificial Lighting and Sea Turtle Hatchling Behavior", Florida Fish and Wildlife Conservation Commission;
http://myfwc.com/research/wildlife/sea-turtles/threats/artificial-lighting/
"Lights Out for Loggerheads", South Carolina Department of Natural Resources;
http://www.dnr.sc.gov/seaturtle/lights.htm
"Coastal Protection of Sea Turtles in Florida", Katherine R. Butler, Florida State University;
http://www.law.fsu.edu/journals/landuse/vol132/butl.htm

[3] Resources on songbirds: "Apparent Effects of Light Pollution on Singing Behavior of American Robins", Mark W. Miller in *The Condor*;
http://www.jstor.org/pss/4123202
"Night Light Pollution Affect Songbirds' Mating Life, Research Suggests", *Science News*, 2010;
http://www.sciencedaily.com/releases/2010/09/100916121322.htm

[4] Resources on human health: "Illuminating the deleterious effects of light at night", Fonken & Nelson, 2011;
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3169904/
"Circadian mechanisms in the regulation of melatonin synthesis: disruption with light at night and the pathophysiological consequences", Reiter, et al., 2011;
http://www.scopemed.org/?mno=2587

[5] Resources on bats: Bats & Lighting Research Project;
http://www.batsandlighting.co.uk/Research%20Areas.html
Bats and Light Pollution (PDF), centroregionalechirotteri.org;
http://www.centroregionalechirotteri.org/download/eurobats/Bats and light pollution.pdf

[6] Resources on insects: "Light Pollution Decimates Insects in the Environment";
http://physics.fau.edu/observatory/lightpol-Insects.html

[7] Resources on light color: "The Color of Lights: More Than Meets the Eye" (this website);
http://www.illinoislighting.org/lightcolor.html