Striking a Balance Between Starry Skies and Urban Illumination

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For countless centuries, people have looked up at the night sky in awe and wonder. However, the starry night skies have been increasingly subsumed by ambient light from cities. Many urban areas across the world are over-illuminated, leaving city dwellers unable to take in the natural day-night pattern of the skies. This disruption is not merely a setback for stargazers; excessive lighting from city streets can have an adverse impact on wildlife and human welfare. Sea turtle hatchlings, which instinctively crawl towards the night sky to reach the safety of the ocean, may be enticed by the stronger glow of nearby streetlights. Artificial lights also steer migratory bird species off course and interfere with their ability to detect ideal conditions for nesting.[1] Overly bright lighting in residential areas can disrupt human sleeping habits as well. These impacts associated with excess lighting show that cities have an important role to play in regulating lighting sources.

Understanding Light Pollution

If cities are to successfully curb light pollution, it is important to understand how light illumination is measured. One basic measure employed when discussing lighting sources is the term lumen. The International Dark Sky Association, a group calling attention to light pollution, defines a lumen accordingly: "[a] unit of luminous flux; the flux emitted within a unit solid angle by a point source with a luminous intensity of one candela."[2] A candela is a unit of measurement for luminous intensity. For the purposes of regulatory enforcement, city governments generally use lumen totals to describe the acceptable range of streetlights and other forms of artificial illumination.

Another term to be mindful of is color temperature, which measures a light source's warmness or coolness. Color temperature range, measured on the Kelvin scale, is based on what a piece of metal would look like if heated to a certain temperature.[3] For example, a lamp with a color temperature of less than 3,200 K would emit a pinkish color and be considered warm. By comparison, a lamp with a temperature greater than 4,000 K would emit a bluish-white light and be considered cool. The concept of color temperatures is important when examining LED lights.

With the arrival of LEDs to the lighting market in the early 2000s, the ability to procure cheap sources of illumination became easier. Traditional incandescent light bulbs provided 10 lumens for every watt of power; by comparison a new LED light bulb can deliver more than 100 lumens per watt. While LEDs are prized for their energy efficiency and longevity compared to older lighting technologies, they bring new challenges. LEDs emit a different type of light than traditional incandescent bulbs, enhancing blues and whites in contrast to incandescents, which enhance reds and yellows. Older streetlights, for example, emit a color temperature of 2,000 K; LEDs, by comparison, emit cooler color temperatures of 3,000 or even 4,000 K.[4] Cool color temperatures that are in the blue or white spectrum are more comparable to regular sunlight; thus, such wavelengths can suppress melatonin at night, interfering with human sleeping patterns. Lights in the white spectrum also increase skyglow much more than comparable illumination levels with a warmer color temperature.

When Tucson, Arizona phased out high-pressure sodium lighting fixtures in favor of LED fixtures, the city reduced its lumen budget from about 480 million lumens to 170 million lumens. This reduction in the city's lumen budget for streetlights effectively compensates for the cooler color temperatures emitted by its LED lights.

Cities may opt to connect new streetlights to a wireless network to control the amount of light from city light fixtures. In Tucson local officials connected 23,000 new streetlights to a wireless network that enables dimming and

also collects data on energy usage.[5] The new streetlights are used at reduced luminosity as a way to limit light pollution. For example, all the lights were dimmed to 90 percent brightness when first installed, and in areas with low nighttime foot traffic the lights are dimmed to 60 percent brightness at midnight or at 3 am in other areas.

Learning Lessons from Flagstaff's Dark Sky Approach

One city at the forefront of using lighting regulations to control light pollution is Flagstaff, Arizona. Flagstaff, which is home to the U.S. Naval Observatory, has a compelling economic interest in ensuring that city lights do not interfere with night sky observation. The city first adopted lighting regulations nearly 60 years ago, and it continues to modify its regulatory approach to address new lighting technologies. Its innovation in lighting regulation and use of dark sky friendly urban illumination earned the city the world's first International Dark Sky City designation in 2001.[6]

Flagstaff's lighting regulations divided the city into lighting zones, with maximum lumens per net acre set for each zone. Three distinct lighting zones are set within the city, and the lumens per net acre range from 10,000 lumens for zone 1 residential properties to 100,000 lumens for zone 3 commercial and industrial properties. To comply with lighting zone standards property owners generally have two options: install lights with low illumination outputs or deploy full or partial shielding on city light sources to ensure that illumination doesn't spill over onto adjacent properties. For external illumination, Flagstaff recommends installing low-pressure sodium lamps or narrow-spectrum amber LED lights.

In highly developed commercial zones, however, more high-powered sources of illumination are needed to advertise, and that is where light shielding becomes more pressing. Lighting ordinances in Flagstaff stipulate that all light fixtures, even security lighting, must be aimed and shielded so that illumination is confined to the property boundaries of the light source. Shielding is an opaque material that blocks or constrains the transmission of light. Shielding may be installed internally within the casing of the light fixture or attached externally to the light fixture. External shields must be painted black to minimize reflectivity. Shields bring more high-powered light sources into compliance and confine light to the area where external illumination is needed.

In addition to having lighting regulations, cities can also help keep urban illumination to a minimum by educating the citizenry on the value of dark skies and providing basic information on how to reduce light pollution. Flagstaff has helped enhance dark sky education by obtaining community buy-in for city projects to reduce light pollution. When Flagstaff was planning on installing new streetlights, local government officials put up test sections of different fixtures, so citizens could see the new lighting options in action and provide feedback. The city's commitment to dark skies is also heavily touted in city marketing campaigns. Around 2019 the city conceived the Flagstaff Lunar Legacy Campaign, which promotes astronomy-based tourism.[7] The city's night skies are prominently displayed on the front cover of the 2020 Flagstaff Visitor Guide and a locally organized Dark Skies Coalition helps organize events centered on stargazing.

Regulating Illumination for the Benefit of Wildlife

Preserving dark skies for astronomy is a primary driver of lighting regulations, but it is not the only one. For coastal cities and counties, one consideration for lighting regulations is the protection of sea turtles that use the shorelines as nesting sites. The problems city lights pose for sea turtles are twofold: nesting females may be confused by bright lights and leave the beach unable to nest, and new turtle hatchlings may mistake city lights for the starry sky and wander into populated areas away from the safety of the ocean.[8] The longer it takes turtle hatchlings to reach the ocean increases the likelihood of hatchlings succumbing to dehydration, predation, and death.

To better understand lighting regulations within this policy context, a good starting point is to review the different ordinances enacted in Florida with its vast shoreline and large number of coastal communities. In Florida, officials there have developed a model lighting ordinance for the purposes of marine turtle protection. The model ordinance is available for download at the Florida Fish and Wildlife Commission website.[9] The website lists the different Florida municipalities and county governments that have adopted sea turtle protection ordinances.

For Mississippi and Alabama, the City of Gulf Shores, Alabama, is a good example of a local coastal community that imposes lighting standards for sea turtle conservation within its zoning ordinances.[10] To start, Gulf Shores designated a Marine Turtle Conservation Zone which includes the beach and all land abutting the beach from the mean high tide line between two highways within city limits. Within that zone, only certain exterior lighting on structures is allowed.

According to the zoning ordinances, the regulations are "intended to protect marine turtle hatchlings from the adverse effects of artificial lighting, to provide overall improvement in nesting habitat degraded by light pollution, and to increase successful nesting activities and production of hatchlings on the beaches located within the Marine Turtle Conservation Zone." Additional restrictions are placed to limit light from within structures. The zoning ordinance requires tinted glass in all windows and glass doors that can be seen from the beach, including structures outside of the Marine Turtle Conservation Zone. The tinted glass is required to limit transmittance value light from inside to outside to 45 percent or less. Street lights, including existing fixtures, must meet three requirements to help turtles:

- The point source of light or any reflected surface of the light fixture is not directly visible from the Beach;
- Areas seaward of the Frontal Dune are not directly or indirectly illuminated; and
- Areas seaward of the Frontal Dune are not cumulatively illuminated.

Artificial light fixtures near, or adjacent to sea turtle nesting habitats should try and conform to three basic management principles: keep it low, keep it long, and keep it shielded. Light fixtures should remain low to the ground to minimize light trespass (where light shines beyond the area it is intended to illuminate) and use long wavelength light sources, such as amber and red light bulbs. It is also strongly recommended that any beachfront illumination use shielding to keep light from shining beyond the area it needs to illuminate. For beachfront properties, many regulations also advise tinting windows to reduce artificial illumination.

An analysis of existing sea turtle lighting ordinances conducted by the University of Florida highlights best management practices for ensuring that sea turtle protection regulation is robust.[11] One best practice is prohibiting direct or indirect illumination in areas seaward of the frontal dune system. A coastal lighting ordinance may also place seasonal restrictions on building bonfires while sea turtles are nesting. Since sea turtle nesting can range from as early as March 1st to as late as October 31st, public education is critical in achieving compliance with local regulations. Many coastal jurisdictions, such as Escambia County, maintain a sea turtle lighting webpage which details the impacts associated with excess lighting and gives basic recommendations to residents on how they can make their home sea turtle friendly. The Florida Fish and Wildlife Commission also has a "wildlife lighting" designation coastal communities can reference that identifies artificial lighting options that will not interfere with coastal wildlife such as sea turtles.

Conclusion

As urban lights have become a hallmark of human settlement, their negative externalities have grown such that they disrupt natural rhythms and cycles. This has negative consequences for animals and for city-dwellers as well. In light of these findings, planners should consider developing regulatory standards aimed at curbing the intensity of light sources. Cities may enact lighting zones, which set different lighting standards for different regions of the city, or provide regulatory guidance on properly shielding light fixtures to minimize their impact. Through a careful application of city lighting regulations and continual monitoring of external lighting innovations, cities will be able to take back the night in some modest measure for local stargazers and animal life.

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Endnotes

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2. International Dark Sky Association, *Glossary* (March 25, 2020).
3. Allen Best, *Dark Skies, Bright Future*, Planning Magazine (May 2017).
4. Scott Johnson, *How Flagstaff, Arizona, switched to LEDs without giving astronomers a headache*, Ars Technica (Oct. 22, 2019).
5. Kelly Presnel, *LED streetlight conversion makes Tucson skies slightly darker, says Dark Sky Association*, tucson.com (July 14, 2018).
6. City of Flagstaff Zoning Code Div. 10-50.7 *Outdoor Lighting Standards* (Feb. 18, 2020).
7. Stacey Wittig, *Dark Skies on the Rise*, Flagstaff Business Journal (March 6, 2020).
8. Escambia County, *Barrier Island Lighting Ordinance* (2016).
9. Fla. Admin. Code Ch. 62B-55 *Model Lighting Ordinance for Marine Turtle Protection*.
10. City of Gulf Shores Zoning Ordinance (Oct. 14, 2019).
11. Nicholas Barshel, et al., *Sea Turtle Friendly Lighting A Model Ordinance for Local Governments & Model Guidelines for Incorporation into Governing Documents of Planned Communities: Condominiums, Cooperatives and Homeowners Associations*, Conservation Clinic, Univ. of Florida Levin College of Law (April 2014).