BUREAU OF LAND MANAGEMENT

Night Sky and Dark Environments: Best Management Practices for Artificial Light at Night on BLM-Managed Lands

Technical Note 457

APRIL 2023

IB2023-038_att1

Suggested citation:

Sullivan, R., N. Glines-Bovio, K.N. Rogers, J.H. McCarty, D. Korzilius, and H. Hartmann. 2023. Night Sky and Dark Environments: Best Management Practices for Artificial Light at Night on BLM-Managed Lands. Tech Note 457. U.S. Department of the Interior, Bureau of Land Management, National Operations Center, Denver, CO.

Production services provided by:

Bureau of Land Management
National Operations Center Information and Publishing Services Section
P.O. Box 25047
Denver, CO 80225

BLM/OC/ST-23/001+8430

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U.S. Department of the Interior
Bureau of Land Management

April 2023

IB2023-038_att1

Acknowledgments

The Bureau of Land Management (BLM) appreciates the many professionals whose comments improved this technical note. This technical note is a product of many different BLM programs and perspectives from field, state, and national levels. It reflects the input of dozens of program staff and many others.

In addition to Argonne National Laboratory, the BLM thanks the following government agencies and nongovernmental organizations for providing extensive review and technical expertise:

- AE Design
- Clanton & Associates, Inc.
- Colorado Department of Transportation
- Colorado Plateau Dark Sky Cooperative
- Colorado State University
- Consortium for Dark Sky Studies at the University of Utah
- Federal Communications Commission
- Institute of the Environment and Sustainability at UCLA (University of California, Los Angeles)
- International Dark-Sky Association
- Kaibab Paiute Tribe
- Leibniz-Institute of Freshwater Ecology and Inland Fisheries
- National Park Service
- Night Sky Metrics LLC
- Sierra Club, Grand Canyon Chapter
- Space Art Travel Bureau
- Stantec
- Starry Skies Lake Superior IDA
- The Nature Conservancy
- University of Utah
- U.S. Fish and Wildlife Service
- U.S. Forest Service

The authors thank Paul Doshkov, Tamara Faust, Joelle Gehring, Ram Hari, David Korzilius, Kristen Lalumiere, P. Evan Myers, Jesse Pluim, Karla Rogers, Greg Shine, Kyle Sullivan, Robert Sullivan, David Walker, Haley Webster, and Bob Wick for providing photos into the public domain for use in this publication. A special thanks goes to those who gave extra effort to acquire photos to illustrate specific concepts in this publication.

List of Acronyms

ADLS........................... aircraft detection lighting system

ALAN .... artificial light at night

BLM .... Bureau of Land Management

BMP .... best management practice

BUG..................................... backlight, uplight, and glare

CCT..................................... correlated color temperature

CRI .... color rendering index

DOE.. Department of Energy

DOI... Department of the Interior

EA .... environmental assessment

EERE................................ Office of Energy Efficiency and Renewable Energy

EIS................................ environmental impact statement

ESPC .... energy savings performance contract

FAA................................ Federal Aviation Administration

FCC.. Federal Communications Commission

FLPMA.. Federal Land Policy and Management Act of 1976

GIS.................................. geographic information system

IDA .... International Dark-Sky Association

IDSP .... International Dark Sky Places

IES................................ Illuminating Engineering Society

K... Kelvin

LCS .... Luminaire Classification System

LED.. light-emitting diode

LZ.. lighting zone

MLO .... Model Lighting Ordinance

M/P .... melanopic/photopic

MSHA .... Mine Safety and Health Administration

NPS .... National Park Service

OSHA............................ Occupational Safety and Health Administration

ROW.. right-of-way

USFS .... U.S. Forest Service

Contents

Abstract

Outdoor lighting at night is considered essential to modern human life. It allows us to safely extend our daytime activities into the night hours. Without proper precautions, the addition of artificial light at night can change the natural night sky conditions and affect scenic, historic, cultural, scientific, recreational, and ecological values that depend on darkness and dark night skies. The mission of the Bureau of Land Management (BLM) is to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations. BLM-managed lands provide differing types of activities, developments, and visitor services that include outdoor lighting where appropriate to provide for worker and visitor safety, security, and enjoyment. Due to growing public concern and research available about light pollution, this technical note provides a set of best practices for outdoor lighting. The information comes from research and practical experience published by industry and other sources and provides knowledge on the relationships between dark night skies and scenic, historic, cultural, scientific, recreational, and ecological values. This technical note provides an easy reference for a variety of ways the BLM can protect night skies and dark environments by reducing or avoiding sources of light pollution from BLM-managed lands to maintain visible clarity of night skies and ensure a healthful dark environment for wildlife and people.

Piper Mountain Wilderness in California.

1. Introduction

1.1 Why Attention to Outdoor Lighting is Important

Outdoor lighting at night is considered essential to modern human life. It allows us to safely extend our daytime activities into the night hours—everything from work activities to high-speed travel to leisure and recreation. Yet outdoor lighting can have many negative consequences if not used responsibly. Outdoor lighting can interfere with our enjoyment of the night sky and negatively impact the many ecological processes that depend on darkness.

Without proper precautions, the addition of **artificial light at night**[1], commonly known as ALAN, can change the natural night sky conditions and affect scenic, historic, cultural, scientific, recreational, and ecological values that depend on darkness and dark night skies.

The mission of the Bureau of Land Management (BLM) is to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations. The BLM is responsible for more land than any other federal agency, approximately 245 million acres

[1] Glossary terms are sometimes highlighted in bold throughout this technical note, and definitions appear in the glossary.

of public lands, predominantly in western states, including Alaska. Throughout the nation, the BLM also administers approximately 710 million acres of subsurface mineral estate. In accordance with the Federal Land Policy and Management Act (FLPMA), the BLM manages public lands for a variety of uses, including, but not limited to, livestock grazing, energy development, wildlife habitat, and outdoor recreation, while conserving natural, cultural, and historic resources. Section 102(a)(8) of FLPMA directs the BLM to manage the public lands "in a manner that will protect the quality of scientific, scenic, historical, ecological…and archeological values...and provide for outdoor recreation and human occupancy and use." BLM-managed public lands are some of the least developed areas in the United States. Exterior lighting is often used on facilities to provide site security, worker and visitor safety, and activity support. Outdoor lighting at night can cause **light pollution**, which is a growing public concern that can be addressed by following lighting best practices.

This technical note provides a collection of **best management practices** (BMPs) to assist decisions about nighttime lighting on BLM-managed lands to reduce contributions to light pollution that impairs the visible clarity of night skies, negatively impacts wildlife, and affects human health and wellbeing. For purposes of this technical note, light pollution is any adverse effect of manmade lighting, such as excessive illumination of the night sky by artificial light. Light pollution is an undesirable consequence of outdoor lighting that includes such effects as skyglow, light trespass, light clutter, over-illumination, and glare. Night skies and dark environments are an important quality of scenic, historic, cultural, scientific, recreational, and ecological values. Applying lighting BMPs minimizes light pollution contributed by public land management activities.

This technical note provides BLM staff, industry, and other stakeholders with proven, effective, and vetted BMPs to provide safe and efficient operations at night while preserving the night sky and dark environments in proximity of BLM-managed lands by limiting light pollution sources. This technical note is intended primarily for use by BLM realty, recreation, minerals, and resource program staff. It can serve as a helpful reference to staff in other agencies, nongovernmental organizations, and others with an interest in night skies and **natural darkness** protection.

The proactive incorporation of artificial light at night BMPs into the planning of federal actions will likely result in a more efficient environmental review process, increase operating efficiency, reduce long-term operating costs, reduce final reclamation needs, and cause minimal impact to the environment. Applying lighting best practices is encouraged on facilities managed by the BLM (e.g., office buildings, fire stations, recreation sites) and facilities that support authorized permitted uses (e.g., wind, solar, and geothermal energy generation; energy transmission; fluid and hardrock mineral extractive activities; communication towers; recreation uses such as camping and hiking). The BMPs are written for easy incorporation into project plans to address lighting issues with specific projects. The BMPs were compiled from a variety of sources, including guidance documents developed by various government agencies and nongovernmental organizations, professional practice literature, consultation with BLM staff and other subject matter experts, and field observation.

This technical note is intended to:

- Improve understanding of night sky and natural darkness values and their importance in the context of BLM land use management activities.
- Improve understanding of outdoor night lighting and how artificial lighting can contribute light pollution that affects a variety of resources found on or near BLM-managed lands.

- Improve outdoor lighting design for land use activities with artificial light to preserve natural night skies and dark environments as a component of providing a quality-built environment on BLM-managed lands.

This technical note is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or equity by a party against the United States, its departments, agencies, instrumentalities or entities, its officers or employees, or any other person.

1.2 How to Use This Technical Note

This technical note is divided into three main parts:

- The first part (Section 2) introduces the subject of night sky and dark environments, in general and within the specific context of BLM-managed public lands. Section 2 further explores the scenic, historic, cultural, scientific, recreational, and ecological values of night skies, as well as the critical role that night skies and natural darkness play in proper ecosystem function, including the health and behavior of plants and animals.
- The second part (Section 3) presents information about the relationship between artificial light and light pollution. Section 3 discusses causes of light pollution, the different types of light pollution, and the mechanisms by which light pollution affects humans, animals, and plants. Section 3 explores various ways that light pollution can affect socioeconomic and environmental resources, including scenic, historic, cultural, scientific, recreational, and ecological resources.
- The third part (Sections 4 and 5) presents general outdoor lighting principles and specific BMPs. Section 4 introduces six principles of outdoor lighting that guide effective lighting design and use. These principles apply to any outdoor lighting scenario. Section 5 presents specific BMPs for lighting a range of facilities that occur on BLM-managed lands. The BMPs are organized into sections that correspond to the six guiding principles of artificial light at night to minimize light pollution, along with a section associated with land use and project planning.

Nighttime recreation in Gold Butte National Monument in Nevada.

When selecting applicable BMPs, consider the purpose and need for the project and the role of outdoor lighting in context with the social and natural elements specific to the site. Also, consider how the context and setting may affect the technical feasibility of BMPs under consideration. Consider outdoor lighting design in the context of other public land qualities, resources, and values as well as operational function. Early and frequent consultation with the developer, other resource specialists, and potentially affected stakeholders helps ensure that artificial light at night BMPs are applied where they are needed, where they are effective, where the costs of implementing them are appropriately weighed against the benefits, and where they do not adversely affect workplace safety or other important environmental resources.

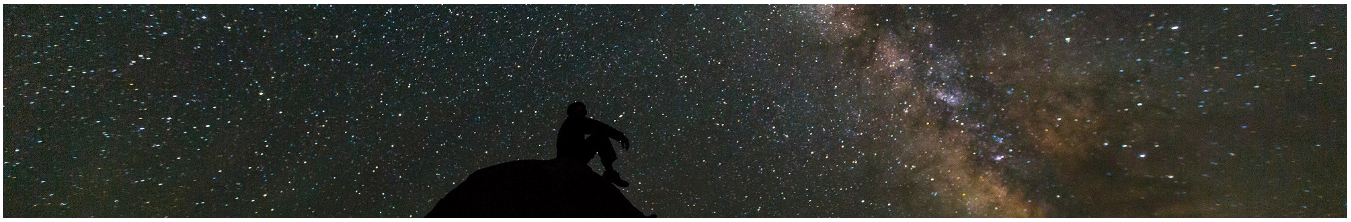
While many of the BMPs are common-sense measures that would apply in nearly every situation, efficient and safe illumination of large facilities is a complex undertaking requiring the expertise of an illuminating engineer or qualified lighting designer. These professionals are trained in the design and installation of lighting equipment and systems for buildings, roadways, and other outdoor lighting applications. Other subject matter experts may need to be consulted in certain situations, such as designing lighting systems in ecologically sensitive areas.

People experiencing the night sky.

2. Night Sky and Darkness Values

Until about 200 years ago, outdoor electrified lighting was essentially nonexistent on a large scale. Human societies developed in very close connection to the night sky and darkness itself, and even well into the 20th century, most humans routinely experienced dark night skies. Viewing the pristinely dark night sky can be a beautiful and emotionally powerful experience (Henderson 2010). While dark night skies and dark environments are important natural resources valued for their aesthetic (scenic) and spiritual qualities, they are also essential to the proper functioning of ecological systems. Life on Earth is adapted to natural cycles of light and darkness, and many plants and animals depend on these cycles for optimal health and even survival (Gaston et al. 2013).

The night sky and darkness are an important element of the natural world and our humanity. As a society, we are only beginning to comprehend the importance of dark night skies and environments. Research is mounting that documents the value dark skies have on topics relevant to public land management, such as culture, heritage, art and aesthetics, history, recreation, tourism, economics, ecological and biological systems, and wildlife (Gallaway 2010; Stone 2018). Taylor Stone illuminates the importance of describing various night sky values: "…by articulating what values we seek to achieve and incorporating them into design requirements and processes, we can help to create nighttime lighting infrastructure that is socially and environmentally acceptable" (Stone 2018).



Experiencing the beauty of the night sky can be an aesthetic or spiritual experience and embodies wilderness values.

This technical note focuses on two types of values—night sky values and darkness values. Night sky values are associated with the ability to view the stars and other celestial objects at night. Certain animals use the stars and other celestial bodies for navigation and other purposes (Foster et al. 2018). Darkness values are associated with naturally dark environments where the only sources of light at night are natural such as the stars, moon, Milky Way, and other celestial phenomena.

2.1 Aesthetic, Spiritual, and Wilderness Values of Night Skies

Contemplation of the night sky is a highly valued pastime. Many people enjoy viewing the stars, planets, Milky Way, meteors, auroras, and other celestial objects. Those who are fortunate enough to see the night sky in a truly dark place, with thousands of stars and the faint ribbon of the Milky Way arcing across the sky, may find it to be an incredibly beautiful sight and a unique and deeply moving aesthetic experience (Bogard 2008; Henderson 2010). Gallaway (2014) suggests that interacting with the night sky can contribute to an individual's happiness.

For many, experiencing the beauty of the night sky is also a spiritual experience that leads to reflections on the vastness of the universe and our place in it. The night inspires a sense of awe and wonder. It has been described as "that most glorious and compelling and inspiring of nature's faces" (Schaaf 1988). Artists, writers, and poets throughout history have been inspired by the night sky's natural beauty, and it has figured prominently in art, music, and literature.

The night sky contributes to a wilderness experience that many people seek when they visit wilderness areas. Seeing a dark night sky filled with stars and unobscured by artificial light at night is seeing part of the world in its natural condition, untouched, free from development, and free from evidence of human society (Duriscoe 2001).

The BLM manages areas with some of the darkest night skies in the United States. Many of these areas are near millions of Americans living in light-polluted areas who do not see dark skies in their daily lives. As a result, BLM-managed public lands are frequently visited by people seeking to enjoy the beauty of the night sky in a natural setting. According to BLM Manual 6220, titled "National Monuments, National Conservation Areas, and Similar Designations," "The BLM will protect the night sky by avoiding light spill or light pollution when designing and installing lighting and facilities within [national] Monuments and NCAs [national conservation areas]."

2.2 Historic and Cultural Values of Night Skies

The dark night sky provides a direct connection to our ancestors. The night sky remains essentially unchanged, allowing current and future generations to experience a shared sense of wonder and mystery with their ancestors. Throughout history, the night sky has been intimately linked to human civilization, shaping the beliefs, traditions, and mythologies of peoples throughout the world (Romano 2002). The natural rhythms of changing day length through the seasons, the monthly cycles of the moon, and the rising and setting of particular stars or constellations throughout the year played critical roles in human events, from timing of planting and harvesting to celebrating religious festivals. Many peoples have elaborate mythologies connected to the stars, Milky Way, and other celestial objects, in some cases linked to creation myths and other religious or philosophical beliefs (Brady 2013). Historically, night skies have played key roles in other human endeavors, such as navigation, the sciences of mathematics, astronomy, physics, astrophysics, and the practice of astrology (Krupp 1984). The knowledge and insights gained through these endeavors have had far-reaching effects on our modern culture and worldview.

Throughout the world, including the lands that would eventually become the Western United States, early inhabitants built monuments, temples, and other important structures to align with celestial bodies or events, such as the summer solstice (Malville 1991). Chaco Culture National Historical Park is famous for its numerous celestially aligned structures and petroglyphs and pictographs that record important astronomical events (NPS 2016a), and it is recognized as an International Dark Sky Park.[2] This recognition shows a commitment by people of today to preserve darkness and star visibility similar to what would have been seen more than a thousand years ago. Efforts like these allow for a continuation of shared human experience across generations and an enhanced understanding of a past time and culture.

In the modern world, many societies enjoy cultural values associated with the night sky. People the world over have woven the night sky into their mythologies and cultural and religious values (Brady 2013). Knowledge of the night sky is important to many aspects of various cultures including storytelling, symbolism, art, architecture, and religious practices. For example, the Kaibab Band of Paiute Indians in Arizona has been designated as an International Dark Sky Community. Roland Maldonado, Kaibab Paiute Tribal Chairperson, stated, "We acknowledge the immense value dark skies bring to our traditions, conservation of wildlife, and to future generations." Kaibab Paiute Tribe Environmental Department Director Daniel Bulletts stated, "The Kaibab Paiute Tribe and its people have depended on the night sky for guidance, cultural awareness and preparedness for life's great journey upon [M]other [E]arth" (IDA 2015).

Astronomical rock art at Chaco Culture National Historical Park.

Glowing cedar bark houses built by local Dumma, Kechayi, and Western Mono tribal members in California in partnership with the San Joaquin River Gorge Special Recreation Management Area. This practice provides a glimpse of the world before artificial light was present.

Poster for the Kaibab Band of Southern Paiute Indians International Night-Sky Nation.

Tyler Nordgren

[2] The International Dark-Sky Association defines an International Dark Sky Park as "a land possessing an exceptional or distinguished quality of starry nights and a nocturnal environment, and that is specifically protected for its scientific, natural, educational, and/or cultural heritage resources, and/or for public enjoyment" (IDA 2018).

Star parties are a popular nighttime recreation activity on BLM-managed lands, such as this one at Amboy Crater in California.

2.3 Recreation Values of Night Skies

High-quality night skies and natural darkness are essential components of a variety of nighttime recreation activities that take place on public lands, including BLM-managed lands. Primary among these activities is astrotourism, a type of tourism that involves travel for the purpose of enjoying the night sky. Each year, thousands of people travel to remote environments—including national parks and BLM-managed lands—to enjoy dark night skies. Many of them attend "star parties," gatherings of amateur astronomers, typically equipped with binoculars and telescopes, where people observe the night sky. Small star parties may be one-night events, but large star parties may last several days, attracting hundreds or thousands of participants. A list of annual star parties in the U.S. and Canada includes more than 100 events, many of which take place in the western states on BLM-managed lands (Danko 2019).

In addition to star parties, many other nighttime recreation activities take place on public lands, including night sky interpretive programs, backcountry recreation experiences (e.g., wilderness backpacking), camping and campfire events, night skiing and snowshoeing, night sky photography, nighttime wildlife viewing (e.g., owling), nighttime viewing of cultural and historical resources, viewing the aurora borealis and other natural night sky events, and festivals and special events (Smith and Hallo 2013). Many of these experiences, which depend on or are enhanced by high-quality night skies and natural darkness, have important economic and social benefits in addition to recreational benefits.

Stargazing at the Alabama Hills National Scenic Area in California.

Camping under the stars at Alabama Hills National Scenic Area in California.

2.4 Astronomical and Scientific Values of Night Skies

KPNO/NOIRLab/NSF/AURA/R.T. Sparks

Night sky over Kitt Peak National Observatory located outside Tucson, Arizona.

More than 2,000 public and private astronomical observatories are in the U.S. and Canada, including many in the western states on BLM-managed lands (Danko 2019). Professional and amateur astronomers value dark night skies for clear views of faint astronomical objects, such as distant nebulae and galaxies (Crawford 2000). The ability to see faint astronomical objects is decreasing with the general brightening of the sky, also known as skyglow (see Section 3.1 to learn more about light pollution).

Astronomers also need skies free from light pollution for spectroscopy, the study of the spectra (light signature) of light emitting bodies, in this case celestial bodies. Spectroscopy is used to derive the chemical composition, distance, temperature, and many other properties of stars and galaxies. Particular types of lights (e.g., certain LED sources) emit wavelengths of light that mask spectral information from celestial bodies (Kornreich 2015).

Dark night skies are so important for astronomy that professional observatories are typically built on remote mountaintops and islands to avoid impacts from light pollution (Henderson 2010; Luginbuhl et al. 2009). For the same reason, many amateur astronomers routinely travel hundreds or even thousands of miles to experience pristinely dark night skies.

2.5 Biological Values of Natural Darkness and Night Skies

More than 60 percent of invertebrate and one third of vertebrate animals are not **diurnal** (primarily active during the day) (Hölker et al. 2010). These organisms are **crepuscular** (primarily active at twilight), **nocturnal** (primarily active at night), or both. Through evolutionary processes, these animals have adapted their physiology and behavior to function under low or extremely low light conditions, bats being an obvious example. Many animal species rely on natural cycles of daylight and darkness to trigger and regulate behaviors such as hunting, hiding from predators, mating, nesting, navigating, and communicating.

Many animals are active at night and dusk, such as this northern spotted owl.

Regardless of whether they are diurnal, crepuscular, or nocturnal, most animals are highly dependent on light for vision and for regulation of physiological processes and behaviors critical for survival. Natural cycles of daylight and darkness are essential to the health of most animals, including humans. Plants also depend on natural light cycles to regulate physiological processes such as flowering, leaf senescence, and growth form (Bennie et al. 2016).

2.6 Night Sky and Darkness Values in Relation to BLM-Managed Lands

The darkest skies in the U.S. are in western states and associated with BLM-managed public lands. Figure 1 shows maps of artificial night sky brightness derived from Falchi et al. 2016. Black areas on the maps have the least artificial light and the darkest skies, which makes sense, given the relatively few people and general lack of industrial development on western federal public lands. Find detailed state-level maps of the Western U.S. here: https://cires.colorado.edu/Artificial-light.

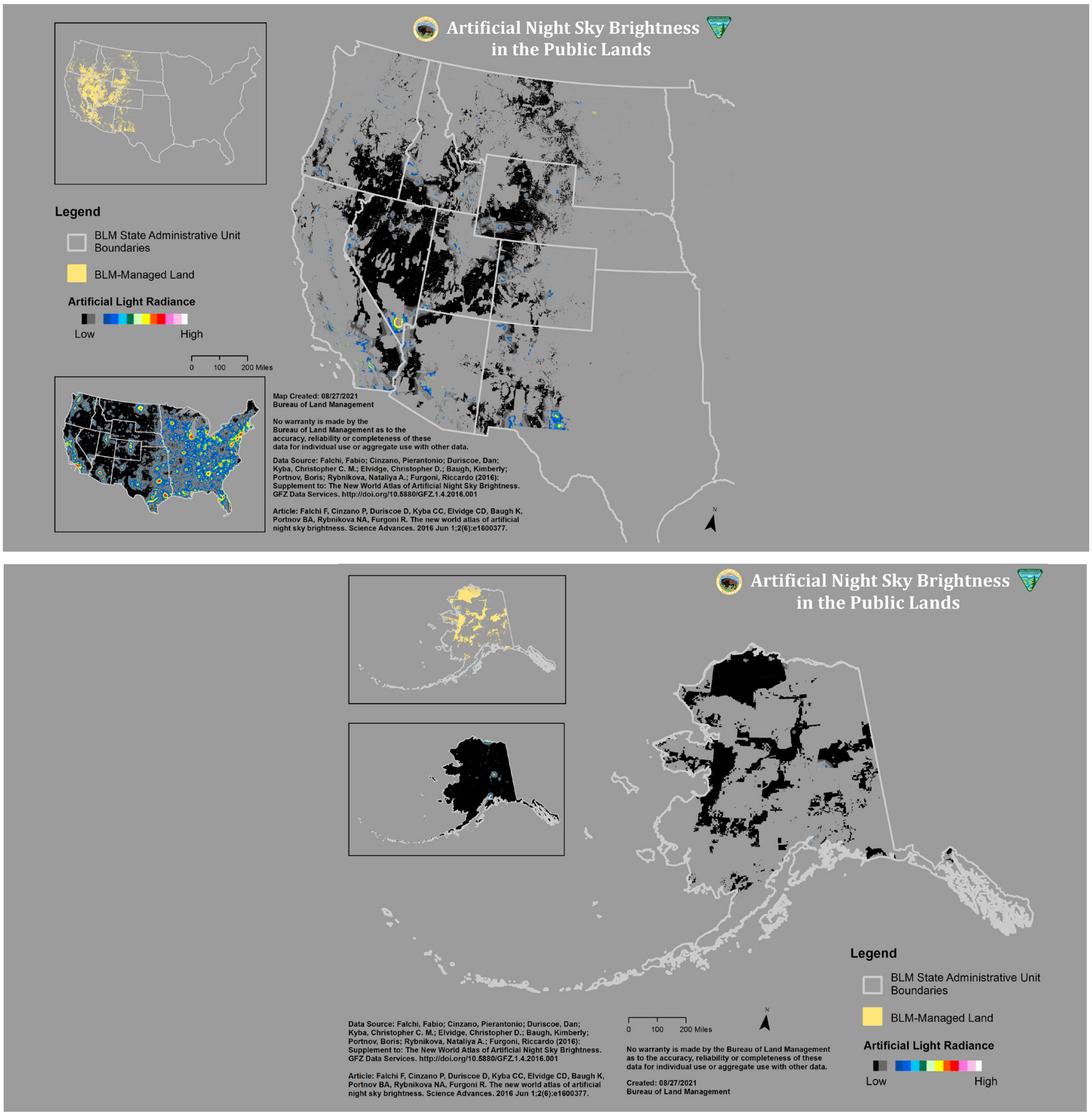


Figure 1. Artificial night sky brightness over BLM-managed surface lands.

Recreation, Wilderness, Cultural, and Education Values

BLM-managed lands are an important resource for nighttime recreational and educational activities. Several BLM visitor areas offer staff-led night sky programs (Mimiaga 2017). Night sky resources on BLM lands provide opportunities for aesthetic, spiritual, wilderness, religious, and cultural experiences. Astrotourism is an important recreation activity that brings important economic benefits to nearby communities (see Section 3.3.6 for discussion of economic effects of light pollution). Regardless of whether these activities occur on BLM-managed lands or other lands, the vast, generally undeveloped public lands are preserving dark skies throughout much of the Western U.S. to the benefit of many federal, state, or regional locations, including communities that are international destinations for astrotourism and other nighttime recreation.

Winter campers view the northern lights at Caribou Bluff in the White Mountains National Recreation Area in Alaska.

The Canyons of the Ancients National Monument in Colorado has regular, well-attended night sky programs.

Ecological Value

BLM-managed lands provide important ecological functions, including habitat and migratory pathways, for thousands of species of animals, some threatened and endangered. Many of these animal species are crepuscular (primarily active at twilight) or nocturnal (primarily active at night) and rely on the abundant and undisturbed naturally dark environments found on BLM-managed lands. BLM-managed lands also have many rare plants, some of which rely on the length of the night to determine proper season for budding, flowering, and other life cycle activities. These plants may also rely on nocturnal insect, bat, and bird pollination (Bennie et al. 2016; Knop et al. 2017).

The bobcat, mountain lion, and great gray owl are crepuscular and nocturnal animals found on BLM-managed lands.

Electrical substation on BLM-managed lands in Eldorado Valley in Nevada. Skyglow in the background is from the city of Las Vegas.

3. Light Pollution: Exposure Mechanisms and Effects

Natural darkness once made it unsafe or impractical to continue activities into the night. With electricity, artificial light at night is widely used for a variety of purposes (Ekirch 2005). Providing light into the dark hours does benefit society, yet there is also a cost of **light pollution** with inefficient exterior light design. This section defines artificial light and language to describe light. The discussion then turns to light pollution, sources of light pollution, and ways it can affect human, animal, and plant ecology and wellbeing. Through awareness raised by organizations such as the International Dark-Sky Association (IDA)[3], the National Park Service, university programs, and private industry, it is known that light pollution from artificial light at night affects humans, animals, and plants in a variety of ways.

[3] The IDA is a leading global nonprofit organization with the mission “to preserve and protect the nighttime environment and our heritage of dark skies through environmentally responsible outdoor lighting” (IDA 2018a).

3.1 Basics of Light and Light Pollution

Light pollution happens when the night sky is brightened from the use of artificial lights so that stars and other celestial objects are washed out from view. It can affect natural ecological systems dependent on patterns of light and dark (Longcore and Rich 2004; Cinzano 2001). Not all lighting that is installed for night activities causes light pollution. Light pollution generally refers to excessive, misdirected, or intrusive outdoor light sources such that it causes adverse effects (Henderson 2010).

Longcore and Rich (2004) make a distinction between **astronomical light pollution** and **ecological light pollution**. Astronomical light pollution affects the visibility of astronomical objects in the night sky. The negative effects of astronomical light pollution are often referred to as **night sky impacts** or effects. Night sky impacts primarily (but not exclusively) affect human values and activities, such as aesthetic values, cultural values, economic values, nighttime recreation, and astrotourism.

The loss of natural darkness caused by light pollution is often referred to as ecological light pollution, because it primarily affects the health and functioning of ecosystems, which are biological communities of interacting organisms and their physical environment. Ecological light pollution can have a variety of negative effects on health and behavior of individual organisms (including humans), the interactions between organisms, such as predator-prey relationships, and reproductive behavior.

Light pollution from a manufacturing plant near Salt Lake City, Utah, illuminates the adjacent hillside (light trespass), altering the natural dark environment. This may affect ecological health and function.

Note that the terms astronomical light pollution and ecological light pollution should not be interpreted too narrowly. Night sky effects can apply to ecological resources, and loss of natural darkness can negatively affect human values. For example, loss of visibility of the night sky can negatively affect certain birds and insects that use the stars for navigation. Moreover, humans value natural darkness for reasons beyond its benefits to human health.

The following section provides basic information about light qualities, how they are measured, and types of light pollution. This information is useful to introduce the artificial light at night principles (Section 4) and lighting BMPs on BLM-managed lands (Section 5).

3.1.1 Light Qualities

The qualities of light that influence visibility are based on the following factors:

- Light intensity
- Physical form, direction, and dissemination of light
- Color of light

Light Intensity

Light intensity is the amount of light falling on a surface. The more intense the light source, the more light falls on an object. **Illuminance** is measured by a light meter (corrected for the curve of the human eye) in footcandles (square foot) or **lux** (square meter) (Green Business Light UK 2021). The **lumen** is a measure of the total amount of light produced by a light source. Differences in light intensity are perceived by people as a change in brightness.

Physical Form, Direction, and Dissemination of Light

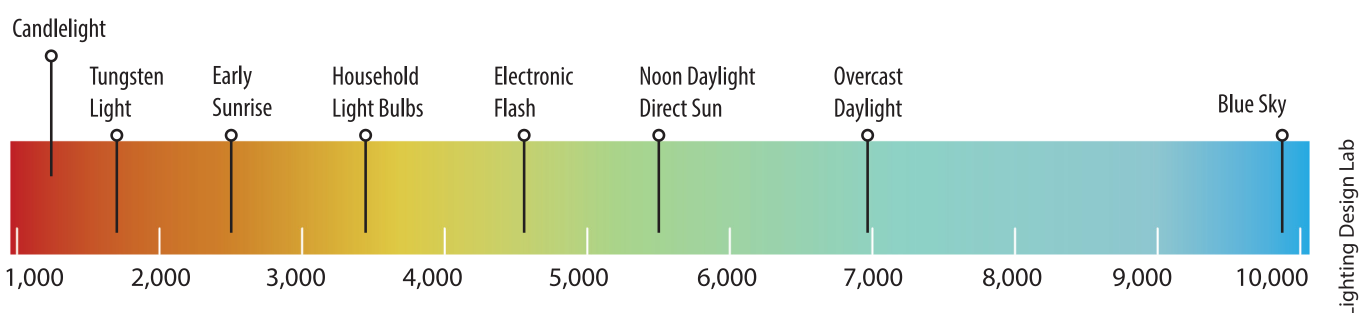
Light broadcasts across surfaces of objects and moves through space to the eye where it is translated into a sense of form, location, movement, and appearance. Light allows the eye to identify an object in terms of its shape, scale, proportion, and position. Lighting from multiple directions, angles, and colors can be duplicative, causing reflectivity, glare, and shadows that may impact visibility.

Different types of lighting may influence how an object and its features are seen within a specific setting or from various distances. The direction of the light may influence what can be seen by illuminating a narrow or wide expanse of an object

Color of Light

All light has color, containing primary colors within the color spectrum. Primary colors of light are red, green, and blue. Primary colors of light should not be confused with the primary colors of pigments, which are red, yellow, and blue. The three primary colors of light can combine to produce any other color, including white. The secondary colors of light are formed when any two primary colors combine. The three secondary colors are magenta (red and blue), yellow (red and green), and cyan (blue and green). The human eye is more sensitive to yellow-green gradients of the visual spectrum (about 550 nanometers) than it is to red or blue at the ends of the spectrum.

The appearance of color from a light bulb is commonly described using the Kelvin (K) temperature scale. The color of the glow/light emitted at different temperatures are the basis for the standard Kelvin color temperature scale. Colors at lower temperatures are warmer (red, orange, yellow); white is a midrange temperature; and colors at higher temperatures are cool (blues, violet, ultraviolet) (NIST 2021). Studies show that artificial light at higher color temperatures (> 3,000 K) interferes with normal biological rhythms (Lin et al. 2019).

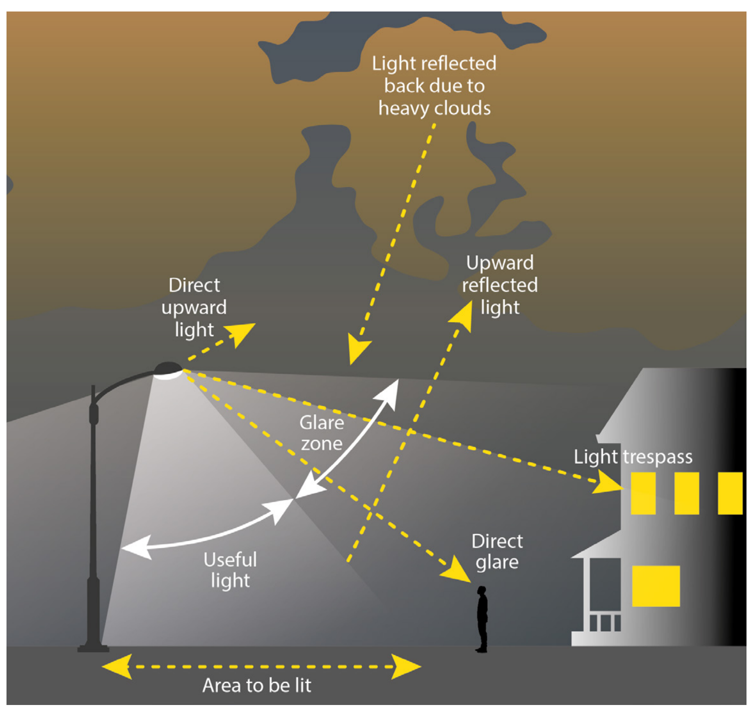


Color temperature scale.

3.1.2 Types of Light Pollution

There are different types of light pollution, and each type is associated with different effects:

- **Glare:** Excessive brightness that causes visual discomfort or visual impairment.
- **Skyglow:** Overall brightening of the night sky caused by atmospheric reflection of outdoor lighting and other causes.
- **Light trespass:** Light falling where it is not intended or needed.
- **Light clutter:** Bright, confusing, and excessive groupings of light sources.
- **Over-illumination:** Lighting intensity higher than that which is appropriate for a specific activity.



Visual description of glare, light trespass, and skyglow.

Glare

Glare is a visual condition where there is an inappropriate distribution of light creating excessive **contrast** that compromises the ability to distinguish details and objects (Vos et al. 2002). Glare is often perceived as excessive brightness. The perception of glare depends on the level of light/dark adaption of the viewer. Light/dark adaptation is the process of eyesight adjusting to the ambient light level. If a viewer is in a dark environment and their eyes are fully adapted to the darkness, even a relatively dim light may be perceived as glare, while that same light would cause no discomfort in a brightly lit environment in which the viewer's eyes are adapted to higher light levels. The sensitivity to glare varies between individuals, with older people typically being more sensitive. Disability glare refers to reduction in visibility caused by intense light sources in the field of view, while discomfort glare is the sensation of annoyance or even pain induced by viewing an overly bright light source (Rea 2000).

Glare is possible during the day or night. In the daytime, glare is most common as the reflection of sunlight off smooth surfaces, such as car windows, metallic roofs, or lakes. At night, natural light sources are generally too faint to cause glare. Rather, nighttime glare sources include direct views of bright artificial light sources, such as car headlights, or their reflections off specular surfaces, such as wet pavement. On BLM-managed lands, nighttime sources of glare may also include unshielded lighting at energy and other facilities.

Jesse Bower

Glare from direct view of light sources and reflection from wet pavement.

Skyglow

Skyglow (or sky glow) is the brightening of the night sky that results from light pollution. Skyglow is caused by light directed or reflected upwards or sideways and reduces the visibility of stars and other celestial objects. Sky brightness has both natural and human causes. Natural components of sky brightness include moonlight, airglow, zodiacal light, integrated starlight (unresolved stars in the Milky Way galaxy), and diffuse galactic light (starlight reflected by interstellar dust) (Duriscoe 2013). Artificial light shining upward into the night sky or reflecting off surfaces is scattered by dust particles and gas molecules in the atmosphere, producing a luminous glow often with an orange or whitish cast.

Skyglow is more visible in poor weather conditions and polluted skies because there are more particles in the atmosphere to scatter light. The effects of skyglow on dark night skies are greater for blue-rich light sources than for yellow-rich light sources (Luginbuhl et al. 2014). A technical memorandum by the Illuminating Engineering Society, titled "Description, Measurement, and Estimation of Sky Glow," describes the causes, characteristics, and potential impacts of human-caused skyglow and identifies methods for quantification and control (IES 2021).

Skyglow over the lights of Las Vegas as seen from the BLM-managed Red Rock Canyon National Conservation Area.

Light Trespass

Light trespass[4] is illumination of an area where the illumination is not wanted or needed. A familiar example is a light in the neighbor's yard shining into bedrooms of a neighboring property. The light is not intended to illuminate the interior of houses on adjacent properties and is neither needed nor wanted by the affected homeowners. A less obvious example is the sight of distant flashing lights on communication towers or wind farms or operating lights on industrial facilities, visible to recreationists in a naturally dark environment within a wilderness viewshed. While such lights have important safety functions, they are not intended to illuminate the wilderness area and are neither needed nor wanted by the viewers within the wilderness. While they would not necessarily be considered obtrusive in a typical city environment with numerous visible lights, they may be very noticeable in the context of BLM-managed lands, where there are typically far fewer visible lights.

Light Clutter

Light clutter refers to excessive groupings of lights, such as are seen in typical urban environments where there are large numbers of lights of different types. Light clutter may be distracting, confusing, aesthetically impacting, and may contribute to skyglow, light trespass, and glare.

Over-Illumination

Over-illumination refers to the use of lighting intensity higher than that which is appropriate for a specific activity. An example would be a very brightly lit parking lot where the illumination is far greater than that needed to safely park, locate one's vehicle, and walk. Over-illumination often contributes to the other types of light pollution previously described and also has economic effects because of wasted light (energy consumed that achieves no useful purpose).

Ways that light pollution may affect humans are described in Sections 3.2 and 3.3. Ways that light pollution may affect ecological systems are described in Sections 3.4 and 3.5.

Unshielded lighting at this electrical substation in Nevada is a major source of light trespass and glare into the surrounding desert.

Chris Dickens

Light clutter is common in urban environments.

Much of this scene is over-illuminated.

[4] The term "light trespass" may have a legal definition in various jurisdictions that includes specific requirements (e.g., thresholds for illumination levels occurring a certain distance from a property line). In this technical note, the term light trespass is a type of light pollution in which light is cast where it is not wanted or needed.

Lighting at this solar facility on BLM-managed lands in Nevada as seen at 15 mi (24 km). The foreground lights are from vehicles traveling on Interstate 15.

3.1.3 How Distance Affects Light Pollution

Multiple types of light pollution may occur simultaneously in a given setting. The types of light pollution differ in many respects, including the magnitude of their effects at varying distances.

Relatively little field-based research exists to address the question of distance related to light pollution and measured effects. It is known that some effects of light pollution are of ecological importance even at relatively short distances. For example, effects on crop plants occur within tens of meters of a light source (Sinnadurai 1981), and photosynthesis induced by artificial light at night is thought to occur when vegetation is within inches of a light source (Gaston et al. 2013). Light pollution may affect animal behavior from far greater distances. For example, Van Doren et al. (2017) observed bird attraction to sources of light in the dark as far as 4 km. No available studies have calculated the distances that glare (which is a subjective effect that varies from viewer to viewer) is troublesome to humans at night. Glare from reflected sunlight in the daytime can cause discomfort at distances exceeding 20 mi (32 km) (Sullivan and Abplanalp 2015).

The distance at which light trespass, light clutter, or over-illumination is noticeable is limited only by the maximum distance at which the associated light sources themselves or their reflections from the ground, structures, or water bodies are directly visible. Sullivan et al. (2012) observed nighttime wind turbine lighting at more than 36 mi (58 km), and it is likely that brighter lights are visible at substantially greater distances, though the distance may not be as great in areas with high humidity or poor air quality. Sullivan and Abplanalp (2017) observed night lighting at a solar facility on BLM-managed lands at 29 mi (47 km). Skyglow may be visible at very long distances. Skyglow from Las Vegas is sometimes plainly visible from within Death Valley National Park, at more than 100 mi (161 km).

The relatively long distances at which some types of light pollution are noticeable is important to consider in the context of BLM-managed lands. Light pollution from sources miles away can affect resources and people on BLM lands, and in the case of skyglow, the effects can be noticeable even when there is no direct line-of-sight from the offending light sources. Similarly, light from facilities and activities on BLM-managed lands can affect people and animals many miles away from BLM lands. Addressing light pollution requires cooperation between the BLM and its neighbors. For example, the BLM is a member of the Colorado Plateau Dark Sky Cooperative, an organization that links local, state, and federal agencies; tribes; businesses; nonprofits; educational institutions; and local communities in a collaborative effort to protect night sky values by minimizing the effects of light pollution (Colorado Plateau Dark Sky Cooperative 2018).

3.2 Exposure Mechanisms: How Artificial Light at Night Affects Humans

Often, light pollution is thought of as affecting the visibility of the night sky and particularly the visibility of celestial objects, and many may consider light pollution to be almost exclusively an aesthetic effect (e.g., interference with the ability to enjoy the stars and the Milky Way). In reality, light pollution affects a wide range of human values and can cause health issues for people, animals, and ecological resources (effects on ecological resources are discussed in Sections 3.4 and 3.5).

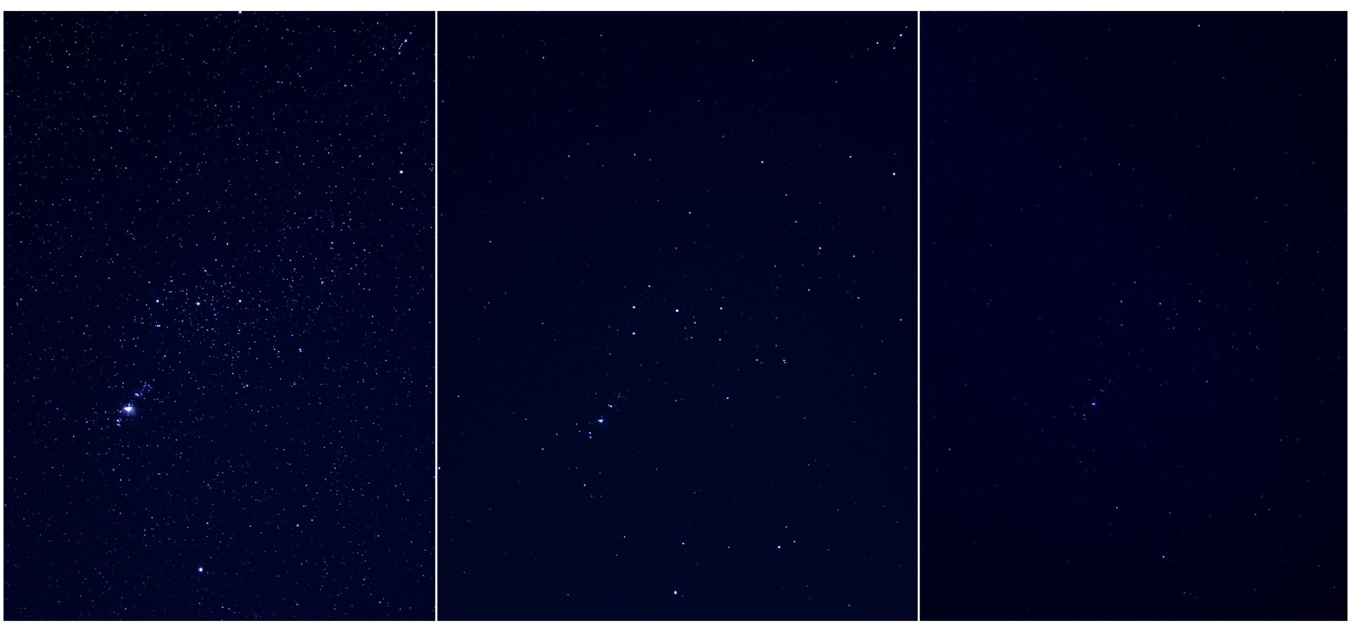
The exposure mechanisms discussed in this section include:

- Increase in brightness of the night sky.
- Effects on visibility of objects in dark or near-dark conditions.
- Too little light or too much light.
- Light trespassing where it is not wanted.

Artificial light at night may interact with other annoyances that affect humans (e.g., disruption of sleep from artificial light may be exacerbated by noise).There may also be synergistic effects between the various types of light pollution, such as glare and light clutter combining to increase nuisance effects.

3.2.1 Increase in Brightness of the Night Sky

Skyglow makes it difficult to see the stars, planets, Milky Way, and other celestial objects. Human activities that rely on or are enhanced by clear visibility are affected by skyglow. This can include stargazing; enjoyment of naturally dark environments for various nighttime recreational activities; amateur and professional astronomy; and cultural, religious, and spiritual-based activities. In addition, the inability to see celestial objects interferes with understanding and enjoyment of certain cultural and historic sites that have an association with the night sky.



Photographs of the constellation Orion show the effects of skyglow on the visibility of stars. The photo on the left is from the dark sky friendly BLM-managed Agua Fria National Monument. The photo in the center is from the outskirts of Phoenix, Arizona. The photo on the right was taken from an urban sports field. Skyglow can substantially increase the brightness of the night sky, reducing the visibility of celestial objects.

3.2.2 Effects on Visibility of Objects in Dark or Near-Dark Conditions

The human eye functions at an enormous range of light levels, from starlight to bright sunlight (Figure 2). The eye uses two different photoreceptor cells—cones and rods—to see this range of light levels. Cones and rods function at different levels of light.

Compared to rods, cones are capable of functioning at higher levels of light (referred to as photopic light levels), are used to see and distinguish between colors, have the greatest **visual acuity** (clarity and sharpness), and adapt to changes in light levels relatively quickly. Vision that uses the cones exclusively is referred to as **photopic vision**.

Rods function at low levels of light (i.e., dark environments). Rods distinguish shades of gray and **grayscale contrast** and are more sensitive than cones to small variations in light levels, but rods cannot distinguish colors and have relatively poor visual acuity. Rods respond much more slowly than cones to changes in light levels. Vision that uses the rods exclusively is referred to as **scotopic vision**.

In near-dark conditions (referred to as mesopic light levels), both the rods and cones function. Most nighttime outdoor and traffic lighting scenarios are in the mesopic range.

Ambient light levels influence which vision system is used. In naturally dark environments, scotopic vision is used. Artificial light causes the eyes to shift from using scotopic vision for seeing in the dark to using photopic vision for seeing in lit environments. As a result, this literally changes what is seen. Importantly, because rods are very sensitive but respond very slowly to changes in brightness, the sight of a bright light in otherwise dark conditions can substantially degrade scotopic vision, thus degrading or even eliminating the ability to detect faintly lit objects for a period of time, requiring as long as 50 minutes for a full recovery (Ruseckaite et al. 2011). Lights in otherwise naturally dark environments can pose a safety concern for people moving out of the lit area into the dark. Vision can be greatly diminished as the eyes shift from photopic to scotopic vision.

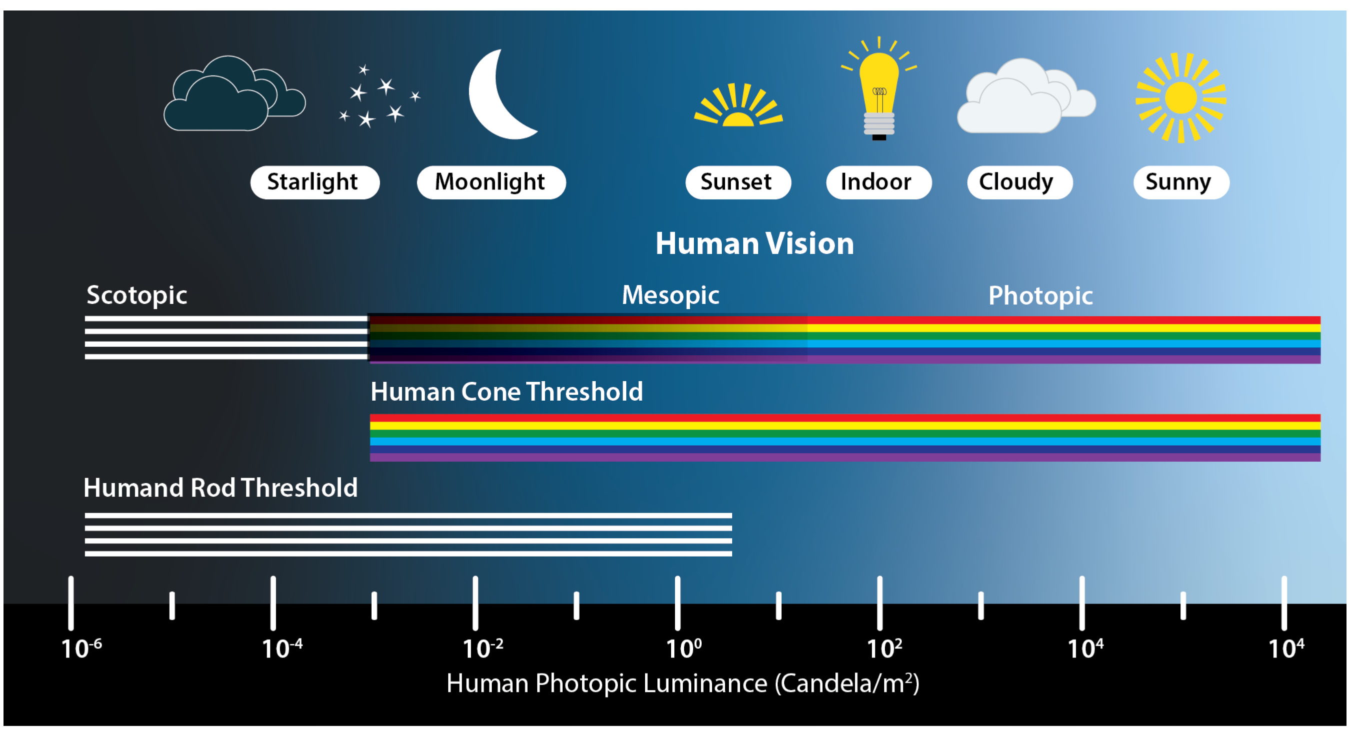
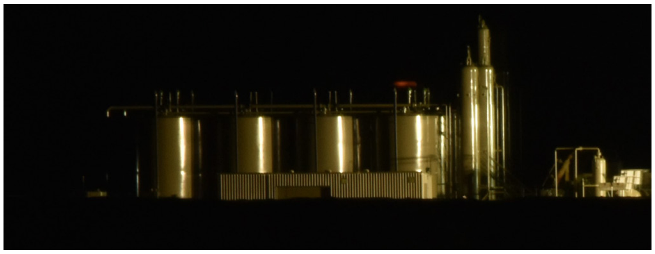


Figure 2. Human vision at different light levels.

3.2.3 Too Little or Too Much Light



Intensely bright lights at a remote natural gas facility in New Mexico.

Poorly designed lighting that results in inadequate lighting (too few lights, too low intensity, or inadequate coverage) or over-illumination (too many lights, too high intensity, or excessive coverage) poses a safety risk for humans. Lighting is needed for safety in certain situations, and too few lights, overly dim lights, or lights spaced too widely may result in poor illumination and accidents. However, over-illumination may also cause accidents because it negatively affects dark adaptation and can cause so much **contrast** that objects in less illuminated areas cannot be seen at all. Additionally, if the light source contrast is so great that glare occurs, over-illumination may cause visual discomfort or temporary visual impairment that causes viewers to look away or reduces their ability to see at all. Over-illumination may also present a personal security risk because high contrast between illuminated and nonilluminated areas may make it very difficult to see people in darker areas away from light sources (Kraus 2016).

If too many lights are in view from a given location, the resulting light clutter may have aesthetic effects or even pose safety risks due to distraction, primarily of drivers, but also potentially of workers at a facility. These effects are more common in urban areas, due to massive over-illumination, but may occur on intensively developed BLM-managed lands, such as major oil and gas fields.

3.2.4 Light Trespassing Where It Is Not Wanted

Light trespass is light where it is not wanted or needed (e.g., streetlights shining into bedroom windows at night, the synchronized flashing of lights on wind turbines). In other words, lighting is present in an area where little or no lighting is desired. The lighting does not have to be close by to cause an impact; as noted in Section 3.1.3, lights at night can be visible at distances exceeding 36 mi (58 km) (Sullivan et al. 2012).

The synchronized lights on wind turbines are a source of light trespass that may be visible for many miles.

3.3 Effects of Artificial Light at Night on Humans

Research on the effects of light pollution on humans is a relatively new field but clearly shows that numerous effects are occurring. This section summarizes the major effects of light pollution on humans, including aesthetic, spiritual, and recreational effects; historic and cultural effects; astronomical and scientific effects; nuisance effects; human health effects; and economic effects.

3.3.1 Aesthetic, Spiritual, and Recreational Effects

As discussed in Section 2.1, viewing dark night skies relatively free from light pollution is a highly valued aesthetic experience and, for many, a deeply spiritual experience. Dark night skies also contribute to the wilderness experience, which many people seek when they visit wilderness areas.

Skyglow often diminishes the aesthetic, spiritual, and wilderness values of the night sky by making it difficult to see fainter stars and other faint celestial objects, such as the Milky Way, meteors, and zodiacal light. This may diminish the enjoyment many people derive from viewing the night sky. It is estimated that 80 percent of North Americans are unable to see the Milky Way from their homes (Falchi et al. 2016). In addition, lights, particularly flashing lights, may distract viewers and introduce obvious human-made elements into the view. This detracts from the feeling of naturalness (an important wilderness value) and may also negatively affect the aesthetic or spiritual experiences of viewers (Duriscoe 2001).

Many people who live in light-impacted environments, such as this person from Denver, travel to areas like this dark sky park to enjoy the star-filled sky.

Skyglow, light trespass, light clutter, over-illumination, and glare may also affect nighttime recreational activities (Smith and Hallo 2013). Some activities, such as star parties, night sky interpretive programs, night sky photography, nighttime wildlife viewing, and observing celestial events such as the aurora borealis and meteor showers, are directly dependent on having a relatively light-pollution-free night sky. Many other nighttime recreation activities, such as night hiking; night bike riding; night boating, canoeing, kayaking, and rafting; night skiing and snowshoeing; and night hunting and fishing may be enhanced by relatively light-pollution-free night sky conditions. While the presence of substantial light pollution does not make these activities difficult or impossible, it likely reduces the quality of the recreation experience.

3.3.2 Historic and Cultural Effects

All types of light pollution have potential negative effects on cultural and historic values. Skyglow in particular has negative effects on cultural values associated with the night sky, because it affects the ability to see fainter stars and the Milky Way, and celestial objects of cultural significance may simply not be visible. Skyglow that results in loss of visibility of celestial objects may negatively affect the ability to recognize, understand, or enjoy archeoastronomy sites and other cultural/historic sites that are directly connected to the night sky, because often the connection relies on alignment of structures with celestial objects or events. If the celestial objects are difficult to see, the connection may not be seen or appreciated.

Poorly designed lighting that results in light trespass, over-illumination, glare, or light clutter may interfere with views and enjoyment of historic sites visited at night. While some lighting may be considered necessary for safety or security and to see the features of a historic site, improper lighting practices may interfere with visibility of the site or its structures, cast shadows that detract from the view, diminish the historic "feeling" of the site, and could decrease visitor safety by introducing such strong visual contrast that objects in shadow are not visible. Light pollution may also detract from the historic feel or character of the landscape. For example, visible lighting could diminish the experience of people traveling along a national historic trail at night to attempt to recreate the authentic pioneer experience of the night sky.

3.3.3 Astronomical and Scientific Effects

Griffith Observatory

Skyglow has seriously impacted professional astronomy at many observatories as seen at the Griffith Observatory in Los Angles, California.

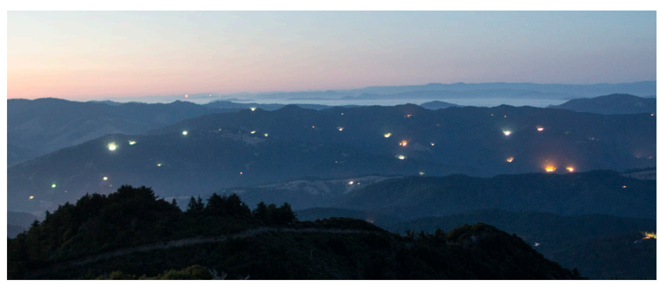
Skyglow has profound effects on amateur and professional astronomy. It makes dim celestial objects difficult or impossible to see. It also makes long-exposure astrophotography of faint celestial objects difficult because the overall sky brightness causes overexposure (ADSA 2016).

Light pollution interferes with spectroscopy, an important astronomical tool that is used for identifying the chemical composition, temperature, and distance of celestial objects. Artificial light masks the spectral lines of celestial objects of interest, with white or bluish light causing much greater problems. As a result, astronomers encourage the use of sodium vapor lamps, as they interfere less with spectroscopy (Kornreich 2015). The advent of **light-emitting diode (LED) lighting** posed a particular problem for astronomers since the first economically viable outdoor lighting applications used broad spectrum light with high **correlated color temperature (CCT)**. Now, warmer color LEDs (i.e., light sources with lower CCTs) are increasingly being used, which is helpful. Unfortunately, because LED lighting is much cheaper than other forms of lighting, and because many people assume that more lighting is better lighting, the overall trend is an increase in lighting use that continues to cause an increase in brightness of night skies worldwide (Kyba et al. 2017).

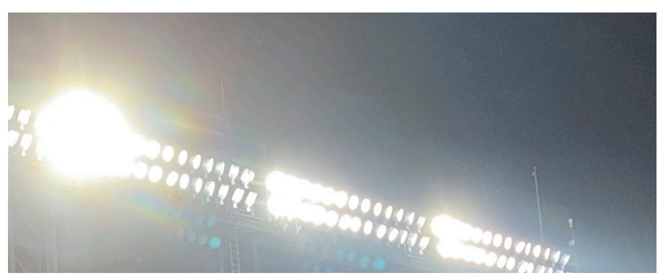
3.3.4 Nuisance Effects

Light trespass that involves bright lighting at short distances from the viewer can constitute a nuisance effect. Similarly, the visibility of more distant lighting at night has been identified as a nuisance effect of wind energy and other projects, including those located on BLM-managed lands (Sullivan et al. 2012) and elsewhere (Hardy and Eller 2017; van der Zee 2016). The flashing lights of wind turbines have been identified as a nuisance in lawsuits against wind projects (McEowen 2011) and were found to cause stress reactions in research subjects based on annoyance (Michauda et al. 2016). Greenhouse production of marijuana in California has been identified as a source of light pollution and is prominently visible from BLM-managed lands (Wick 2019; Rich et al. 2020).

At night, perception of glare depends on the level of dark adaptation of the eyes. Even lights that are not extremely bright can cause glare in very dark environments. Glare can create visual discomfort or temporary visual impairment caused by excessive and uncontrolled light source brightness. Glare can interfere with the ability to view and enjoy the night sky and the ability to perform tasks because of visual discomfort or temporary visual impairment.



Light from marijuana greenhouses in California, as seen from BLM-managed lands.



Glaring banks of light, such as stadium lights, may cause visual discomfort or temporary visual impairment when in direct view.

3.3.5 Human Health Effects

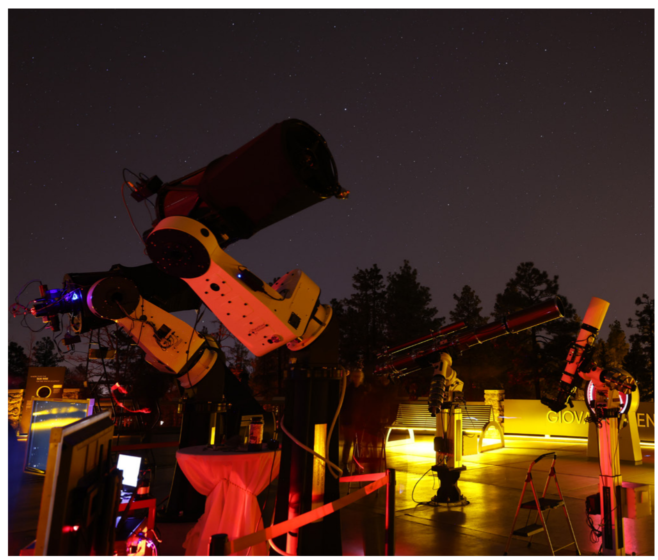
Humans have **circadian rhythms**, sometimes referred to as "biological clocks[5]," that have developed in response to the earth's day-night cycle, and among other things, they set the human sleeping and waking cycle. Exposure to artificial light at night can interfere with and suppress **melatonin**[6] production, affecting human health and sleep. (Tähkämö et al. 2019). Light timing and wavelength are important with respect to circadian disruption and the suppression of melatonin secretion. Melatonin suppression peaks at light wavelengths around 480 nanometers. Melatonin suppression is especially sensitive to shorter light wavelengths in the evening, with cooler colored (bluer) light suppressing melatonin production more than warmer (redder) light (Tähkämö et al. 2019). For this reason, it is important to use warmer light colors regardless of lighting type to minimize health effects to both humans and animals (see Sections 3.4 and 3.5 for discussion of health effects in animals).

Evidence suggests direct and indirect links between exposure to artificial light and melatonin suppression that may result in various medical problems in humans, including increased risk of obesity, heart disease, and various types of cancers (Hurley et al. 2014; Kloog et al. 2009; McFadden et al. 2014). It is important to note that humans typically get most of their nighttime light exposure in indoor spaces, not outdoors, and consequently, much of the research into human health effects has examined indoor effects of lighting.

3.3.6 Economic Effects

The night sky and darkness are often not considered in terms of economic benefits; however, there are positive economic effects of dark night skies. It is also clear that light pollution can have negative economic effects.

Expenditures associated with nighttime recreation on public lands can in some instances be estimated. For example, astrotourism is associated with economic activity in nearby communities, as many participants require overnight stays (Collison and Poe 2013). A study conducted for the National Park Service by Mitchell and Gallaway (2019) conservatively estimates astrotourism-related spending in national parks in the Colorado Plateau alone at $5.75 billion for the 10-year period between 2015 and 2024. To the extent that light pollution prevents or discourages astrotourism and other nighttime recreation activities, related economic activity is reduced. The effects of light pollution have caused some major observatories to be rendered useless for the types of astronomical work for which they were intended, and it is now common practice to build new observatories in extremely remote locations, at great additional cost (Luginbuhl et al. 2009; Henderson 2010).



Stargazing opportunities are growing in popularity and demand. Locations and facilities that support astrotourism are increasing like this observatory deck at the Lowell Observatory located in Flagstaff, Arizona. The city is actively working to limit light pollution in recognition of the growing importance to local tourism.

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[5] Technically, circadian rhythms and biological clocks are not the same. Circadian rhythms are physical, mental, and behavioral changes following a daily cycle, determined by an organism's biological clocks but affected by environmental factors, including light and darkness in the organism's environment. Biological clocks are an organism's innate timing device, composed of proteins that interact in cells in nearly every tissue and organ (NIH 2017).

[6] Melatonin is a hormone that, among other important functions, affects circadian rhythms, sleep and wakefulness, and biological repair mechanisms.

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Although there is evidence of human health effects with exposure to artificial light, the economic costs of these effects are not known. Costs could include those to treat diseases, lost worker productivity due to disrupted sleep resulting in fatigue, and any related industrial or transportation accidents. It should be noted that known health effects are primarily from indoor lighting and thus would likely not apply to outdoor lighting on BLM-managed lands.

Effects on plant and animal species and associated ecosystems from ecological light pollution could also have negative economic effects where humans depend on these species and ecosystems for services such as food, clean water, flood abatement, etc. Quantifying the economic cost of effects associated with ecological light pollution on wildlife species and resulting damage to ecological systems is difficult and has not been undertaken.

A direct and quantifiable economic effect of light pollution is wasted energy. Unshielded and incorrectly directed **luminaires** cast light where it is not needed, using energy to illuminate areas unnecessarily. The estimated cost of this wasted light is $3.3 billion annually, and the wasted energy generates 21 million tons of carbon dioxide per year (IDA 2012b).

Finally, some effects cannot be measured in monetary terms. The cost of diminished night skies to our culture and history cannot be measured, nor can its effect on aesthetic and wilderness values. One cannot calculate the value of the diminishment or loss of species and ecosystems negatively affected by light pollution. Similarly, the cost to humanity of losing dark skies is immeasurable.

3.4 Exposure Mechanisms: How Artificial Light at Night Affects Animals and Plants

The loss of naturally dark environments is an increasing concern for ecological systems. Effects of this type are often referred to as **ecological light pollution** rather than **astronomical light pollution** (Longcore and Rich 2004).

Nighttime light can have biological effects on a wide variety of animals and plants spanning all major taxonomic levels—invertebrates, fish, amphibians, reptiles, birds, and mammals (Longcore and Rich 2004; Gaston et al. 2013). Gaston et al. (2013) identified six major ways that artificial light at night can affect animals and plants:

1. **Temporal niche partitioning effects:** Light-induced activity or suppression of activity of animals at times outside of their normal activity patterns.
2. **Dark repair and recovery effects:** Light-induced suppression of biological repair mechanisms in organisms.
3. **Photoperiodism and circadian rhythm effects:** The alteration of behaviors that are dependent on light and dark cycles.
4. **Effects from enhanced visual perception:** Enhanced vision of animals at night.
5. **Effects on spatial orientation and navigation:** The inability of animals to orient or navigate properly at night.
6. **Photosynthesis effects:** The induction of photosynthesis in plants at night; a type of photoperiodism due to artificial light.

Influences on photosynthesis are specific to plants, while repair and recovery effects and **photoperiodism** and circadian rhythm effects can occur in both plants and animals. It should be noted that effects on photosynthesis are not the only effects on plants (see Section 3.5.2).

While this technical note primarily addresses direct effects on certain species, understanding the broader ecological context is important. The influences of artificial light into naturally dark environments may be various as types of light pollution interact and also interact with other influences (e.g., noise). Furthermore, numerous and complex ecological interactions occur between the elements of ecosystems. Therefore, direct effects to one species may cause indirect effects to other species through changes in resource competition, predator-prey dynamics, or other mechanisms.

Finally, the direct effects to living organisms may cause changes in population sizes and community composition (Sanders and Gaston 2018; Desouhant et al. 2019). These effects in turn may affect the nonliving parts of ecosystems by changing flows of energy, nutrients, and water.

3.4.1 Temporal Niche Partitioning in Animals

Bright sunlight is approximately 100 million times brighter than a moonless night (Schroer and Hölker 2016). Animals have highly developed vision systems and behaviors to function in a range of lighting conditions, and some species are active only within a particular range or show a strong preference for a particular level of light. Animals in the same environment may be adapted to different lighting levels and will be active at different times as a result. This is an example of **niche partitioning**, the process by which competing species use the environment differently to help them coexist.

Under **natural lighting** conditions, animals that are diurnal (active during the day) become inactive as darkness falls. Nocturnal animals become active only after darkness falls. This is **temporal niche partitioning**, the partitioning of various species' activity periods over time based on varying levels of light. Changing the natural light levels can change interactions between species. Artificial light at night can cause diurnal animals or crepuscular animals (those active during twilight) to extend their period of activity into the nighttime hours (sometimes referred to as exploiting the "night light niche") (Garber 1978) and may also affect the activities of nocturnal animals. These changes in activity periods can disrupt interactions between species. For example, these changes can result in competition between diurnal/crepuscular and nocturnal species that would not normally encounter one another. Diurnal animals that may extend their activity in the presence of artificial light at night include anoles, skinks, snakes, toads, tree frogs (Garber 1978; Perry et al. 2008), fish (Keenan et al. 2007), and birds (Amichai and Kronfeld-Schor 2019; Santos et al. 2009; Nordt and Klenke 2013).

A lesser nighthawk hunting several hours after twilight to take advantage of insects drawn to bright lights.

Artificial light at night may affect predator-prey relationships by causing some predators to hunt at times when it would otherwise be too dark. Visually oriented predators (those that rely primarily on vision to hunt) may be able to extend their hunting periods to times when they would normally be inactive. Prey species that forage only under specific lighting conditions may delay their activities or may avoid lit areas to avoid exposure to predators. As a result, artificial light may change predator-prey activities and reduce foraging opportunities, both of which can influence survival at the individual and population levels. For example, research shows that exposure to artificial light can reduce or delay foraging opportunities in small desert mammals (Brown et al. 1988; Kotler 1984; Shier et al. 2020) and certain bats (Boldogh et al. 2007; Stone et al. 2009).

Certain species of fireflies are only active under particular light levels, which separates the activity periods among species to reduce competition. This partitioning may be disrupted in the presence of artificial light at night (Lloyd 2006). Other species, including certain insects and frogs, only mate during the darkest part of the night, presumably to avoid predators (Buchanan 2006).

3.4.2 Role of Darkness in Biological Repair and Recovery

Mammals require darkness for melatonin production. Melatonin affects sleep and wakefulness in animals, regulates circadian rhythms, and regulates biological repair mechanisms in both plants and animals. Many animal species need uninterrupted darkness to produce melatonin. Evidence shows that exposure to relatively low levels of artificial light can interfere with melatonin production, and this can negatively affect animals in several ways. For example, there are links between melatonin suppression and increased growth of tumors in rats (Blask et al. 2005). The reduction in melatonin production is greatest from blue light (Brainard et al. 2001). Exposure to artificial light can suppress immune system response in quail (Moore and Siopes 2000), cockerels (Kirby and Froman 1991), and rats (Oishi et al. 2006). Research also shows that exposure to artificial light can inhibit recovery of clover from ozone damage (Vollsnes et al. 2009).

3.4.3 Photoperiodism and Circadian Rhythms in Animals and Plants

Light affects the timing of biochemical, physiological, and behavioral processes in plants and animals. Organisms that live in illuminated environments respond to the cycle of day and night, seasonal changes in day length, and the monthly lunar cycle. **Photoperiodism** is the physiological reaction of organisms to the length of day or night. An organism's response to the 24-hour day/night cycle is referred to as its **circadian rhythm**.

For many organisms, daylight of a certain length is an essential trigger for important events or behaviors. Day (or night) length often interacts with temperature to signal or initiate photoperiodic events. For example, leaf drop in certain plants is triggered by shortening day length and falling temperatures in autumn, while bud set in some plants is triggered by longer day length and warmer temperatures in the spring. In certain animals, photoperiod and temperature changes result in changes to fur color (e.g., in snowshoe hares) and feathers in birds. Other behaviors subject to photoperiod include hibernation, migration, and mating behavior in various animal species (Gaston et al. 2013).

Even very low levels of light can affect organisms' photoperiodic triggers and circadian rhythms. These can include changes to immune system response, metabolism, and stress levels in some animals (Bedrosian et al. 2011; Fonken et al. 2010; Zubidat et al. 2010); changes in reproductive behaviors with photoperiodic triggers, such as the timing of dawn chorus in some birds (Kempenaers et al. 2010); reproductive timing in mammals (Robert et al. 2015); and negative effects on seed set and leaf drop in plants (Bennie et al. 2016). Artificial light can affect egg laying in chickens (Burger 1949) and mating receptivity in juncos (Rowan 1925). Artificially lighting otherwise dark environments can influence seasonal niche partitioning. For example, if artificial light illuminates environments that would otherwise be in darkness, it could delay the departure of a particular species during seasonal fall migration (Tabor et al. 2004), and it could facilitate hunting by visually oriented predators of prey that are seasonally available during darker times of year (Jetz et al. 2003).

3.4.4 Visual Perception in Animals

Artificially illuminating otherwise dark environments makes it possible for some animals to see better in low-light conditions, and these animals may benefit more than others from the increased light levels, including predators that may have increased success at hunting (Santos et al. 2010). Predators tend to benefit over prey species in the presence of artificial light (Longcore and Rich 2016), though some prey species that cluster, such as flocking birds and schooling fish, may benefit because the extra light facilitates communal vigilance (Nightingale et al. 2006).

3.4.5 Spatial Orientation and Navigation in Animals

Almost all animal species use light detection and other visual cues to navigate the nighttime environment (Longcore and Rich 2016). Therefore, illuminating environments that would otherwise be dark influences spatial orientation and navigation. Awareness is growing through research and media that lights in buildings and on structures may attract birds often with fatal results (USFWS 2016). Likewise, the attraction of sea turtle hatchlings to lights is also well documented (see Section 3.5.1.4.).

Everyone likely has observed swarms of moths and other nocturnal insects attracted to lights at night. These swarms may alter navigation patterns as predators move to take advantage of the easy access to prey. Artificial light at night can influence predator-prey relationships, with possible effects on populations of the species involved.

Artificial light can also influence reproductive behavior by affecting spatial orientation. For example, fireflies use **bioluminescence** to find mates under cover of night; these communications are best seen by potential mates in dark environments.

Effects on spatial orientation and navigation depend in part on the spectral composition of the light. Research shows that most insects are more attracted to light sources that include blue or ultraviolet light (Poiani et al. 2014), whereas some birds are preferentially attracted to red lights (Poot et al. 2008).

3.4.6 Photosynthesis in Plants

Lights of sufficient brightness can cause plants to photosynthesize when natural darkness would normally prevent it. Artificial light can potentially cause photosynthesis to occur at night, but this requires that the light source be extremely close to the affected plants. This situation would likely be very rare for BLM-managed lands, except in naturally dark cave environments, where even very low levels of light can support certain species of plants (Gaston et al. 2013).

3.5 Effects of Artificial Light at Night on Animals and Plants

This section summarizes select research about plants and various types of animals that is most relevant to environments the BLM manages but is not specific to BLM-managed lands. The body of research is growing about darkness dependencies of plant and animal species. Research specific to BLM special status species represents a field for future study. The information presented focuses on taxonomic groupings that can be applied to the context of plants and animals common to BLM-managed lands. The information is intended to raise awareness and encourage education of local plant and animal darkness dependencies.

3.5.1 Effects of Artificial Light at Night on Animals

General changes in natural darkness of the environment (ecological light pollution) may affect niche partitioning, photoperiodism and circadian rhythms, health as related to dark repair and recovery, enhanced/extended visual perception, and orientation and navigation behaviors in dark environments.

Many animals also exhibit **phototaxis**, a behavioral response to light characterized by movement toward light sources (positive phototaxis) or away from light sources (negative phototaxis). For example, many flying insect species (e.g., moths) are attracted to artificial light sources (positive phototaxis). Cockroaches and some bat species avoid light sources (negative phototaxis). Phototaxis has various effects. For example, positive phototaxis in flying insects can lead to increased predation by bats, birds, and other predators, while negative phototaxis in mice can decrease their opportunities for foraging in illuminated areas.

3.5.1.1 Effects on Insects and Other Arthropods

Mechanisms by which insects are affected by and respond to artificial light sources are summarized by Desouhant et al. (2019). The authors discuss effects on population dynamics and community composition and functioning. Also discussed are evolutionary changes due to selective pressures created by artificial light.

Insects and other arthropods use visual information to navigate, find food, and avoid predators. As previously noted, moths and many other nocturnal insects are attracted to lights, and billions of insects die as a result. Why insects are attracted to light sources is unclear. However, it appears to affect their night vision and ability to orient and navigate (Schroer and Hölker 2016). Research shows that the composition of invertebrate communities within the vicinity of streetlamps is affected, and with that, numbers of predator and scavenger species on the ground nearby also increases in response to increased numbers of prey (Davies et al. 2012).

Research also shows that artificial light at night affects development, survival, and reproduction in some types of insects, particularly when the source contains blue or ultraviolet (UV) wavelengths (Schroer and Hölker 2016), and as previously noted, these wavelengths are particularly attractive to certain species. Several studies show the effects on moths. Certain types of moths exhibit reduced mating success (van Geffen et al. 2015a). Artificial light at night can also interfere with pollination (Macgregor et al. 2017); reduce feeding time in several species of moths (van Langevelde et al. 2017); negatively affect pheromone production (van Geffen et al. 2015b); and disrupt initiation of diapause and cause other life cycle changes (van Geffen et al. 2014). Van Langevelde et al. (2018) identified artificial light as an important driver of declines in the abundance of various moth species that are attracted to it.

Artificial light at night can mask bioluminescence from fireflies, interfering with communication essential for successful reproduction. It also affects niche partitioning, resulting in different firefly species being active at the same time, bringing them into competition that would not otherwise occur. Artificial light at night can suppress melatonin levels in a species of cricket, negatively affecting their immune systems (Durrant et al. 2015). Very low levels of artificial light can affect predator avoidance behavior in aquatic insects (Bishop 1969) and the upward and downward movement of other aquatic invertebrates in response to light levels, which may affect predation on these and other species (Moore et al. 2000).


C.G.P. Grey

Flying insects attracted to a light source at night.

Evidence suggests that artificial light at night may in some cases be an evolutionary driver for certain insect species. Altermatt and Ebert's (2016) study of "flight to light" behavior in ermine moths suggests that moths from light polluted urban environments have evolved over the course of several decades to show less attraction to lights compared to moths from naturally dark areas.

Insect responses to artificial light and evolutionary influences may create indirect effects on other species. For example, many animals prey on the swarms of insects drawn to lights (Davies et al. 2012), including birds, bats, frogs and toads, spiders, and other insects. While these species may benefit from the easy access to prey, the abundance of the prey species is reduced, which in turn may reduce the availability of food for other species. Knop et al. (2017) found there is reduced visitation to flowering plants by nighttime insect pollinators when there are artificial light sources, resulting in reduced fruit set. The reduced plant reproduction was predicted to negatively impact daytime pollinators that rely on the plants for food.

3.5.1.2 Effects on Mammals

Dark environments that are artificially lit can affect mammals that are nocturnal or active both day and night. Available laboratory and field studies on various mammal species (e.g., bats, rodents) indicate that artificial light affects dark repair and recovery from melatonin suppression, circadian rhythm, and vision (Gaston et al. 2013). Artificial light at night may influence mammal reproduction, foraging, predator-prey relationships, and potentially spatial orientation.

A laboratory study shows that exposure to very low levels of light at night suppressed melatonin production and promoted tumor growth in rats (Dauchy et al. 1997). The illuminance used in the study was well below that expected for the ground underneath a streetlight. Even lower levels of light at night can affect circadian rhythm in bats (Erkert 2004). Melatonin suppression is shown to negatively affect rat reproduction and links to weight gain in mammals (Tan et al. 2011). Captured field mice subjected to extended periods of light produced significantly fewer young than those subjected to natural light/dark cycles (Baker and Ranson 1932).

Compared to other animals, nocturnal animals such as bats may be more affected by artificial light. More than half of the 46 bat species known to occur in the U.S. are found on lands managed by the BLM (BLM 2018). While some species of bats hunt in the vicinity of lights because of the abundance of insect prey found there (Rydell and Baagøe 1996), other species of bats will avoid lighted areas (Stone et al. 2015) or delay their normal period of foraging (Boldogh et al. 2007; Stone et al. 2009). Juvenile bats that colonize on buildings with lighting have shown reduced growth rates and fitness, due to delayed and slower emergence of bats at dusk.

Desert rats and mice in the Mojave Desert have shown reduced foraging opportunities (Brown et al. 1988; Kotler 1984). A study by Bengsen et al. (2010) shows that various rats and other small mammals reduce their foraging intensity. Similar results were found in studies on the Pacific pocket mouse and the endangered San Bernardino kangaroo rat (Shier et al. 2020). Another study in the Mojave Desert (Bouskila 1995) shows that certain rodent species engaged in predator avoidance behaviors under conditions of brighter moonlight to avoid owls, which rely on vision for hunting. Perry et al. (2008) suggest that the same predator avoidance might occur around artificial lights. Bliss-Ketchum et al. (2016) found that artificial light reduced deer mouse and opossum usage of a bridge under-road passage structure.

Desert rats and mice in the Mojave Desert have fewer foraging opportunities in artificially lit areas.

Several studies have examined the effects of artificial light at night on larger nondomesticated mammals. A study of mountain lions in California suggests that when exploring new habitat, they avoided urban glow and navigated toward the darkest horizon (Beier 1995). Bliss-Ketchum et al. (2016) found that Columbian black-tailed deer used an under road passage structure less when lit. Robert et al. (2015) show that reproductive timing in a wild population of wallabies was delayed by melatonin suppression as a result of exposure to artificial light at night.

3.5.1.3 Effects on Birds

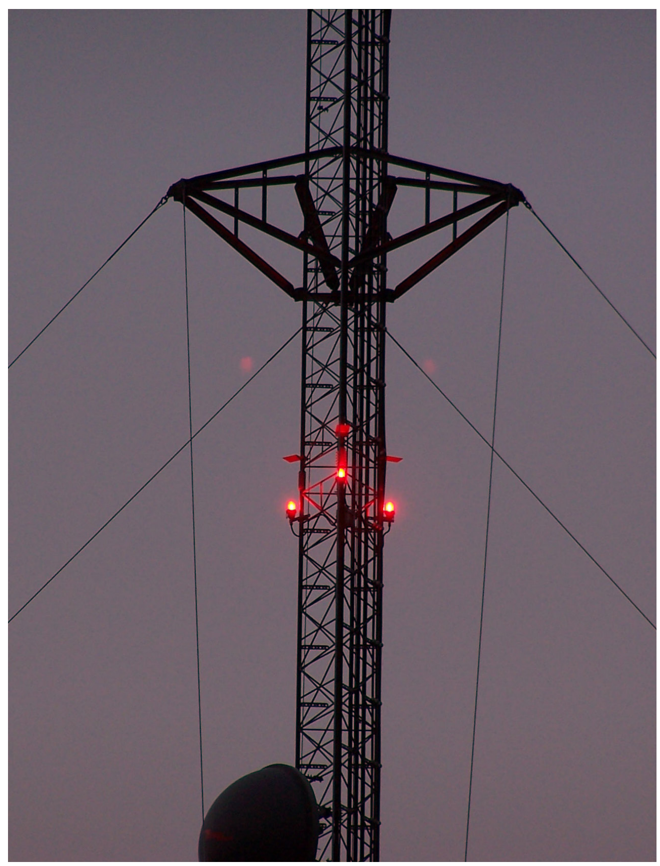
Birds killed by collision with a lighted structure at night.

Laboratory and field studies show that many bird species are subject to a wide range of effects from exposure to artificial light at night, including effects on reproduction and mating behavior, predator-prey relationships, and especially migration and orientation, which has been extensively studied. It has been long known that exposure to artificial light at night can increase egg laying in chickens and delay egg laying in songbirds (Kempenaers et al. 2010). An early experiment with juncos shows that brief exposure to artificially lit environments can alter their reproductive condition (Rowan 1925). Field studies show that artificial light at night can affect territorial singing in mockingbirds (Derrickson 1988) and the timing of dawn chorus in other songbirds (Kempenaers et al. 2010).

The migratory behavior of many species of birds, especially neotropical migrants, is affected by artificial light (Gehring et al. 2009), which may attract and disorient the birds. Birds that migrate during the night are especially affected, and the effect is greatest on overcast or foggy nights or when there is precipitation associated with weather fronts. The disoriented birds may be "captured" by the light and unable to see stars or other navigation cues that they would normally use. Unable or unwilling to fly away from the light, birds can die or become injured by colliding with structures or die from exhaustion after circling the light source for hours (Larkin 2000). In a severe incident, thousands of birds may be killed in one night (Gauthreaux and Belser 2006). These types of incidents occur frequently at communication towers (Gehring et al. 2009) and have occurred at oil well drilling rig sites (Ramirez et al. 2014) and at sites with gas flares (Gauthreaux and Belser 2006).

Disorientation is shown to occur among migratory birds in artificially illuminated areas that are overcast and foggy as well as by bright light sources in clear conditions. Van Doren et al. (2017) studied the attraction of migratory birds to an annual tribute that involves the illumination of New York City from dawn to dusk on September 11. Under clear conditions, they documented an increase from 500 birds within 0.5 km of the light sources before they were turned on to 15,700 birds circling within 0.5 km of the vertical high-intensity light beams shortly after illumination.

Research by La Sorte et al. (2017) shows that many species of migrating birds were preferentially attracted to urban environments. This was at least in part because of the relatively high levels of nighttime lighting, especially in autumn. McLaren et al. (2018) found that autumnal migrant stopover density of birds increased in proximity to the most brightly illuminated areas.



Steady-burning red lights on communication towers are attractive to some birds.

Many migrating birds seem more disoriented by steady burning rather than flashing or strobe lights (Gehring et al. 2009). The exact mechanism by which certain types of lighting disorient birds is uncertain but is believed to involve interference in magnetoreception and celestial navigation mechanisms birds use to orient themselves in unfamiliar locations (Gaston et al. 2013). Changing obstruction lighting to flashing red lights, in accordance with Federal Aviation Administration (FAA) guidance, has been found to significantly reduce mortality of migratory birds at communication towers (Gehring et al. 2009; FAA 2015).

Birds may avoid areas lit at night (e.g., godwits choose nesting sites away from lighted roadways) (de Molenaar et al. 2006). Wading birds foraging and hunting at night have exhibited enhanced success along shorelines where there is lighting (Santos et al. 2010), but this may raise the bird's exposure to predators.

3.5.1.4 Effects on Reptiles

The detrimental effects of artificial light on various species of sea turtles are well documented (Salmon 2003). Sea turtles hatch from clutches of eggs laid on ocean beaches and emerge en masse at night. Under **natural lighting**, newly hatched sea turtles immediately crawl to the ocean and then swim to deeper waters where they are less subject to predation. The hatchlings crawl away from the darkest part of the horizon and toward the lighter part of the horizon. Under natural lighting, because of an absence of shadows and the presence of light reflected from water, the ocean horizon is lighter than the land horizon. In the presence of shorter wavelength artificial light near the beach, the hatchlings do not crawl toward the ocean but rather either wander erratically or crawl toward the light sources, and many die as a result from exhaustion, predators, or accidents. Disorientation in sea turtle hatchlings is dramatically reduced where lights are retrofitted to warmer temperature "wildlife friendly" fixtures and lighting design (Shudes et al. 2013).

In a multidecade effort, the staff and volunteers at Cape Hatteras National Seashore have worked to identify and protect sea turtle nests. This black fabric barrier flanks a sea turtle nest to block artificial light from the nearby development and help hatchlings navigate to the light produced by moon on water.

A study in the Mojave Desert (Bouskila 1995) shows that snake predation on desert rodents decreased under higher levels of nighttime illumination from moonlight because the rodents were better able to see the snakes (which do not rely on vision for hunting). Perry et al. (2008) suggest that exposure to artificial light might have similar effects.

3.5.1.5 Effects on Fish

It is well established that fish are attracted to artificial light at night. Research shows that predaceous fish and their prey species are attracted to light near the water surface (Becker et al. 2013). In some fish species, hatching is photoperiod-dependent (McAlary and McFarland 1993). Artificial light at night can have various effects on development of freshwater fish species (Brüning et al. 2011) and can affect the dispersal of juvenile salmon and the swimming depth of mature salmon (Nightingale et al. 2006). Tabor et al. (2004) found that artificial light at night delayed migration of sockeye salmon fry and increased predation by sculpins. Observations show nonfish predators taking advantage of lighting to prey on migrating salmon (Nightingale and Simenstad 2002).

3.5.1.6 Effects on Amphibians

In certain species of frogs, artificial light at night can affect mating behavior.

Many amphibians are nocturnal, at least seasonally, and some have vision systems adapted for living in extremely dark environments. Research suggests that these species may be extremely sensitive to artificially lit areas (Buchanan 2006). Amphibians generally use vision to capture their prey, so altering light in their environment may change their predatory behavior. Some frogs and toads appear to be attracted to lit areas, presumably to feed on insects and other animals drawn to the light (Wise 2007).

Dark adaptation is the process of the eyes adjusting to dark conditions after exposure to light, and vision is impaired until the eyes are fully adapted. In humans, dark adaptation may take as long as 50 minutes (Ruseckaite et al. 2011). Evidence from various studies show that, for certain frogs, dark adaptation after exposure to light as dim as a headlamp may take hours, and during the period of dark adaptation, frogs were less able to locate prey, potentially affecting their foraging success. Difficulty with dark adaptation may also make them more susceptible to becoming prey or being killed by vehicles after being blinded by automobile headlights while crossing roadways (Buchanan 2006).

In certain species of frogs, artificial light at night can affect mating behavior, including the calling behavior and movement of male frogs (Baker and Richardson 2006), mate selection by female frogs (Rand et al. 1997), and nest locations (Tárano 1998). Some of this behavior is believed to result from avoidance of predation in illuminated areas. Dias et al. (2019) found that artificial light at night affected the calling season length and timing as well as the daily calling behavior of various frogs in Brazilian wetlands.

Artificial light at night can affect toads as well. Dananay and Benard (2018) show that exposure during the larval stage of the American toad affected development and behavior. Touzot et al. (2019) demonstrate that artificial light at night reduced activity levels and changed energy allocation in the common toad in the breeding season. In a separate study, Touzot et al. (2020) show that artificial light at night affected mating behavior and fertilization success of the common toad.

Amphibian behavior and circadian rhythm responds to day length (photoperiodism). Laboratory experiments suggest that artificially lit environments affect larval development and behavior in some species of frogs and toads (Buchanan 2006; Wise 2007). Some of these effects are likely related to suppressed melatonin production. Artificial light at night also may affect emergence and foraging behavior of various frog species that are active only under extremely dark conditions (Buchanan 2006).

3.5.2 Effects of Artificial Light at Night on Plants

Plants use light as a source of energy and information. Light controls plant growth and other functions by providing the energy needed for photosynthesis and by triggering or inhibiting a variety of important processes, such as leaf drop, bud development and flowering, seed germination, and stem elongation (Gaston et al. 2013). Artificial light at night can potentially cause photosynthesis to occur at night, but this is unlikely an important issue on BLM-managed lands. Experiments show that artificial light at night can affect plant growth and respiration and have other physiological effects (Kwak et al. 2017, 2018). In the environment, artificial light at night affects plants primarily by impacting photoperiodism and circadian rhythms. Laboratory experiments suggest there are also effects on dark repair and recovery.

Low levels of light at night can cause significant delay in leaf drop in certain tree species (Matzke 1936; Massetti 2018). Sensitivity varies greatly between species. Laboratory experiments show a wide range of responses to artificial light at night in various plant species, including delay and promotion of flowering, enhanced vegetative growth (Gaston et al. 2013), and delay of budburst (Brelsford and Robson 2018). These types of effects may occur in the environment, but further study is needed. Artificial light at night can negatively affect the growth of certain crop plants in field settings, as discussed in Schroer and Holker (2016), but these potential effects have yet to be studied in noncrop species in the environment.

Many flowering plants are highly dependent on pollinators for reproduction (seed production) and genetic fitness through cross pollination. Effects of artificial light at night on pollinators also affect plants that rely on those pollinators (Altermatt and Ebert 2016; MacGregor et al. 2015; Owens and Lewis 2018) and has been demonstrated in a field study by Knop et al. (2017). Their study shows that the presence of artificial light at night reduced the number of visits to flowers by nocturnal pollinators, which resulted in a significant decline of fruit set in the plants in the study area. The decline in fruit set likely affects the availability of food to daytime pollinators. A study on horse chestnut trees exposed to artificial light at night shows that leaf size and senescence were influenced. This led to faster reproduction of horse-chestnut leaf miners (insects) and increased tree damage (Schroer et al. 2019).

Kurt Kusnicki, Friends of Nevada Wilderness

Dark night skies near Black Rock Point in the Black Rock Desert-High Rock Canyon Emigrant Trails National Conservation Area.

4. Principles of Artificial Light at Night to Avoid Light Pollution

This section discusses six guiding principles of artificial light at night to minimize light pollution. These principles are based on “Five Principles for Responsible Outdoor Lighting” developed by the International Dark-Sky Association and Illuminating Engineering Society (IDA 2018b). These six principles frame the selection and presentation of artificial light at night BMPs:

- Light only if needed: Use alternatives to permanent lighting.
- Light only when needed: Use lighting control technologies.
- Light only where needed: Shield lights and direct them properly.
- Light color matters: Select amber, orange, or red whenever possible.
- Use the minimum level of illumination necessary: Avoid over-illumination.
- Use energy-efficient lights and advanced lighting controls: Save energy while adding useful lighting capabilities.

Properly designed lighting can provide for human use and safety with limited light pollution. A growing number of organizations review and certify lighting products as “wildlife friendly” or more generally as "night sky friendly." Examples include, but are not limited to, the IDA's Fixture Seal of Approval program, the Florida Fish and Wildlife Conservation Commission's Certified Wildlife Lighting program, and the DesignLights Consortium Light Usage for Night Applications (DLC LUNA) requirements that establish criteria for outdoor lighting at night. Outdoor commercial and industrial luminaires with a DLC LUNA classification meet energy efficiency and lighting quality requirements and have attributes to limit light glow and light trespass (DLC 2021).

Be aware of laws and regulations that specify lighting requirements for facilities and activities located on BLM-managed lands. A best practice in one situation may not be applicable in another. A lighting plan will ensure that legal lighting requirements are integrated with opportunities to implement appropriate BMPs listed from this technical note.

Existing lighting may be retrofitted or redesigned to accomplish the six principles. However, the most productive time to consider and incorporate these principles is at the lighting design stage. Considering the lighting needs in an integrated fashion is the most economical way to provide for human utility while minimizing light pollution. Good lighting design relies on a thorough understanding of the lighting requirements of people using an area (e.g., what people do in the area, what visual information they need, amount of time spent in the area, potential safety concerns).

4.1 Light Only If Needed: Use Alternatives to Permanent Lighting

The purpose of the first guiding principle is to ensure there is a need for every light and to avoid using permanent lighting whenever possible, consistent with safety requirements and the requirements of tasks to be performed. Not all areas need illumination, which is especially true where people pass through briefly and infrequently. Painting curbs or steps, installing **retroreflective** or **luminescent** markers, or using light-colored pavement and surfaces are alternatives to permanent lighting in some situations. On trails, people can use red headlamps or flashlights, and on many low-traffic roads, vehicle headlights provide enough illumination for safe travel. The use of shielded vehicle-mounted lights or portable shielded light towers for temporary task lighting also reduces the need for permanently installed light sources.

Wayfinding and tasks can be challenging in areas with **over-illumination** or under-illumination. Over-illumination can create issues for dark adaptation of one's vision. Over-illumination potentially contributes to all types of light pollution (see Section 3.1 for information on light pollution). Avoiding use of permanent lights or using fewer lights (assuming good lighting design and good lighting practices) reduces light pollution affecting ecological resources and humans. It will often save money on energy use, materials, and labor (both for installation and maintenance). For existing lighting systems, simply turning off unneeded lights achieves the same goal. Also, consider whether existing light sources are needed before adjusting or replacing. Where permanently installed lighting is necessary for safety or task performance, careful design can ensure that as little light as possible is used, while providing adequate lighting coverage and illumination.

4.2 Light Only When Needed: Use Lighting Control Technologies

This system allows users to access light when needed without the cost and associated light pollution when the facility is not in use.

The purpose of the second guiding principle is to use adaptive lighting controls and temporary portable lighting sources to provide lighting only at the time the lighting is needed. **Adaptive controls** are electronic or mechanical devices attached to a light to dynamically control the duration, intensity, spectrum, or area illuminated by the lighting. Use of adaptive controls and temporary lighting in most cases substantially reduces the amount of time lights are in use, effectively eliminating the source of light pollution and related effects while also saving energy and money, both through reduced energy costs and extended life of the light sources.

A variety of adaptive controls, such as motion sensors, photo sensors, timers, and dimmers, are available to limit lighting to specified periods when the lighting is needed or to turn lighting on automatically when triggered by the presence of humans. Dim lighting during periods of low human activity. Use lighting controls to turn lights off after business hours, when they are seldom needed. In the absence of automated controls, simply turning lights on only when needed and turning them off when no longer needed is effective and costs nothing.

An **aircraft detection lighting system** (ADLS) is a type of adaptive lighting control for structures taller than 200 ft, including wind turbines, communication towers, and certain electric transmission towers. ADLSs provide radar surveillance of the airspace around these structures and automatically issue signals to activate obstruction lighting when aircraft are detected at a specified distance.

4.3 Light Only Where Needed: Shield Lights and Direct Them Properly

The purpose of the third guiding principle is to direct light only where it is needed, and not elsewhere, by focusing light only on intended surfaces using properly shielded luminaires and, where feasible, other methods, to screen the light from viewers. Using unshielded or partially shielded lights and pointing lights upward, horizontally, at high angles below horizontal, or even downward into rivers, streams, wetlands, and other habitats increases light pollution and may have harmful ecological effects.

Wherever possible, use **fully shielded luminaires**, with additional side shielding. Fully shielded luminaires emit no uplight (i.e., no light is emitted above 90° from horizontal). "Fully shielded" is analogous to a BUG uplight (U) rating of "0" (IES 2020) (see Section 5.1.2 for a description of the IES TM-15-20 BUG rating system).

Consider directing luminaries only at the surfaces requiring illumination (e.g., for task performance) and from an appropriate height to provide the coverage needed without illuminating an unnecessarily large area. These practices limit direct visibility of the light source and the amount of reflected light from the illuminated surface. Additionally, where feasible, place lights so that structures screen the light source or cast light from view.

4.4 Light Color Matters: Select Amber, Orange, or Red Whenever Possible

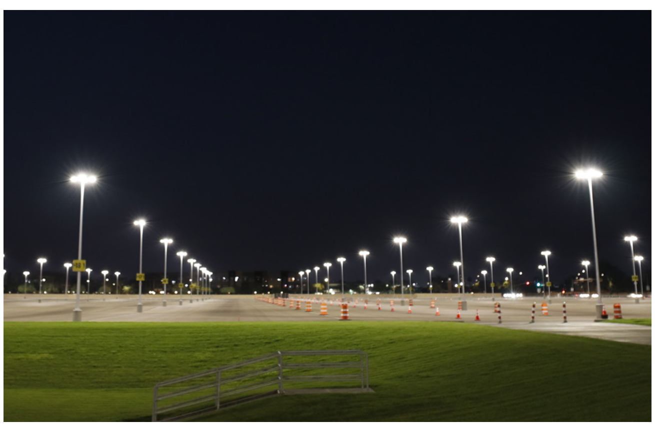
The purpose of the fourth guiding principle is to use light colors that are less disruptive. Warm light colors, such as amber, orange, and red, use longer wavelengths that are less disruptive to humans and wildlife (e.g., melatonin production, dark-adapted vision) and, in general, are dark sky friendly (e.g., less skyglow).

As discussed in Section 3.1.1, blue-rich light (> 3,000 K) generally has greater potential for negative effects than "warmer" color light (< 3,000 K), such as amber or red light. Blue light has the greatest potential for interfering with melatonin production. Insects are preferentially attracted to blue-rich light sources, which can affect development, survival, and reproduction in some insect species. Blue-rich light has a greater effect on skyglow and is more likely to cause disability glare than warmer color light. Shorter wavelength light also degrades **scotopic vision** more than longer wavelength light because the photoreceptors in the eye that are dominant in scotopic vision (the rods) are more sensitive to shorter wavelength light (Motta 2018).

For certain tasks for which accurate color rendition is needed, consider using light with a high **color rendering index** (CRI). CRI values range from 0 to 100, with 100 showing true colors of objects. Lighting with CRI values at 80 or higher are good. The CRI is unrelated to color temperature. For example, lighting products that provide the same color temperature as 2,700 K may have different CRI values.

Correlated color temperature (CCT) or spectral tunable lights offer important opportunities for addressing problems related to light color because they are programmed to adjust color for different tasks or ambient lighting conditions in real time. Theoretically, they could be switched to a brighter and cooler white for specific tasks, and when the task is completed, switched to a dimmer, amber, orange, or red as the default mode where some level of lighting is still needed. Spectral tuning can also be automatically adjusted as human activity decreases, such as during late night hours.

4.5 Use the Minimum Level of Illumination Necessary: Avoid Over-Illumination



This 20-acre parking lot is only open for occasional use yet is brightly lit every night.

The purpose of the fifth guiding principle is to use the lowest possible level of light brightness (lumens) that meets an area's lighting needs; this practice prevents over-illumination. Consider the CRI when accurate color rendition is critical. Over-illumination can make wayfinding and tasks less safe by destroying dark-adapted vision and by causing too much contrast between lit and shadowed areas. It also wastes energy and money, and the excess light may contribute to skyglow, light trespass, and other types of light pollution. Brighter light has greater negative effects on wildlife and human circadian rhythms.

Lighting for facilities and outdoor tasks need not exceed the minimum number of **luminaires**, intensity, and coverage required for safety, basic security, and task requirements. This requires careful design for new lighting systems but can also be achieved for existing lighting systems by simply turning off unneeded lights, installing lights with lower **luminance**, using dimmers to reduce the luminance of existing lights, or adding/improving shielding.

4.6 Use Energy-Efficient Lights and Advanced Lighting Controls: Save Energy While Adding Useful Lighting Capabilities

The sixth guiding principle encourages the use of energy-efficient lighting and advanced lighting controls. When combined with good lighting design and practices, the use of energy-efficient lights and advanced lighting technology can result in improved lighting performance and reduced effects from artificial light at night, while saving energy and money.

Energy-efficient lighting products, such as LEDs, cost less to operate and, if carefully chosen to avoid blue-rich light, can reduce effects on human health, wildlife, and cultural resources. In many situations, new, more efficient lighting pays for itself quickly, because of reduced energy consumption and lower maintenance costs. Advances are not limited to just the lights; a well-designed, shielded luminaire can use a smaller wattage bulb and still be effective. CCT tunable lights can be used to turn off or reduce the **luminance** (and power consumption) of lighting, and their color can be changed as needed, yielding better lighting performance while minimizing energy use.

Good lighting design minimizes both astronomical and ecological light pollution as demonstrated at the Piedras Blancas Light Station and adjacent nautical flagpole, which are unlit to allow the star-filled sky dominate as a dark sky resource.

5. BMPs for Artificial Light at Night on BLM-Managed Lands

This section discusses the range of lighting applications on BLM-managed lands and presents BMPs that BLM staff and operators of facilities or activities can use to minimize light pollution. These BMPs are applicable for any public lands setting, and most could apply in any urban or rural setting, regardless of location in the U.S. or elsewhere. The BMPs are organized by the six guiding principles for minimizing light pollution presented in Section 4, with an additional set of BMPs (presented first) that addresses minimization of artificial light at night for land use planning and project planning.

Lighting applications on BLM-managed lands include (1) lighting for facilities and activities operated or conducted by the BLM, such as campgrounds, interpretive centers, and maintenance and security activities; and (2) lighting for facilities and activities permitted by the BLM but operated or conducted by other government agencies or private developers, such as communication towers, mines, oil and gas production, pipelines, electric transmission, and wind energy facilities. By far the greatest contributor of light pollution on BLM-managed lands are facilities and activities permitted by the BLM and operated by others, because they sometimes include very large industrial facilities that operate at night and typically have relatively high lighting levels. In other cases, they involve very tall structures (200 feet or taller) that require **hazard navigation lighting**, which, while not particularly bright, may be visible for long distances.

The lighting used on BLM-managed lands can be divided into three major types:

1. Lighting for structures such as buildings; transmission, wind, and communication towers; and storage tanks.
2. Lighting for transportation, including roads and paths or trails.
3. Lighting for activities, such as mining or mirror washing at solar power plants.

Although this technical note presents BMPs for all three types of lighting applications, most of the BMPs are either generic good lighting practices or pertain primarily to structure lighting, as this is the most common type of lighting on BLM-managed lands.

The following facilities are commonly found on BLM-managed lands and could be appropriate for application of the BMPs for minimizing sources of light pollution:

- Amphitheaters
- Athletic fields
- Boat docks
- Buildings and structures (e.g., offices, mechanical storage, barns, bunkhouses, cabins, fee stations, fire stations, garages, bathrooms, lighthouses, museums, pump/switch houses)
- Communication towers
- Electrical transmission and substations
- Energy facilities (oil, gas, coal)
- Fuel distribution stations
- Mining facilities
- Parking lots
- Pathways and trails
- Recreational facilities (campgrounds, dump stations, fish cleaning stations, kiosks, picnic areas, shooting ranges)
- Renewable energy facilities (geothermal, solar, wind)
- Roads
- Wareyards (storage and laydown areas)

Activities (such as construction maintenance, oil and gas drilling, hydraulic fracturing, and large-scale recreation at night) and associated areas requiring lighting (such as construction or recreation activity staging areas) are also appropriate for incorporating lighting BMPs.

BMPs are not requirements, and not every BMP listed is appropriate for every project. Some BMPs do not apply in all situations. There may be technical reasons why a specific BMP cannot be implemented. For example, using amber lighting may be ineffective where task requirements require good color rendition. And finally, there may be cost-benefit concerns that might make some BMPs impractical or inadvisable in a particular situation. For example, using tunable CCT lighting controls might not make sense for a single luminaire that is rarely turned on.

In all cases, applicable laws and regulations concerning lighting supersede BMPs that do not achieve those requirements. The local BLM safety manager can help identify safety issues associated with lighting plans or any safety-related requirements that might affect BMP implementation.

5.1 Planning and Design BMPs

The following best practices are best to incorporate early—during land use planning, activity planning, project planning, and project design.

5.1.1 Have a Lighting Plan Prepared by a Qualified Lighting Designer

A qualified lighting designer can best prepare lighting plans for BLM-permitted projects based on resource management objectives (e.g., considering natural, cultural, and historic resources of concern and visitor activities). As early as possible, begin to identify the types and intensity of lighting that will be allowed or needed for a facility or activity area. Sources of light pollution are most easily avoided at the planning and design stage with a carefully considered and well-designed lighting system or retrofit. A lighting plan by a qualified lighting designer will result in efficient operational costs for energy consumption and minimal contributions of light pollution. A detailed lighting plan specifies the following:

1. Appropriate IDA-IES Model Lighting Ordinance (IDA-IES 2011) **lighting zone** performance standard for the application (see Section 5.1.2 for more information).
2. Number of lights; **lumen** output of each; and backlight, uplight, and glare (BUG) ratings (see Section 5.1.2 for more information).
3. Minimum number of luminaires and lights required with the lowest **lumen** output consistent with safe and secure operation of the facility.
4. Lighting layout including luminaire height and aiming (if applicable).
5. Lighting photometric calculations, showing initial **illuminance (light loss factor** = 1) and vertical illuminance at edges of desired illumination areas.
6. Alternatives to lighting (e.g., retroreflective or luminescent markers) in lieu of permanent lighting where feasible.
7. Luminaire design. Luminaires of the proper design, shielded to eliminate uplight (U0), with low glare rating (G0 preferred, G1 maximum), placed and directed to eliminate light trespass (B0 preferred, B1 maximum near edges of desired illumination areas) to offsite locations (see Table 2 in Section 5.1.2 for more information).
8. Light source correlated color temperature (CCT). Lights of the proper CCT or spectral tuning range to minimize night sky and ecological effects (i.e., warm color temperatures—amber, orange, or red).
9. Light source color rendering index (CRI). Lights of the proper CRI to provide accurate color rendering appropriate to the need. CRI is different than color temperature (Kelvin). CRI values range from 0 to 100, with 100 showing true colors of objects. Lighting products may provide the same color temperature yet have different CRI values.
10. Standard operating procedures. Minimization of unnecessary lighting use through adaptive controls such as dimmers, schedule controls (including spectral tuning), timers, motion sensors, and other alternatives to permanent lighting, such as restricting lighting usage to certain time periods and activity levels.
11. Lighting control intent specification, outlining how lighting is controlled throughout the hours of darkness.
12. Any activities that may be restricted or combined to avoid night sky effects.
13. A process for promptly addressing complaints about potential lighting effects.

Notes: Development of a lighting plan must consider safety and security, as well as any federal (e.g., Federal Aviation Administration, Occupational Safety and Health Administration, Mine Safety and Health Administration), state, or local laws and regulations that govern lighting practices at a facility.

The Architecture and Engineering Branch (OC-670) at the BLM National Operations Center is available on a cost reimbursable basis to provide lighting design services, review lighting plans prepared by others, or procure lighting design services for BLM projects. The branch is also available on a cost reimbursable basis to provide consultation and review lighting plans submitted to the field and district offices as a condition of approval of an authorized land use by a non-BLM entity.

The National Fire Protection Association code #101, Life Safety Code, Chapter 7.8 has specific requirements for lighting that provide for safe egress from buildings during emergencies.

Minor installations with facility components and layout that are essentially identical for all applications might not require customized lighting designs; instead, a "preapproved" design from a qualified lighting designer could be used, unless special circumstances (e.g., unusual terrain, habitat for sensitive species) indicate that a custom design would be appropriate.

5.1.2 Select Outdoor Luminaires Certified to Minimize Light Pollution

Select outdoor luminaires that meet the DesignLights Consortium LUNA requirements (DLC 2021) or the Illuminating Engineering Society (IES) "Luminaire Classification System for Outdoor Luminaires" (IES 2020) to minimize light pollution and glare within natural habitat and nighttime environments. The Luminaire Classification System (LCS) provides a **backlight, uplight, and glare (BUG) rating system** (Figure 3). This resource aids the evaluation of an outdoor luminaire's light output—especially the light escaping in unwanted directions.

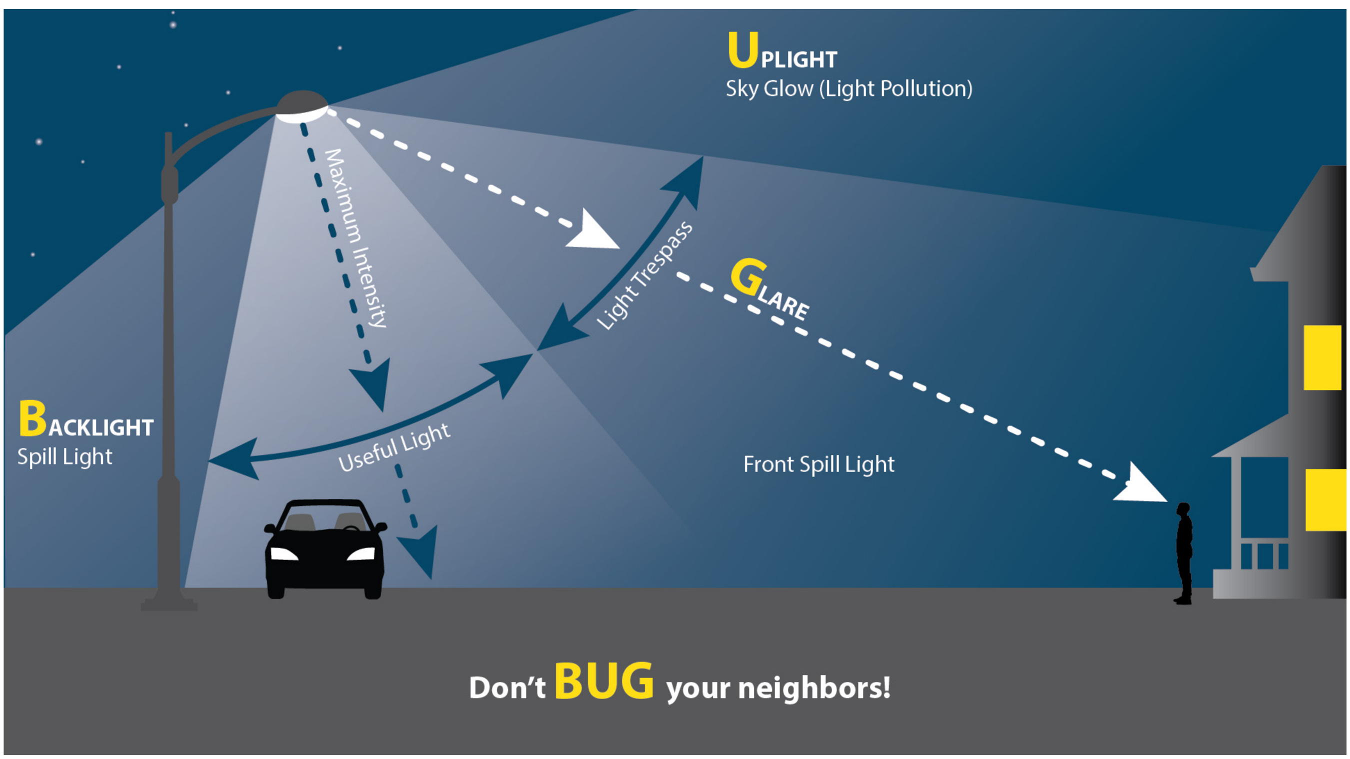
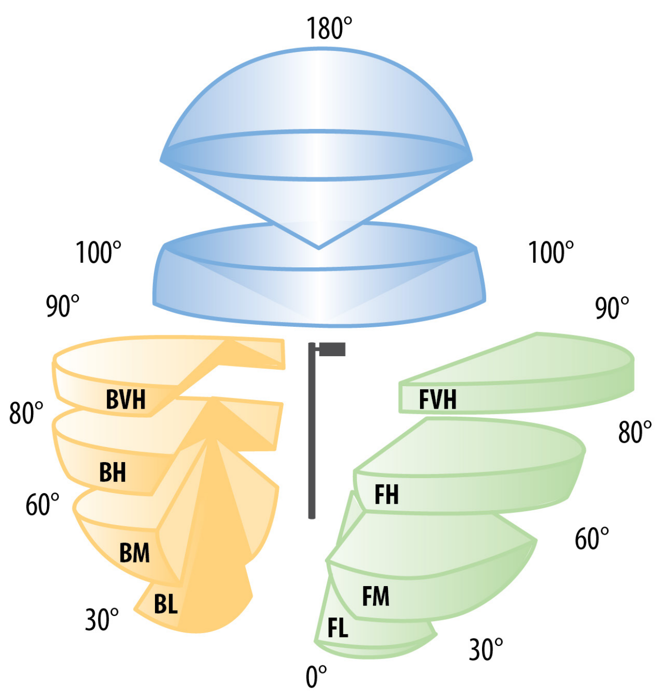


Figure 3. Representation of BUG system and light pollution.

The LCS BUG rating system is based on a sphere around a hypothetical pole-mounted light source in the center of the sphere (Figure 4). The sphere is divided into three sections: **backlight, uplight**, and **glare** (or forward light). The three sections are further divided into zones in which the lumen distribution is rated to determine the light pollution effect of the luminaire. Figure 4 shows a schematic diagram of the BUG rating system, with the different colors representing the division of the light cast from the luminaire into backlight (yellow), uplight (blue), and glare (or forward light) (green) areas. The B, U, and G ratings represent how well the luminaire controls backlight (B), uplight (U), and glare (G), with 0 representing the best control and 5 indicating the worst control. BUG ratings should be used to describe luminaires rather than using the terms "full-cutoff," "semi-cutoff," and "no-cutoff."

The IDA-IES **Model Lighting Ordinance** (MLO) (IDA-IES 2011) is a publication designed to help municipalities develop outdoor lighting standards that reduce light pollution. The MLO identifies performance standards for selecting appropriate luminaires based on their BUG ratings. The MLO uses a system of **lighting zones** (LZs) to identify performance standards for areas with a desired level of lighting (Table 1). The MLO specifies the BUG rating for luminaires to meet the LZ performance standards (Table 2).



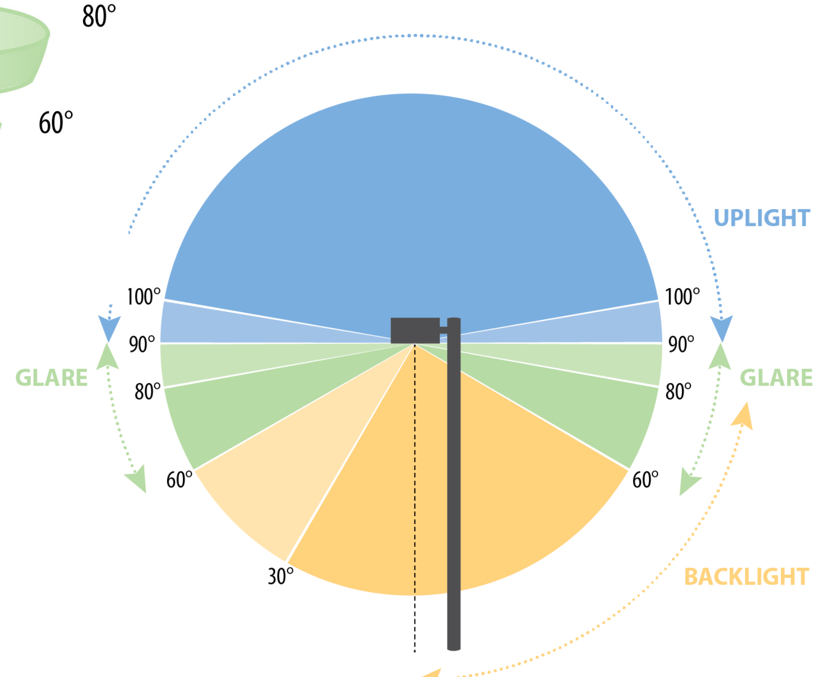


Figure 4. Diagram of the backlight, uplight, and glare (BUG) rating system

Table 1. Descriptions of lighting zone performance standards according to the IDA-IES Model Lighting Ordinance (IDA-IES 2011).

Lighting Zone	Recommended Performance Standard	Notes
LZ0	**No ambient lighting** Areas where the natural environment will be seriously and adversely affected by lighting. Impacts include disturbing the biological cycles of flora and fauna and/or detracting from human enjoyment and appreciation of the natural environment. The vision of human residents and users is adapted to the darkness, and they expect to see little or no lighting. When not needed, lighting should be extinguished.	Lighting zone 0 applies to areas where permanent lighting is not expected and, when used, is limited in the amount of lighting and the period of operation. LZ0 typically includes undeveloped areas of open space, wilderness areas and preserves, areas near astronomical observatories, or any other area where the protection of a dark environment is critical. Special review may be appropriate for any permanent lighting in this zone.
LZ1	**Low ambient lighting** Areas where lighting might adversely affect flora and fauna or disturb the character of the area. The vision of human residents and users is adapted to low light levels. Lighting may be used for safety and convenience, but it is not necessarily uniform or continuous. Most lighting should be extinguished or reduced as activity levels decline.	Lighting zone 1 pertains to areas where low ambient lighting levels are appropriate. These typically include administrative facilities and other commercial or industrial/storage areas typically with limited nighttime activity. May also include the developed areas in recreation and other natural settings.
LZ2	**Moderate ambient lighting** Areas of human activity where the vision of human users is adapted to moderate light levels. Lighting may typically be used for safety and convenience, but it is not necessarily uniform or continuous. Lighting may be extinguished or reduced as activity levels decline.	Lighting zone 2 pertains to areas with moderate ambient lighting levels. These typically include industrial facilities in an area otherwise zoned LZ0 or LZ1.

Table 2. Maximum allowable BUG (backlight, uplight, and glare) ratings for lighting zones (LZs) 0 to 2.
Source: IDA-IES Model Lighting Ordinance (IDA-IES 2011).

	MLO Lighting Zone		
	LZ0	**LZ1**	**LZ2**
Backlight Rating			
> 2 mounting heights from edge of desired illumination area	B1	B3	B4
1 to 2 mounting heights from edge of desired illumination area and ideally oriented	B1	B2	B3
0.5 to 1 mounting heights from edge of desired illumination area and ideally oriented	B0	B1	B2
< 0.5 mounting height to edge of desired illumination area and properly oriented	B0	B0	B0
Uplight Rating	U0	U1	U2
Allowed percent light emission above 90% for street or area lighting	0%	0%	0%
Glare Rating			
Any luminaire not ideally oriented with 1 to < 2 mounting height to any edge of desired illumination area	G0	G0	G1
Any luminaire not ideally oriented with 0.5 to 1 mounting height to any edge of illumination area	G0	G0	G0
Any luminaire not ideally oriented with < 0.5 mounting height to any edge of illumination area	G0	G0	G0

Example of Applying the BUG Rating System (see Table 2)
In an area where LZ0 lighting standards are judged appropriate, the BUG rating for a luminaire under consideration might be rated: B0-U0-G1. A luminaire rated B0-U0-G1 would provide excellent control of backlight and uplight and good control of glare. However, because the glare rating of G1 is greater than G0, as indicated in Table 2, the luminaire does not meet the standard for LZ0 and so would not be suitable for use in areas where maintaining a very low level of light is important.

The Luminaire Classification System, MLO, and Illuminating Engineering Society Recommended Practices[7] provide guidance on selecting luminaires and appropriate lighting levels for specific applications. Choosing the appropriate LZ for an area allows enough lighting for tasks while minimizing the overall amount of light pollution generated.

[7] IES Recommended Practices publications include the following: RP-33-14, "Lighting for Exterior Environments"; RP-7-17, "Recommended Practice for Lighting Industrial Facilities"; RP-8-18, "Recommended Practice for Design and Maintenance of Roadway and Parking Facility Lighting"; and RP-39-19, "Recommended Practice: Off-Roadway Sign Luminance." Relevant IES guides include: DG-22-12, "Sustainable Lighting: An Introduction to the Environmental Impacts of Lighting"; DG-29-11, "The Commissioning Process Applied to Lighting and Control Systems"; G-1-16, "Guide for Security Lighting for People, Property, and Critical Infrastructure"; LEM-3-13, "Upgrading Lighting Systems in Commercial and Institutional Spaces"; and LEM-7-13, "Lighting Controls for Energy Management."

The correct application of the LCS BUG rating system in combination with MLO lighting zone-based performance standards helps minimize ecological and human effects and is likely to save money, energy, and pollution associated with the generation of wasted energy.

While reviewing project plans, the BLM can consider the following performance standards from the LCS and MLO. Details are provided in Table 1:

- IDA-IES lighting zone LZ0 performance standard would presumably correspond to most undeveloped BLM-managed lands; it indicates an intrinsically dark area without permanent lighting.
- IDA-IES lighting zone LZ1 performance standard would correspond to areas occupied by or planned for BLM or BLM-permitted administrative facilities and related infrastructure.
- IDA-IES lighting zone LZ2 performance standard would correspond to areas occupied by or planned for major BLM-permitted facilities and related infrastructure.

The requirements of applicable laws and regulations supersede the recommended performance standards of any zone. The recommended lumen allowances for each zone are available in Chapter 9 of the MLO.

5.1.3 Consider Using an Energy Savings Performance Contract (ESPC) for Lighting

Energy savings performance contracts (ESPCs), provided through the Department of Energy (DOE) Federal Energy Management Program, allow federal agencies to procure energy savings and facility improvements with no upfront capital costs or special appropriations from Congress. An ESPC is a partnership between an agency and an energy service company.

The U.S. Department of Energy's Federal Energy Management Program helps federal agencies procure energy savings and facility improvements.

After being selected for a potential award, the energy service company conducts a comprehensive facility energy audit and identifies improvements to save energy. In consultation with the agency, the energy service company designs and constructs a project that meets the agency's needs and arranges financing to pay for the project.

The energy service company guarantees that the improvements will generate enough energy cost savings to pay for the project over the term of the contract. After the contract ends, all cost savings accrue to the agency. The agency is responsible for contract administration for the entire term of the contract.

Using ESPCs for lighting systems on BLM facilities, where appropriate, can reduce energy costs while reducing effects from artificial light at night, and the energy service company designs and builds the lighting system.

5.1.4 Take Advantage of DOE Assistance for Outdoor Lighting

The DOE Office of Energy Efficiency and Renewable Energy (EERE) aids agencies and municipalities in lighting programs designed primarily to decrease energy usage but that also have night sky and environmental protection as objectives. For example, EERE's Federal Energy Management Program works with federal agencies to meet agency energy-related goals, identify affordable solutions, facilitate public-private partnerships, and provide energy leadership to the country by identifying government best practices. Taking advantage of DOE assistance can potentially reduce cost of retrofitting lighting or adding new lighting systems.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The DOE Office of Energy Efficiency and Renewable Energy aids agencies and municipalities in lighting programs.

5.1.5 Consider Nearby Astronomical Observatories before Installing Lighting Systems

Light pollution can negatively affect research activities at astronomical observatories.

Consider nearby astronomical observatories before installing outdoor lighting systems on BLM facilities or BLM-permitted projects. Observatories and the research conducted at them are very sensitive to light pollution, especially skyglow. This practice fosters observatory activities and recognizes human value for stargazing and astrotourism.

5.1.6 Educate Stakeholders Concerning Night Sky and Darkness Resources

Kurt Kuznicki, Friends of Nevada Wilderness

The Massacre Rim Wilderness Study Area in Nevada is designated as an International Dark Sky Sanctuary by the International Dark-Sky Association.

Education increases awareness about the value of darkness, sources of light pollution, and steps that can be taken to reduce light pollution. Development of information programs about night skies/darkness resources may help curtail overall contributions to light pollution, benefiting wildlife and humans. Information programs can also provide valuable science, technology, engineering, and mathematics (STEM) education opportunities.

The International Dark-Sky Association founded the International Dark Sky Places Program in 2001 to encourage communities, parks, and protected areas around the world to preserve and protect dark sites through responsible lighting policies and education. There are five different types of designations through the program: International Dark Sky Community, International Dark Sky Park, International Dark Sky Reserve, International Dark Sky Sanctuary, and Urban Night Sky Place. Designation is based on a rigorous application process that requires applicants to demonstrate robust community support for dark sky protection. International Dark Sky Places designations do not have legal or regulatory authority and do not impose any legal authority over agency plans or decision processes. These designations demonstrate a commitment to preserve and protect night skies by encouraging responsible lighting policies and public education.

As BLM offices work on International Dark Sky Places certification proposals with their partners, it is recommended that notice is made to BLM Headquarters. Pioneer work on this topic includes the BLM-managed Massacre Rim Wilderness Study Area that is an International Dark Sky Sanctuary (IDA 2019a) and Grand Canyon-Parashant National Monument (jointly managed by the BLM and the National Park Service) that is recognized as the Parashant International Night Sky Province-Window to the Cosmos (IDA 2014; NPS 2016b).

Tyler Nordgren

The International Dark-Sky Association has designated the Grand Canyon-Parashant National Monument as the Parashant International Night Sky Province-Window to the Cosmos.

5.1.7 Keep Informed about Lighting Best Practices

Lighting best practices are expected to evolve as lighting technology and the effects of artificial light at night are better understood. Keeping up with developments can result in better decision making when it comes to choosing new lighting systems or retrofit strategies.

Notes: A technical memorandum by the Illuminating Engineering Society (IES), titled "Description, Measurement, and Estimation of Sky Glow," describes the causes, characteristics, and potential impacts of human-caused skyglow and provides current methods for quantification and control (IES 2021). The IES and IDA websites and publications and lighting technology conferences are useful sources for learning about new technology and practices.

5.1.8 Identify Light-Sensitive Receptors

Maintain awareness of groups of people, plant and animal species, activities, and cultural and historic sites that are sensitive to light and likely to be affected by it as part of BLM facilities or BLM-permitted projects or activities. These sensitive receptors can help the BLM recognize appropriate or improved project design and land management planning practices.

Notes: For some plant and animal species occurring on or near BLM-managed lands, specific information about light sensitivity may be lacking. However, this is a robust and active area of research, and new information is routinely available.

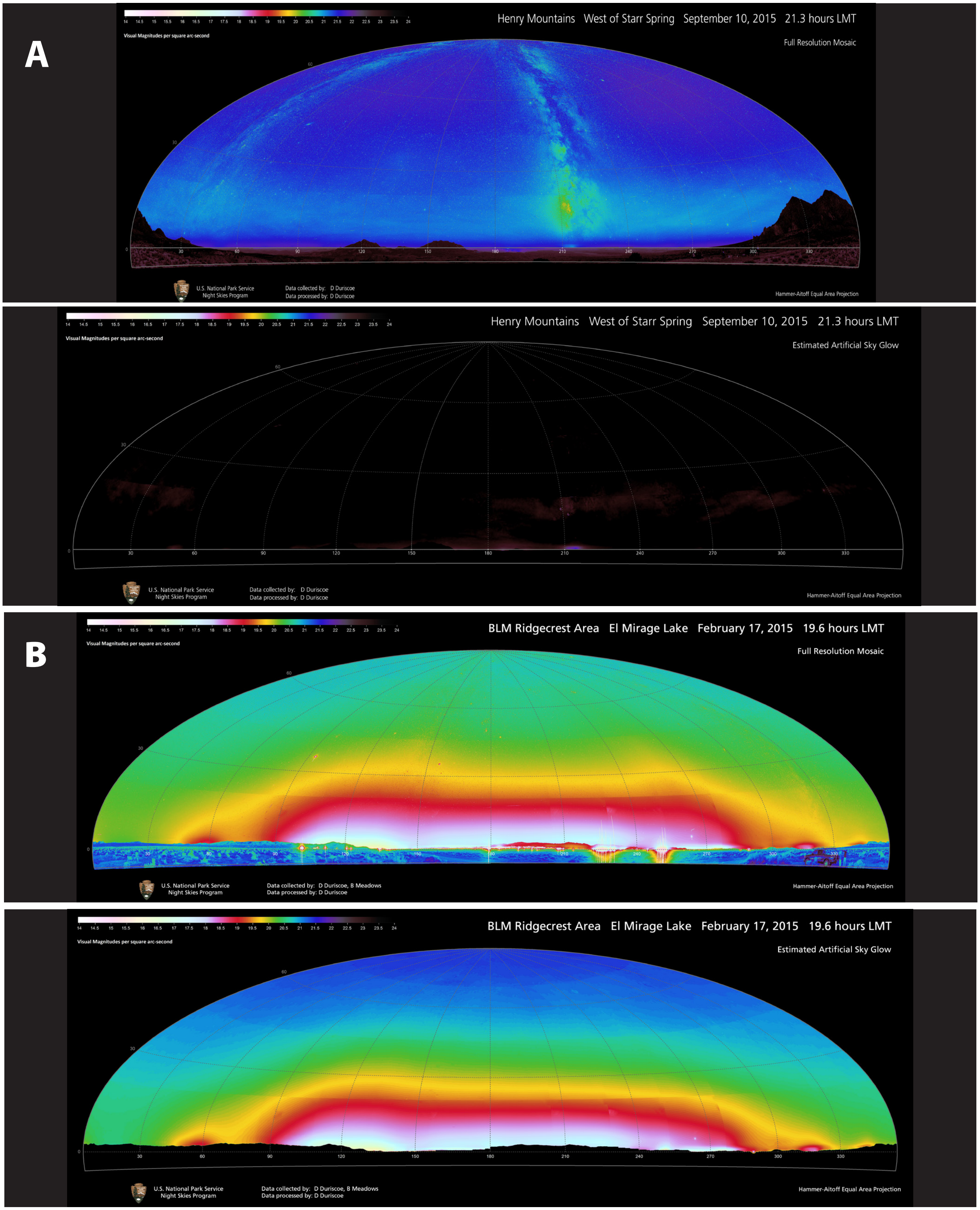
5.1.9 Conduct a Baseline Study of Existing Light Pollution and Night Sky Conditions

An initial step for any BLM-managed area where the naturally dark environment is important is to conduct a baseline study of existing light pollution and night sky conditions prior to any proposed development. Such a study provides a sound scientific basis for

The California leaf-nosed bat is listed as a sensitive species by the BLM.

resource quality and impact assessment needed for monitoring. The baseline study typically assesses skyglow; light trespass from directly visible light sources; and instances of glare, light clutter, and over-illumination. To the extent possible, such studies also identify sources of light pollution and determine their location (whether within or outside the boundaries of BLM-managed lands).

Notes: It may be necessary to consult or collaborate with third parties to design and conduct the baseline study. A method for assessing light pollution using commercially available digital single-lens reflex (DSLR) cameras and software is discussed by Jechow et al. (2019). The Utah Community Development Office's Dark Sky Assessment Guide, while intended primarily for communities, is a useful resource for designing and administering a baseline study of night sky pollution and night sky conditions (Utah Community Development Office 2019).



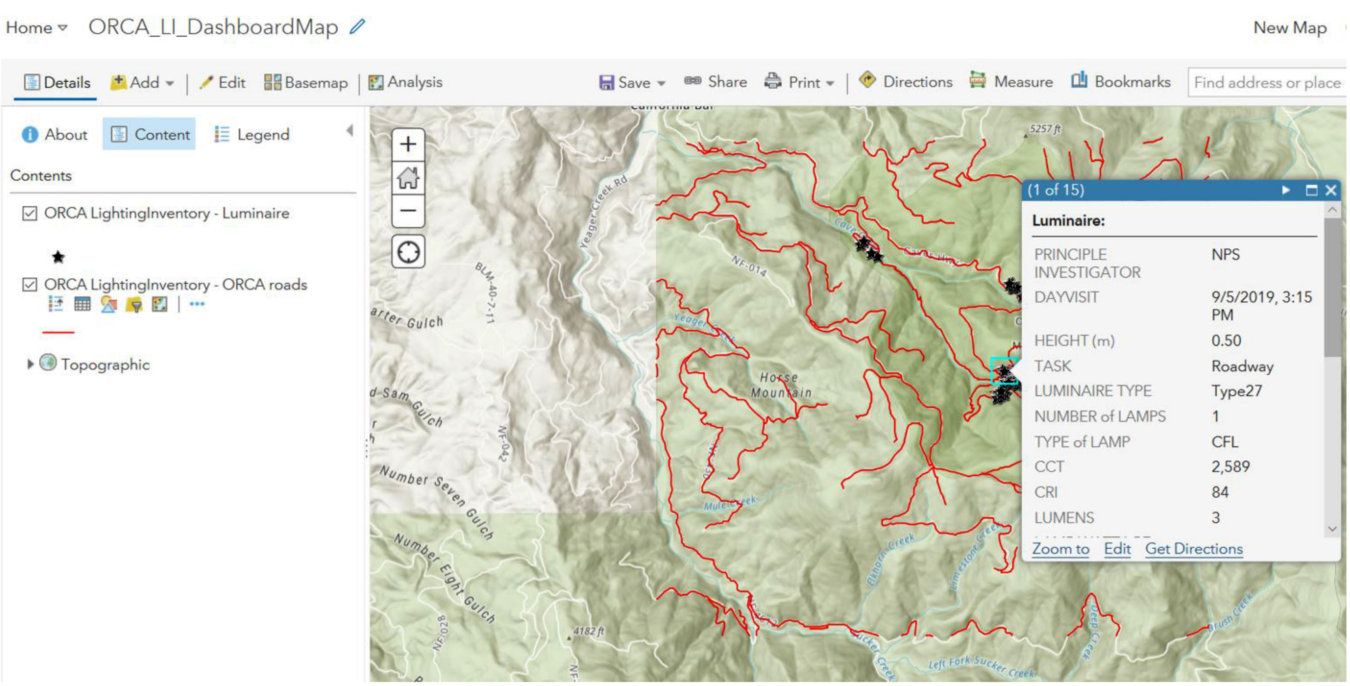
These two photo pairs compare natural and artificial light sources combined (top photos) and natural light sources only (bottom photos) over (A) the Henry Mountains in Utah and over (B) El Mirage Lake in California. The skyglow over the Henry Mountains is due to celestial light. In contrast, the skyglow over El Mirage Lake is nearly all due to artificial light.

5.1.10 Conduct an Inventory of Existing Lighting When Retrofitting

When implementing artificial light at night BMPs at existing facilities, an inventory is essential to identify opportunities for changing lighting equipment and practices to reduce light pollution, quantify cost and benefits for BMP implementation, and measure results. At a minimum, an inventory of existing lighting records the location, luminaire type, light source type, luminaire lumen output, color temperature, wattage, mounting height and aiming (if applicable), adaptive controls (e.g., timers), any shielding, and the lighting purpose/application for each luminaire in the inventory. Other data might also be useful to record. Daytime photographs of the luminaires are helpful as well. Luminaire GIS tags can help develop location maps of lighting equipment.

Notes: The National Park Service has developed a GIS-based outdoor lighting practices and inventory application, which can be used for NPS units with assistance from the NPS Natural Sounds and Night Skies Division (Pipkin and Anderson 2020). The template geodatabase includes a data dictionary to ensure consistency and instructions for collecting information. The inventory records physical properties about each luminaire, their location, and the light characteristics. The inventory data are useful for facility maintenance tasks and supporting IDA Dark Sky Places certification.

The Utah Community Development Office's Dark Sky Assessment Guide, while intended primarily for communities, is a useful resource for designing and administering a lighting inventory (Utah Community Development Office 2019).



A screen capture of the National Park Service GIS-based outdoor lighting practices and inventory. The inventory records luminaire data important to artificial light minimization as well as luminaire locations.

5.1.11 Establish a Lighting and Light Pollution Monitoring Program

A monitoring program for the collection and analysis of lighting and light pollution data protects against "ad hoc" lighting additions and poor lighting practices, identifies potentially underperforming BMPs, and helps detect malfunctioning lighting and controls. Monitoring light pollution over time is also essential for resource quality assessment.

Notes: Staff effort and equipment are required to conduct monitoring. A method for assessing light pollution that could be used for monitoring purposes is discussed by Jechow et al. (2019); however, it does not include a monitoring protocol.

A scientist in the field uses photographic equipment to assess night sky darkness.

5.2 BMPs for Lighting Only If Needed

The following BMPs address lighting avoidance where possible. Note that the BLM cannot control skyglow from distant sources or light trespass from neighboring areas.

This is Vista Point in the Santa Rosa and San Jacinto Mountains National Monument, which shows a stark contrast of unlit landscape against the developed Coachella Valley.

5.2.1 Critique New or Evaluate Existing Lighting Systems

Assess all sources of illumination and remove those that do not serve an operational, safety, or security need. Consider if a light is necessary to maintain when replacement is needed. Assess the level of light necessary and the position of lights, their brightness, and color temperature. Elimination of unnecessary lights can provide immediate relief from environmental light pollution, benefitting both wildlife and humans. It also saves money, reduces wasted energy, and may improve safety and security in overlit/glare situations.

Notes: For determining minimum safe lighting levels, engaging a qualified lighting designer may be necessary, especially for public use areas. Ensure lighting essential for safety/security is maintained.

Use of an energy savings performance contract (see Section 5.1.3) may help reduce costs associated with implementing this BMP.

5.2.1.1 Consider Essential Light Sources Associated with a Built Environment

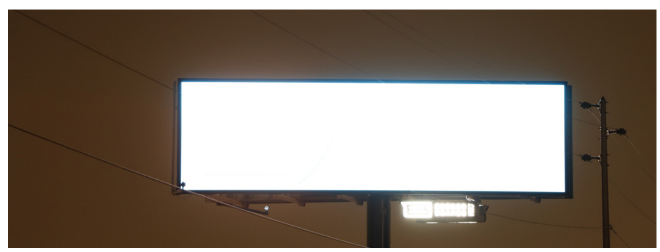
Consider alternatives to permanent lighting through scheduling or relocation of tasks. For example, scheduling different outdoor tasks to be concurrent instead of at different times can reduce the duration of lighting. Relocating parking to areas immediately adjacent to a structure may allow light sharing or eliminate the need for path lighting. These practices help limit light pollution.

Notes: Modifying the built environment, relocating tasks, and altering work schedules requires planning, potentially additional spending on infrastructure, and may not be feasible in some situations. Where lighting is necessary to identify structures, stairs, pathway markers, etc., determine if nonillumination solutions are adequate, such as painting curbs or steps, using retroreflective or luminescent markers, or using light-colored pavement and surfaces. Signs and markers are more visible with retroreflective or photoluminescent coating. This practice is low tech by not requiring a power source, reduces ecological and human effects, and saves installation and maintenance costs.

The use of nonillumination solutions in lieu of permanent lighting is only feasible where it can be done safely and consistent with safety laws and regulations. It may not be appropriate in some situations. Depending on the technology used, some maintenance may be required (e.g., replacement of reflective tape, repainting).

5.2.1.2 Consider Nonessential Light Sources Associated with a Built Environment

Lighting is often used to create aesthetic appreciation or draw attention. Often, lights are used to highlight objects or architectural features. Electronic signs are appearing with more frequency in less developed and rural areas with the intent of capturing attention. Large permanent electronic message centers or electronic billboards are an example. Electronic message centers are composed of a matrix of LED lights that are used to aim an image or message outward. The horizontal and upward light emissions cannot be shielded. Based on research by the IDA, electronic billboards can be up to 10 times brighter at night than traditional billboards. These signs can cause issues with dark adaptation and glare. The IDA has developed guidelines to minimize potential light pollution. "The primary method of mitigation is through luminance control, limiting hours of operation, and avoiding locating signs adjacent to sensitive areas or residential areas" (IDA 2019b).



Roadside electronic message center in Arizona.

5.2.2 Consider Dark Adaptation Needs of People and Wildlife

Measures to promote dark adaptation for people and wildlife may include lighting upgrades (retrofitting) where there is evidence of people and wildlife being affected by existing artificial light. Adaptation considerations should be applied at all stages of management, from the development of planning schemes to the design, approval, and execution of individual developments or activities, through retrofitting of light fixtures and management of existing light trespass.

Measures to aid dark adaptation for people and wildlife include the following principles:

- Design should start with natural darkness and only add light for specific purposes.
- Use adaptive light technology controls to manage light timing, intensity, and color.
- Light only the object or specific area and ensure that lights are placed close to the ground and the light source is directed and shielded to avoid light trespass.
- Use low-intensity lighting appropriate for the specific intent.
- Understand the color values and material sources within the area being lit and the potential for light absorption and reflectivity. Where possible, use nonreflective, dark-colored surfaces.
- Use lights with an amber, orange, or red color temperature (< 3000 K).

5.2.3 Encourage Alternatives to Permanent Lighting for Infrequent Lighting Needs

Headlamps or flashlights (preferably with red lights) can be used in lieu of permanent lighting where feasible and safe to do so.

Where lighting needs are infrequent, minimal, and temporary, consider using headlamps or flashlights (preferably using red light) in lieu of permanent lighting. Headlamps or flashlights are an alternative to permanent lighting for infrequent task work where doing so is consistent with safety laws and regulations. This practice greatly reduces ecological and human effects, saves the cost of installing and maintaining permanent lighting, and reduces wasted energy.

> **Notes:** The use of headlamps or flashlights in lieu of permanent lighting is not feasible where it would violate safety laws and regulations and may be inadvisable in areas where human-made hazards are prominent.

Use vehicle-mounted lights or portable light towers for temporary task lighting. If possible, such lighting should use low correlated color temperature (CCT) and should be equipped with hoods or louvers and be aimed toward the ground to avoid causing glare and skyglow. As is the case for permanent lighting, it is recommended that luminaires meet the IES TM-15-20 BUG ratings (IES 2020) as installed for the applicable lighting zone performance standard (see Sections 5.1.2 and 5.4.5). Properly used, portable lighting provides lighting only where and when needed, thus reducing effects on wildlife and humans. Over time, it will usually result in cost savings and reduce wasted energy.

> **Notes:** Vehicle-mounted lights or portable light towers may contribute light pollution that is greater than properly installed permanent lighting. The difference is that the duration would be short and more localized. Some tasks may have lighting requirements that cannot be met by portable lighting units.

Portable light tower.

At Homestead National Historical Park, most visitor center lighting is turned off at night.

5.3 BMPs for Lighting Only When Needed

The following BMPs address lighting only when needed for safety, security, and task completion.

5.3.1 Use Lighting Controls to Limit Lighting to Specified Periods

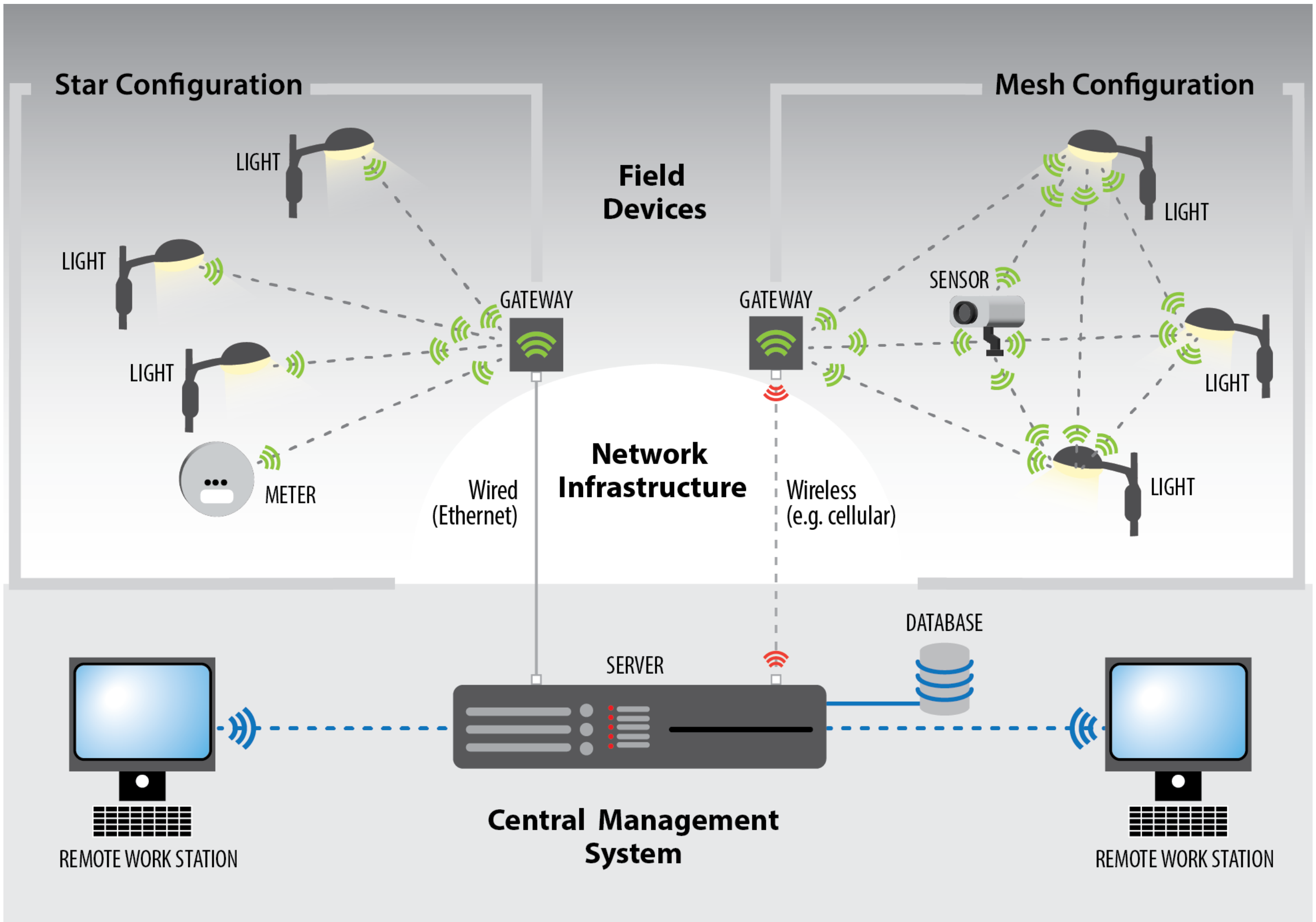
Ensure that any lights that are not motion-activated or otherwise automatically controlled are turned off when not in use (USFWS 2016), especially architectural lighting, upper story interior lighting, and lobby or atrium lighting. This practice potentially reduces all types of light pollution, benefitting both wildlife and humans. It also saves money and reduces wasted energy.

Notes: To turn lights off when not needed, keep the lighting controls accessible and understandable to the users.

Additionally, use lighting controls, such as motion sensors (both interior and exterior), infrared sensors, photo sensors, radar sensors, and timers, to limit lighting to specified periods when it is needed, to turn lighting on automatically when triggered by the presence of humans, and to dim/turn off lighting when there is little or no activity. This practice can reduce effects on wildlife, reduce aesthetic and astronomical effects, save money, and reduce wasted energy. Lighting controls can also change the light source spectrum through spectral tuning for certain times of the night or seasonally (see Section 4.4)

Notes: Motion detectors have a variety of capabilities, so choose devices carefully for the intended application. The user can generally adjust the duration of the lighting once triggered. The lighting should stay on no more than 5 minutes before the light is again switched off. Motion detectors have limited distance ranges and are subject to accidental "tripping" by animals. Generally, the user can adjust the sensitivity threshold at which the sensor triggers. Ensure the motion sensor is pointed at the proper location to trigger the light. Maintain and check motion sensors periodically for proper operation. Dusk-to-dawn lighting controlled by photocell alone is not recommended where required for safety.

Artificially illuminated areas may cause some bats to delay emergence from roosting sites.



Pacific Northwest National Laboratory

Networked outdoor lighting control systems used with sensors and timers can limit lighting to the times needed.

5.3.2 Switch Off or Dim Lighting during Times of Critical Biological Activity

Switch off or dim lighting during high biological activity, such as during foraging, breeding, or dispersal/migration. This practice will reduce effects on wildlife.

Notes: Some facilities are unable to lower/restrict lighting because of safety/security concerns or task requirements, especially if already implementing effective lighting BMPs. Manual lighting control is an option in many cases.

5.3.3 Include Lighting Season/Date Restrictions in Operations Permits

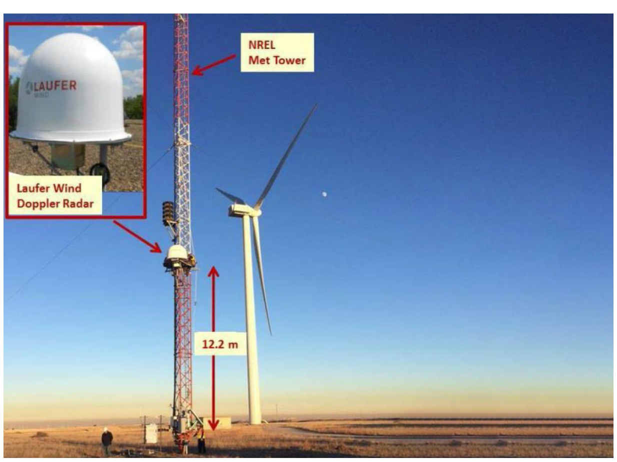
Limiting when locations may be illuminated by seasons or periods of human occupancy protects resources. Consider plant and animal needs too (e.g., bird migration) or periods of concentrated human use (e.g., historical reenactments on historic trails). These actions will protect ecological processes dependent on natural night darkness as well as heritage values.

Notes: Season/date restrictions may impede certain activities from occurring at night. Dependent on the purpose and need of the permit/activity, this may increase the need for discussions to make such decisions and to include appropriate planning and coordination.

5.3.4 Use Aircraft Detection Lighting System (ADLS) Technology for Hazard Navigation Lighting

Where approved by the FAA, aircraft detection lighting system (ADLS) technology is an option for aviation obstruction lighting on structures taller than 200 ft (USFWS 2021). An ADLS is a radar-based obstacle avoidance system that activates aviation obstruction lighting only when an aircraft is proximate to an obstruction on which this technology is mounted, such as a wind turbine. The obstruction lights are inactive when aircraft are not in proximity to the obstruction. The use of ADLS technology greatly reduces the negative aesthetic effects of lighting from tall structures and should also reduce avian mortality. It also reduces wasted energy and prolongs the life of obstruction lighting.

Notes: ADLS technology costs substantially more to purchase and install than conventional "always-on" lighting. Consider laws and regulations from the FAA and other agencies that govern lighting practices when designing facility lighting. Only ADLS technology that meets the requirements of Chapter 14 of FAA Advisory Circular 70/7460-1L, "Obstruction Marking and Lighting" (FAA 2015) should be used. FAA consultation may be required or desirable in the early stages of facility lighting design. An ADLS may be inappropriate in some situations (e.g., when the facility is located close to an airport).



Federal Aviation Administration

An ADLS radar unit mounted on a meteorological tower at a wind energy facility.

5.4 BMPs for Lighting Only Where Needed

The following BMPs address directing lighting only where needed for safety and task completion.

5.4.1 Direct Light Only Where It Is Needed

Luminaires should be selected, sited, and the light they produce directed so that they illuminate only the area needed to support a particular task (e.g., parking, driving, walking, working). All light directed where unneeded is wasted light that may cause various types of light pollution. Use luminaires that meet the IES TM-15-20 BUG ratings (IES 2020) for the applicable lighting zone performance standard (see Sections 5.1.2 and 5.4.5). Directing light only where it is needed reduces offsite light trespass and glare and may also decrease skyglow and light clutter. It may also improve safety and security in over-lighted/glare situations and save energy that would otherwise be wasted.

Notes: Some lights cannot be pointed in a particular desired direction because of the luminaire design. These lights should be avoided, where possible. Modern LED luminaires can often be aimed with great precision.

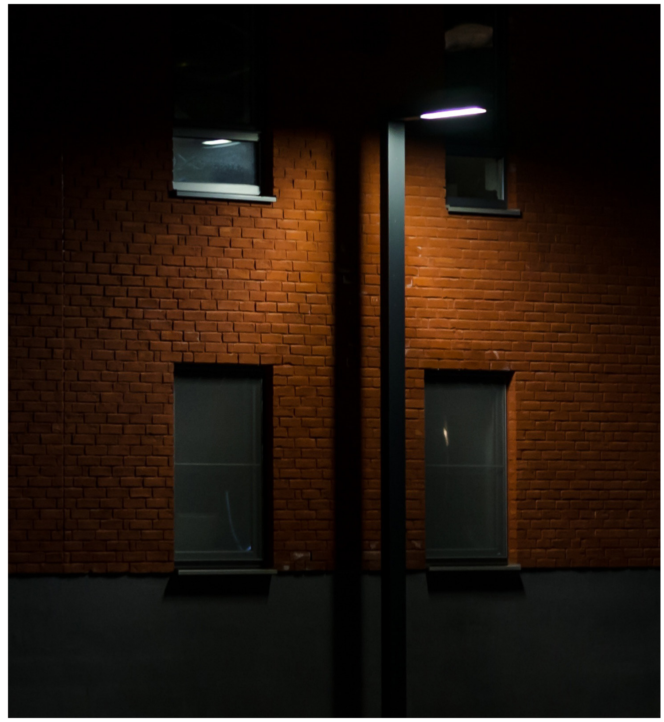
This plaza at the Lowell Observatory is properly lit to provide enough light where it is needed for safe enjoyment of the outdoor area and to navigate to adjacent buildings and parking areas.

5.4.2 Do Not Aim Lights Upward, Horizontally, or at Large Angles from the Ground

Lights aimed into the night sky are a major source of skyglow. Lights that are aimed horizontally, or nearly so, produce more skyglow at long distances than lights aimed upward, because the light travels through a longer distance of atmosphere and thus encounters more scattering particles. Lights aimed at a large angle from vertical may also greatly increase light trespass and glare. It is recommended that luminaires meet the IES TM-15-20 BUG ratings (IES 2020) as installed for the applicable lighting zone performance standard (see Sections 5.1.2 and 5.4.5). Aiming lights downward (e.g., on drilling rigs) reduces light trespass, glare, and skyglow. It may also improve safety and security in over-lighted/glare situations and reduce shadowing.

Notes: The "Luminaire Classification System for Outdoor Luminaires" (IES 2020) specifies the amount of light allowable in each zone for a given BUG rating, including high angle zones (front high, front very high, back high, and back very high zones), as shown in Figure 4 in Section 5.1.2. The amount of light emitted in each of these zones is often found in luminaire specifications. Aiming lights straight downward is impossible in some situations. Avoiding uplight does not ensure that sensitive habitats are protected from adverse impacts. Do not point lights downward into rivers, streams, wetlands, and other sensitive habitat areas.

These horizontally aimed floodlights cause skyglow, light trespass, and glare.



Downward directed lights reduce skyglow, light trespass, and glare.

5.4.3 Re-Aim Existing Lights to Illuminate Task Targets

Existing lights may be improperly aimed, either without awareness or inadvertently. After careful consideration of lighting needs for an illuminated area, ensure lights are aimed properly to illuminate task targets. This may reduce light trespass and glare and may improve safety by providing better task lighting, as long as lights do not over-illuminate the target.

Notes: Some lights cannot be re-aimed. Others can be re-aimed at the task area, but if the task area is too far from the light source, the light may point at a high angle from the ground surface, which could increase skyglow, light trespass, and glare.

5.4.4 Use Dark Sky-Compliant Luminaires

Use dark sky-compliant luminaires or luminaires designed to reduce environmental effects. A properly designed and installed lighting fixture that follows the six guiding principles provided in Section 4 is considered dark sky friendly.

Notes: A growing number of organizations review and certify lighting products as "wildlife friendly" or more generally as "night sky friendly." Examples include the IDA's Fixture Seal of Approval program, the Florida Fish and Wildlife Conservation Commission's Certified Wildlife Lighting program, and the DesignLights Consortium's LUNA requirements that establish criteria for outdoor lighting at night.

5.4.5 Use Luminaires with an IES TM-15-20 BUG Rating System Uplight (U0) Rating

Use luminaires with a BUG (U0) rating (formerly referred to as full-cutoff luminaires) for all permanent lighting, except as required to meet the minimum safety requirements (e.g., collision markers required by the FAA, other emergency lighting triggered by alarms). These luminaires do not emit light above the horizontal, thus substantially reducing skyglow and potentially light trespass. Additional side shielding further reduces skyglow and light trespass.

BUG is an acronym for backlight, uplight, and glare. The BUG rating system replaces the "cutoff" system. The BUG rating system is a tool to quantitatively evaluate the light output of an outdoor luminaire and, in particular, light escaping in unwanted directions. The system is based on a sphere around a hypothetical pole-mounted light source in the center of the sphere (see Figure 4 in Section 5.1.2). The sphere is divided into three sections: backlight (yellow in Figure 4), uplight (blue in Figure 4), and glare (or forward light) (green in Figure 4). The three sections are further divided into zones in which the lumen distribution is rated to determine the light pollution effect of the luminaire.

The BUG rating system is particularly helpful for selecting luminaires where directional lighting is a concern. For example, it is usually desirable to have very low backlight (B) ratings for lights along the edges of illuminated areas (to avoid light trespass into adjacent dark areas), while higher backlight ratings are appropriate for lights in the middle of a parking lot.

Notes: Luminaires with a BUG U0 rating can still cause substantial light trespass and glare. To reduce these effects, use luminaires with low BUG ratings for backlight (B) and glare (G). Ensure the luminaire is mounted properly and not tilted, as a tilted luminaire may cast light above 90 degrees and thus no longer achieve a U0 rating.

5.4.6 Retrofit Existing Poorly Shielded Lights with Luminaires with a BUG U0 Rating

It is recommended to replace existing unshielded or partially shielded luminaires with luminaires with a BUG U0 rating and low B and G (G0 preferred, G1 maximum) ratings to reduce skyglow, light trespass, and glare (Table 2). Photometrically test retrofitted lights to ensure the BUG rating of each specific luminaire type.

5.4.7 Where Necessary, Install Customized Shielding

Install customized shielding where necessary so luminaires do not emit light above the contour of the land surface and cause light trespass. This is particularly important for lights installed on hilltop or sloped locations (especially on poles) that may emit light toward lower elevations, even if they have **fully shielded luminaires** installed horizontally. Where needed, this practice reduces light trespass and potential for glare. Additional side shielding further reduces skyglow and light trespass.

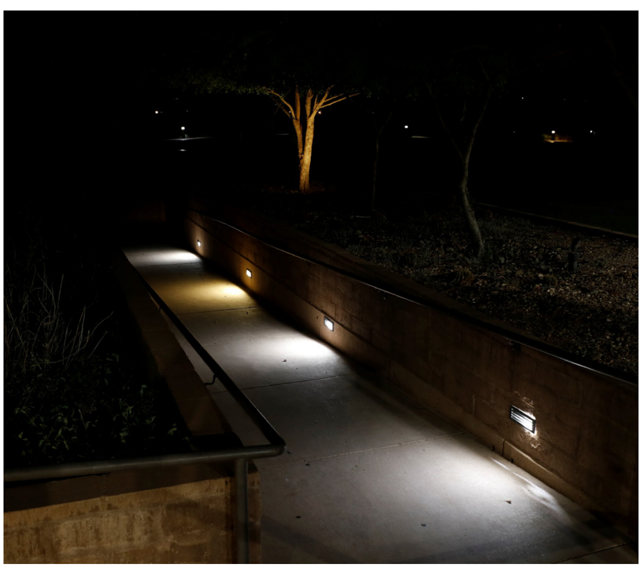
Notes: Use only original equipment manufacturer-approved shields. Modifications not approved by the manufacturer may void the product warranty, cause damage to the luminaire, or present a hazard. For example, improperly installed "homemade" shields on lights may compromise the thermal mitigation of luminaires, creating a fire hazard.

5.4.8 Use Low-Height, Fully Shielded Step or Path Lights

Where lighting is needed for walking paths and stairways, use low-height, fully shielded step or path lights. This practice reduces light trespass and potential for glare.

Asaph441

Low-height, fully shielded path lighting.



Shielded ramp lighting. Notice the different colored light and the slight light bleed due to installation against a rough surface. Routine maintenance is important to ensure lighting plans are followed as intended.

5.4.9 Install Window Coverings Inside Buildings

Install window coverings to prevent light spill at night from inside buildings, regardless of room occupancy (USFWS 2016). This practice reduces light trespass and glare potential and reduces attraction to wildlife. It also reduces heat loss in cold weather and reduces cooling costs in hot weather, thus saving money, reducing wasted energy, and improving privacy.

Notes: For effectiveness, use window coverings on a regular basis. The use of occupancy sensors along with window coverings helps if occupants leave lights on and forget to use the window coverings.

5.4.10 Mount Lights at the Proper Height

It is important to mount lighting at the proper height. Luminaires mounted too high cast light onto a larger area than necessary and may be too dim, such that brighter lighting is needed. Luminaires mounted too low may not illuminate a large enough area and may result in over lighting. Mounting lights at the proper height may reduce light trespass and glare and better illuminate tasks, which can improve safety and reduce human health effects.

Notes: The need to lower the height of lighting could potentially result in needing more lights in some situations (thereby increasing installation and maintenance costs), or there could be situations where there is room for only one light, higher up than is desirable. Photometric studies should be performed to determine the best height and light output for the area that needs illumination.

5.4.11 Install Lights at the Tops of Signs and Buildings, Pointing Downward

Install lights at the tops of signs and buildings pointing downward, rather than mounting on the ground pointing upward. This practice reduces skyglow and wasted energy.

Notes: In some cases, mounting lights at the top of a structure is more expensive than installing lights on the ground and is less convenient from a maintenance standpoint. If installed on the ground, shield the luminaires to minimize light going into the sky.

Recessed downlighting reduces skyglow and wasted energy. In this example, the use of vertical shielding to prevent horizontal light spill would further minimize potential light trespass and skyglow.

5.4.12 Avoid the Use of Swivel-Mounted Floodlights

The use of swivel-mounted floodlights (shown here) can result in improper aiming, which can result in skyglow, light trespass, and glare.

Because of the potential for improper aiming, avoid the use of swivel-mounted floodlights. Avoiding swivel-mounted floodlights reduces the potential for skyglow, light trespass, and glare.

Notes: Use of any lighting product that includes mounting equipment that allows the user to change the orientation of the lighting is not considered best practice, because of the potential to improperly aim the light.

5.4.13 Avoid Uplighting Where Possible

Uplighting is not recommended, except where the luminaire is shielded from the night sky by a roof overhang or similar structure; where the luminaire does not cause light to extend beyond the structural shield; or where available luminaire mounting locations are limited and specific lighting tasks require uplighting for safety reasons.

Notes: Uplighting is frequently used for aesthetic reasons, often resulting in light trespass, glare, skyglow, or wasted energy. Very few situations require uplighting for safety. Use uplighting only where necessary, and in these locations, use appropriate minimizing measures to reduce duration, intensity, etc. Provide local switching for infrequently used uplights, preferably paired with a timer switch so lights are not inadvertently left switched on.

Uplighting should not be used for aesthetic reasons, as in this photo. Uplighting can cause skyglow, light trespass, and glare.

5.4.14 Screen Lighting Where Possible

Use structures (including building eaves) to minimize light emissions beyond a developed site. Low-profile facilities, below-ground installations, and other design features can also be used to minimize light emissions beyond a developed site. These practices reduce light trespass and glare.

Notes: Many situations exist for which there is no natural screening, and adding screening might be prohibitively expensive or conflict with other project goals or requirements. Added screening may affect plant and animal habitat, movement, and other behavior in unintended ways (e.g., affect predator-prey relationships). Vegetative screening is not recommended for these reasons and because vegetation may be subject to leaf drop, damage, pruning, or removal that reduces or eliminates its screening capability.

The vegetation at left partially screens the unshielded light source behind it, but this screening would decrease significantly due to leaf drop, tree pruning, or tree removal.

5.4.15 Use Pole-Mounted Lights with Low BUG Ratings for Backlight Close to Property Boundaries

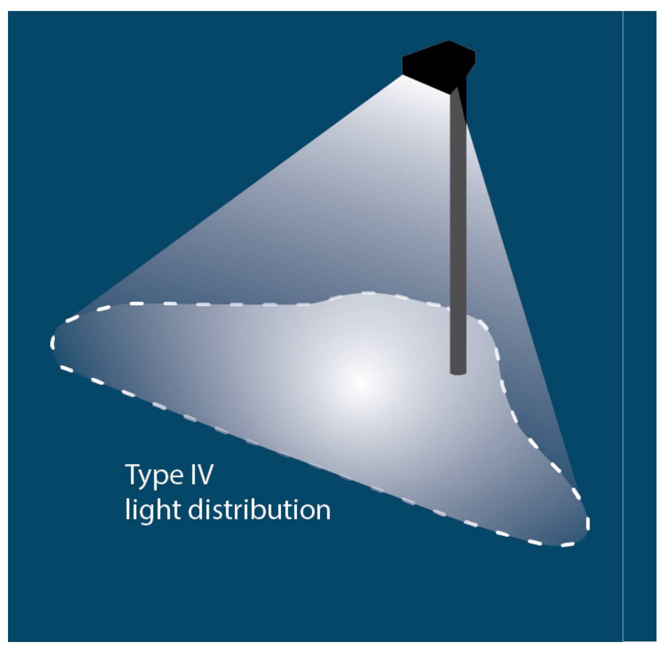
Install pole-mounted lights with a low BUG system backlight rating (e.g., B0) near site boundaries (or edges of areas requiring illumination). This practice reduces light trespass and the potential for offsite glare.

Notes: Some luminaires (e.g., forward throw asymmetric luminaires) are designed to minimize backlight. The use of photometric calculations is preferred to determine luminaire locations. In some situations, it is not be possible to install lights away from a site boundary.

5.4.16 Use Forward Throw Asymmetric Luminaires Where Appropriate

Use forward throw asymmetric luminaires where lights cannot be located directly above the area where illumination is needed. Forward throw asymmetric luminaires are luminaires with a light distribution pattern that casts light in an oval pattern offset from the pole such that there is minimal backlighting. These luminaires decrease light trespass and glare and concentrate light where it is needed.

Notes: Forward throw asymmetric luminaires should not be used where light is needed on all sides of a luminaire (e.g., in the middle of a parking lot).



Forward throw asymmetric luminaires have a light distribution pattern that minimizes backlighting.

5.4.17 Choose Roadway Luminaires to Maximize Lighting the Road and Minimize Lighting Away from the Road

When choosing roadway luminaires, maximize the proportion of light emitted on the road, and minimize the proportion emitted off the road (i.e., use luminaires with a low backlight rating in the BUG rating system). These luminaires decrease light trespass and glare away from the road and concentrate light where it is needed.

Notes: Many roads on BLM-managed lands neither have nor require lighting. Engage a qualified lighting designer where road lighting is needed for safety.

5.4.18 Use Lighting Transition Zones between Brightly Lit and Unlit Areas

Use lighting transition zones to create smooth, gentle transitions between brightly lit and unlit areas to avoid deep shadows and minimize effects on dark adaptation. This practice can improve safety by avoiding glare and improving dark adaptation.

Notes: The use of lighting transition zones requires careful design to provide enough safety illumination for public use areas and may result in an increase in the number of luminaires.

5.4.19 Leave Gaps in Long Linear Arrangements of Lights

A long linear array of lights can impede animal movement by creating a barrier of lights.

Where possible, leave gaps in long linear arrangements of lights (such as along a roadway) to avoid impeding animal movement. Research shows that bats and other species may avoid lights, and their movement may be restricted by a "barrier" of lights.

Notes: This practice could have aesthetic or safety effects if not executed properly.

5.4.20 Provide Dark Corridors to Facilitate Animal Movement

Design and integrate dark corridors to encourage/guide animals away from or around illuminated areas (such as roads). Orient corridors relative to other landscape features and along likely commuting routes for animals (e.g., along hedgerows, heavily vegetated and low-volume roadways, stream courses).

To be more effective, it is recommended that dark corridors:

- Link to existing paths, foraging areas, and other important habitat.
- Contain mature vegetation to provide shelter from predators and weather.
- Contain native plant species to attract insects for foraging.
- Be located away from roads.
- Be consistently maintained (i.e., kept dark).

Notes: This practice could conflict with safety and transportation requirements or other needs. Resolve conflicts to adequately address issues regarding safety and transportation requirements.

5.5 BMPs for Light Color Matters: Select Amber, Orange, or Red When Possible

The following BMPs address lighting of the appropriate color temperature for the task at hand, while minimizing environmental impact.

5.5.1 Use "Night Sky Friendly" Narrow-Spectrum Amber, Orange, or Red Light Sources

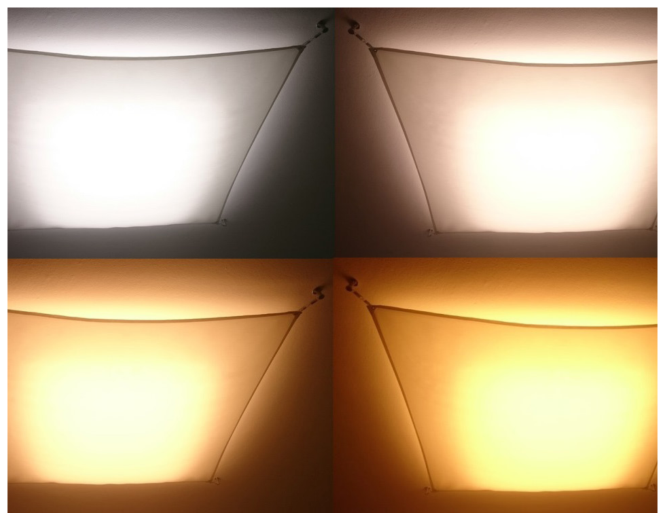
Unless tasks require highly accurate color rendition, use "night sky friendly" light sources that emit narrow-spectrum, long-wavelength (greater than 560 nm) light, such as amber, orange, or red color temperatures (< 3,000 K). These lights are likely to have fewer ecological and human health effects compared with broader spectrum or "whiter" light sources such as many LEDs and metal halide lamps (Longcore et al. 2018). Broad spectrum, bluish-white lighting or lighting rich in UV light (> 3,000 K) are not recommended for use in permanent outdoor lighting. If safety-related lighting requirements call for accurate color rendition that precludes the use of narrow-spectrum, long-wavelength light sources, then broad-spectrum light sources with a correlated color temperature (CCT) of 2,200 K or below can be used, in combination with lighting controls such as motion sensors, timers, dimmers, etc.

Notes: Filters, gels, or lenses should not be used to manipulate color in light sources. Narrow-spectrum amber, orange, or red light sources typically have relatively poor color rendition (i.e., they have a low CRI). Narrow-spectrum lighting may cost more than broad-spectrum lighting. Exercise care when selecting LEDs, and use them in properly designed luminaires that limit light trespass. Avoid increasing light levels beyond minimum levels required for safety.

The pedestrian path to the Lowell Observatory uses "night sky friendly" amber path lighting.

5.5.2 Use Tunable CCT Lighting to Adjust Color of Light Sources

When and where appropriate, use **tunable correlated color temperature (CCT) lighting** to adjust the color of light sources for task requirements (to reduce spectroscopy effects, see Section 3.3.3). Tunable CCT lighting allows changing the color properties of the light source to suit the task at hand. For example, change the light color when performing a task requiring accurate color rendition, and then change it back to a more wildlife friendly color afterwards. When used with other lighting controls such as dimmers and timers, tunable CCT lighting reduces effects on wildlife and saves energy (Council on Science and Public Health 2016).



Claudia Angerer

This set of photos of an indoor lamp shows how tunable CCT lighting controls can be used to alter the color spectrum of a light source on demand.

Notes: Tunable CCT lighting costs more than conventional lighting and requires expertise to select and program correctly. CCT technology with sufficiently low CCT (2,200 K or less) is preferable. A method for rapid assessment of lamp spectra to quantify ecological effects of outdoor lighting was developed by Longcore et al. (2018), though it is not comprehensive.

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5.5.3 Consider Melanopic/Photopic Ratio When Selecting Light Sources

The melanopic/photopic (M/P) ratio is a metric for evaluating the biological effects of light on humans and most vertebrate wildlife, by comparing the proportion of melanopic light (light that affects biological function such as circadian rhythm) to photopic light (light that supports vision) for a given light source. The M/P ratio represents the ratio of light producing biological signals to the brain, compared to the light producing visual responses. The M/P ratio is expressed in a decimal form, for instance, 0.3 or 0.9. The lower the number, the smaller the light's biological effects. The higher the number, the greater the light's biological effects. However, biological effects of light also depend on the light's intensity, duration, and timing. In general, lower M/P ratios and lower light levels are better for areas with sensitive species. If available, consider the M/P ratio when selecting light sources.

Notes: Consideration of the M/P ratio provides a more accurate assessment of the biological effects of lighting, rather than consideration of only CCT. For example, because white light contains colors of many wavelengths, two light sources may both appear white to the eye but have substantially different biological effects. Increasingly, lighting manufacturers use the M/P ratio to better communicate the likely biological effects of lighting. However, at this time, M/P ratio is not widely used to describe commercially available lighting products.

5.5.4 If Necessary, Remove UV Light Content with Filters or Housings

Reduce or remove the UV content of the light with UV filters or glass housings when the use of high-UV content lighting such as metal halide or mercury light sources cannot be avoided.

Notes: Filters/housings may be unavailable or inappropriate for some lights and lighting applications. Luminaire modifications not approved by the manufacturer may void the product warranty, cause damage to the luminaire, or present a hazard.

5.5.5 Use Consistently Colored Light Sources

Where lighting requirements allow, use consistently colored light sources to minimize aesthetic effects.

Notes: Lighting requirements in some situations may require lights of different colors (e.g., lights with a higher CRI for task lighting where color rendition is important). Note also that different colors affect perceived brightness differently (e.g., increasing the short-wavelength content of light sources increases perceived brightness more than an equivalent increase in long-wavelength content).

The use of two very differently colored light sources creates an aesthetic problem.

5.6 BMPs for Minimizing the Level of Illumination

The following BMPs suggest ways to use the lowest possible level of illumination to meet lighting needs for a particular area. These practices prevent over-illumination.

5.6.1 Use the Lowest Possible Level of Illumination that Meets the Lighting Needs

Use the lowest possible level of illumination that safely meets the lighting needs for a particular area. Refer to the IDA-IES Model Lighting Ordinance (IDA-IES 2011) for maximum lighting densities (lumens/ft^2) of hardscape areas for the applicable lighting zone performance standard (see Sections 5.1.2 and 5.4.5). This practice reduces ecological and human health effects, while saving money and preventing wasted energy.

Notes: Determining minimum safe lighting levels likely requires a qualified illumination designer or engineer, especially for public use areas.

5.6.2 Reduce Light Levels of Security Cameras to the Minimum Required for Proper Functioning

Consider minimum light level requirements for security camera function in areas requiring security monitoring. Thermal infrared (night vision) security cameras that can function in complete darkness are recommended. If lighting levels can be lowered, this practice reduces ecological and human health effects, while saving money and energy.

Notes: This practice requires knowledge of the minimum effective lighting level required for the particular security camera used.

Use the minimum amount of lighting required for security cameras, or better still, use infrared security cameras.

5.6.3 Replace Existing Lights with Lower-Output Light Sources

Where there is excessive illumination, replace existing lights with lower-output light sources. This practice reduces ecological and human health effects, while saving money and energy. Using dimming technology may also improve safety and security in over-lighted/glare situations.

Notes: Effort and expense is required to purchase and install replacement lighting; however, the purchase expense may be recouped through lower energy costs. Knowledge of minimum effective lighting level is required and will likely require consultation with a qualified lighting designer.

5.6.4 Use Dimming Lighting Controls to Reduce Over-Illumination

Dimmable luminaires and continuous auto-dimming lighting controls reduce over-illumination by adjusting luminance levels for different tasks or ambient lighting conditions in real time. These technologies reduce ecological and human health effects, while saving money and energy. Dimming technology may also improve safety and security in over-lighted/glare situations. Make sure the LED luminaire has a dimmable driver.

Notes: Effort and expense is required to purchase, install, program, and maintain the dimming technology; however, dimming greatly extends the life of LED luminaires, which reduces maintenance expenses.

5.6.5 Dim Lighting by 30 to 50 Percent after High Traffic Hours in Public Spaces that Must Stay Illuminated

Consider dimming lighting in public spaces that are frequented at night and that must stay illuminated by at least 30 to 50 percent after high traffic hours. Dim when feasible without going below the recommended minimum illuminances. Use motion or other sensors to restore full luminance when needed. Reducing the intensity of the lighting reduces ecological and human health effects, while saving money and energy.

Notes: Effort and expense is required to purchase, install, program, and maintain the dimming technology; however, dimming greatly extends the life of LED luminaires, which reduces maintenance expenses.

WSP/Parsons Brinkerhoff

LED street lighting system shown at initial startup at dusk (left) and 50 percent dimmed after midnight (right).

5.6.6 For Tall Structures, Use Flashing Warning Lights at Night, and Replace Nonflashing with Flashing Lights

Research shows that steady-burning lights on tall structures are more disorienting to wildlife than flashing lights (Gehring et al. 2009), and it is important to avoid their use wherever possible. Using flashing lights (low flash rate lights are best) reduces ecological effects and prolongs the light source's operating time while reducing energy consumption.

Where feasible, and consistent with FAA requirements and safety considerations, replace nonflashing lights with flashing lights (e.g., on communications towers and other tall structures). The FAA has revised its advisory circular (FAA 2015) that prescribes tower lighting to reduce bird collisions. See FCC 2017 for additional information.

Notes: In addition to reduced effects on wildlife, flashing lights are more noticeable to pilots.

Communications tower at night with red lights.

5.6.7 Where ADLS Technology Is Not Used, Use the Minimum Amount of Hazard Navigation Lighting Specified by the FAA

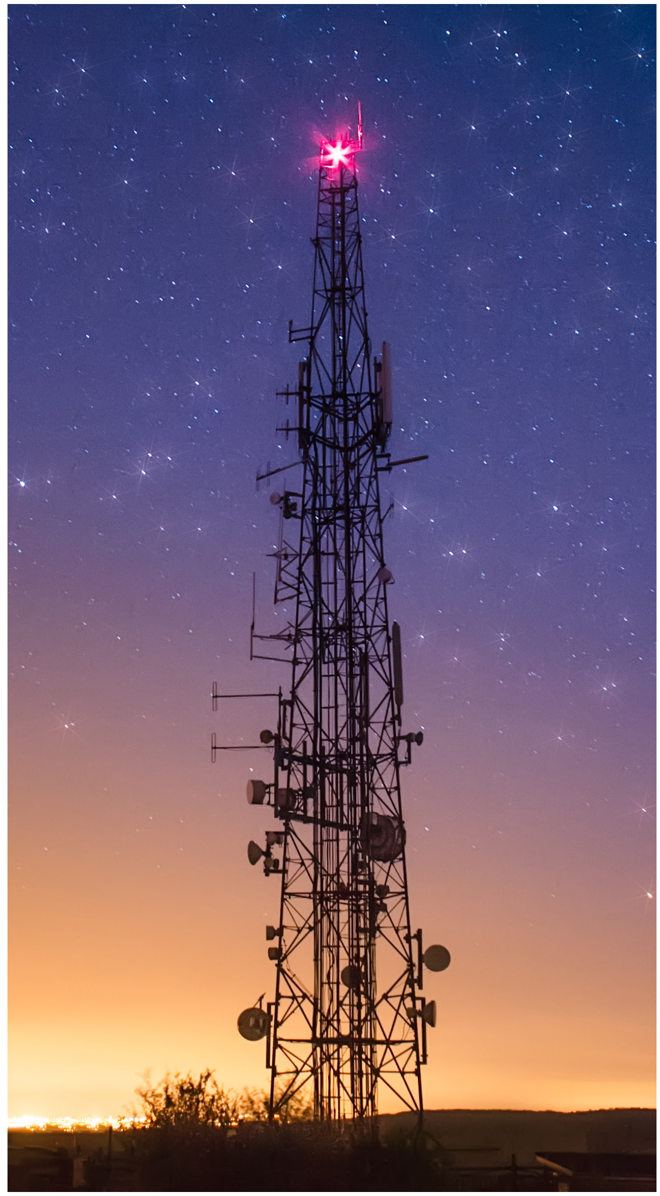
For structures more than 200 ft tall that do not have ADLS technology, the minimum amount of aviation obstruction lighting specified by the FAA should be used (USFWS 2021). This practice reduces ecological effects, reduces aesthetic effects, and saves money and energy. See FAA Advisory Circular 70/7460-1L, “Obstruction Marking and Lighting,” for requirements (FAA 2015).

Notes: Failure to use an ADLS where approved by the FAA can result in greater ecological and aesthetic effects.

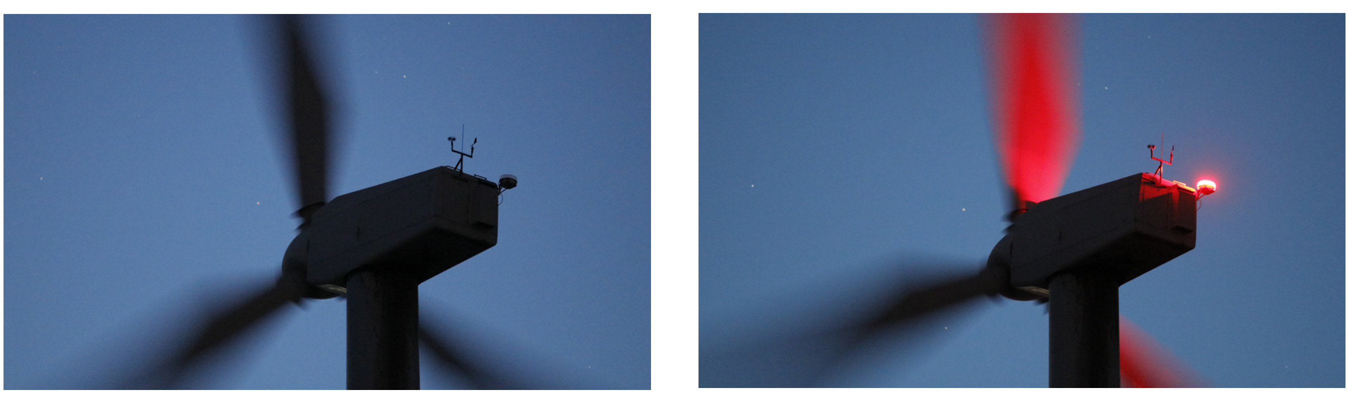
5.6.8 Use Reduced Intensity Lights with Short Flash Durations for Hazard Navigation Lighting

For aviation obstruction lighting (such as on wind turbines and communication towers), use reduced intensity lighting and lights with short flash durations that emit no light during the “off phase,” where approved by the FAA. Research shows that lower intensity flashing lighting is less disorienting to wildlife (Gehring et al. 2009), and it also prolongs the light source’s operating life while reducing energy consumption. See FAA Advisory Circular 70/7460-1L, “Obstruction Marking and Lighting,” for requirements (FAA 2015).

Notes: Flashing lights may increase aesthetic and nuisance effects.



It is recommended that the minimum amount of aviation obstruction lighting specified by the FAA be used.



Taken fractions of a second apart, these photos show a wind turbine that has a flashing red light.

5.6.9 Use Enclosed Flare Systems for Gas Flaring Associated with Oil and Gas and Similar Operations

Enclosed flare systems are also called combustors or thermal oxidizers. Although gas flaring does not occur all the time, when it does occur, it happens for several reasons such as for an emergency or due to equipment issues. Flaring may occur with both oil and gas wells and at various points in the life cycle of the well. When light pollution is a concern, operators may voluntarily commit to enclosed flare systems at permitting. Incorporate enclosed flare systems in the surface use plan of operations (SUPO).

Enclosed flare structures are insulated vertical cylinders (a combustion chamber) containing a burning head. The cylinder shields the light, noise, and heat release. There is no visible flame or flame tower protruding above surrounding structures. Gas flaring systems are used for air pollution abatement as well as for aesthetic effects (EPA 2003; Ohio EPA 2014).

Enclosed flare systems have no visible flame, and their use minimizes ecological and aesthetic effects, while reducing emissions.

Notes: Enclosed flare systems add to a project cost yet add minimal operation and maintenance costs (Attaway and Coyle 2016; Baker Furnace, Inc. 2015).

5.6.10 Where Decreased Visibility Is Desired, Reduce Reflectivity of Illuminated Surfaces

Where decreased visibility is desired, reduce the reflectivity of illuminated surfaces by darkening them with metallic black-out paint or other dark coatings and using matte finish. This practice reduces the brightness of trespass light and glare and is especially effective when surfaces are wet from irrigation, rain, or snowmelt.

Notes: Technical requirements of the surface may dictate the color or finish. Purchase and apply paint and other coatings and maintain as required. Darkening highly reflective surfaces may be difficult or impossible in some situations, if, for example, the surface is subject to extremely high temperatures and cannot be painted/coated. Consider the presence of snow when deciding where and when to light, because snow on the ground may reflect light upward strongly.

The light-colored surfaces of this solar facility reflect light and increase contrast with the surrounding dark environment.

Many municipalities and organizations upgrade lighting systems to take advantage of new lighting and control technology that reduces effects on humans and the environment while saving money.

5.7 BMPs for Energy-Efficient Lights and Advanced Lighting Technology

The following BMPs address ways to use energy-efficient lights and advanced lighting technology to improve lighting performance and save energy and money.

5.7.1 Use Energy-Efficient Lights with Advanced Lighting Technology

Use energy-efficient lights (such as LEDs) with advanced luminaire optics and lighting control functionality. Energy-efficient lighting technologies can save money because of longer light life and lower energy use. Energy-efficient lights with advanced light distribution control and properly selected LEDs can minimize contributions of light pollution (Longcore 2018).

Notes: Select LEDs carefully and avoid increasing light levels beyond minimum levels required for safety/security. While using more energy-efficient light sources potentially eliminates wasted energy, savings are not achieved if more lighting is installed as a result of lower unit lighting costs. If the lighting is excessive, poorly chosen, or poorly controlled, other adverse effects are possible.

5.7.2 Consider the Total Life Cycle Cost When Selecting New Lighting Systems or Retrofitting Existing Systems

Consider the total life cycle cost (initial purchase, installation, operation, maintenance, and decommissioning/disposal) when selecting new lighting systems or retrofitting existing systems. Although the initial purchase cost of new components may be relatively high, new lighting technologies may provide substantial cost savings in the long run especially in reduced maintenance costs, while reducing wasted energy.

Notes: Determining the total life cycle cost of a lighting system requires technical expertise.

5.7.3 Inspect and Clean Luminaires Regularly

Inspect luminaires periodically for proper aiming, luminaire damage, lumen depreciation (loss of the original light output that occurs over time), and lens and reflector degradation, and clean dirt, dust, or dead insects that obscure light or the photocell sensor. These maintenance actions reduce light pollution, allow efficient operation of lighting, and extend the life of lighting components, therefore saving money and energy. They may also improve safety in some situations.

6. Summary

Night skies and dark environments are an important quality of public land scenic, historic, cultural, scientific, recreational, and ecological values. They can be an integral component of aesthetically pleasing surroundings on the public lands forming the backdrop for multiple uses. In response to growing public concern about light pollution, the BLM sponsored this effort to assemble best practices for outdoor lighting. Applying artificial light at night BMPs can help prevent degradation of dark sky qualities over public lands and avoid or reduce light pollution effects of permitted land uses on those lands. The proactive incorporation of artificial light at night BMPs into the planning of federal actions will likely result in a more efficient environmental review process, increase operating efficiency, reduce long-term operating costs, reduce final reclamation needs, and minimize impacts to the environment.

This collection of BMPs is intended to support alternatives development and agency decisions about nighttime lighting on BLM-managed public lands to prevent light pollution that impairs visible clarity of night skies, negatively impacts wildlife, and affects human health and wellbeing. The concepts and BMPs presented in this technical note can be used for facilities managed by the BLM (e.g., office buildings, fire stations, recreation sites) and those facilities that support authorized permitted uses (e.g., wind, solar, and geothermal energy generation; energy transmission; fluid and hardrock mineral extractive activities; communication towers; recreation uses such as camping and hiking). Any outdoor lighting design needs to be considered in the context of other public land qualities, resources, and values as well as operational function. Early and frequent consultation with the developer, other resource specialists, and potentially affected stakeholders will help ensure that lighting BMPs are applied where they are needed and effective, where they do not adversely affect workplace safety or other important environmental resources, and with consideration of the costs and benefits of implementing them.

The BMPs presented in this report are for consideration in the design and maintenance of facilities located on public lands. The goal of assembling these BMPs is to promote practices that prevent unnecessary degradation of dark sky qualities over public lands and avoid or reduce light pollution effects of permitted land uses on those lands.

7. Glossary[8]

adaptive controls: any electronic or mechanical device attached to a light intended to dynamically control the duration, intensity, spectrum, or area illuminated by the lighting.

aircraft detection lighting system (ADLS): radar-activated lighting technology designed to reduce the impact of nighttime lights by deploying a radar-based system around a facility, turning lights on only when low-flying aircraft are detected nearby.

artificial light at night (ALAN): light that arises from nonnatural sources (i.e., light that does not occur in the natural environment without some action by humans). There are many possible sources of artificial light, but the most common sources involve passing electrical current through various materials. Lighting used specifically to provide illumination during the hours of twilight or darkness.

astronomical light pollution: light pollution that obscures the view of the night sky. See light pollution and ecological light pollution.

backlight: light emitted in the quarter sphere below horizontal and in the opposite direction of the intended orientation of the luminaire.

best management practice (BMP): a practice or combination of practices that are determined to provide the most effective, environmentally sound, and economically feasible means of managing an activity and reducing its effects.

bioluminescence: a type of natural light produced by some form of chemical reaction within a living organism. Bioluminescence occurs in marine vertebrates and invertebrates, some fungi, bacteria and other microorganisms, and certain terrestrial invertebrates (e.g., fireflies).

BUG rating system: BUG is an acronym for backlight, uplight, and glare. The "Luminaire Classification System for Outdoor Luminaires," IES TM-15-20, BUG rating system (IES 2020) is a tool used to quantitatively evaluate the light output of an outdoor luminaire and, in particular, the light escaping in unwanted directions. The system is based on a sphere around a hypothetical pole-mounted light source in the center of the sphere. The sphere is divided into three sections: backlight, uplight, and glare (forward light). The three sections are further divided into zones in which the lumen distribution is rated to determine the light pollution impact of the luminaire. The BUG rating system replaces the earlier "cutoff" system.

candela: a unit of luminous intensity in the International System of Units (SI); that is, luminous power per unit solid angle emitted by a point light source in a particular direction. A common wax candle emits light with a luminous intensity of roughly one candela. See lumen.

circadian rhythm: a roughly 24-hour cycle in the physiological processes of plants, animals, fungi, and other living things. Circadian rhythms are endogenously generated but can be modulated by external cues such as sunlight and temperature.

color: the property of reflecting or emitting light of a particular intensity and wavelength (or mixture of wavelengths) to which the eye is sensitive.

color rendering index (CRI): a measure of a light source's accuracy in rendering different colors properly. To determine CRI, a given light source is compared to a standard reference light source with the same correlated color temperature (CCT). CRI uses a scale from 0 to 100 percent. The higher the CRI, the better its color rendering ability. See correlated color temperature (CCT).

[8] Some definitions in this glossary are from ANSI/IES RP-16-17, "Nomenclature and Definitions for Illuminating Engineering" (ANSI/IES 2020); others are from "Joint IDA-IES Model Lighting Ordinance with User's Guide" (IDA-IES 2011).

contrast: difference in luminance or color that makes an object (or its representation in an image or display) distinguishable. Contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view. See luminance, color, and grayscale contrast.

correlated color temperature (CCT): a specification of the color appearance of the light emitted by a lamp, relating its color to the color of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K).

crepuscular: done, occurring, or active during twilight.

diffuse reflection: reflection of light from a surface such that a ray incident on the surface is scattered at many angles rather than at just one angle as in the case of specular reflection. See specular reflection.

diurnal: done, occurring, or active during the day.

ecological light pollution: light pollution that alters natural light regimes in terrestrial and aquatic ecosystems. See light pollution and astronomical light pollution.

effect: a change which is the result of an action or other cause. Effects may be positive, negative, or neutral. Synonymous with impact. See impact.

forward throw asymmetric luminaire: a luminaire with a light distribution pattern that casts light in an oval pattern offset from the pole such that there is minimal backlighting.

fully shielded luminaire: a type of luminaire that emits no uplight and limits glare between 80° and 90° from the ground. Fully shielded luminaires have a light distribution in which no light is cast at or above an angle of 90° above nadir (straight down) with a U0 rating per IES TM-15-20 (IES 2020). See luminaire and unshielded luminaire.

glare: the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or temporary loss in visual performance and visibility.

grayscale: a range of monochromatic shades from black to white. A grayscale image contains only shades of gray and no color.

grayscale contrast: the amount of grayscale differentiation that exists between various image features in an image. Images having a higher grayscale contrast level generally display a greater degree of grayscale variation than those of lower contrast. See grayscale and contrast.

hazard navigation lighting: the illumination of an object for increased conspicuity to ensure the safety of air or water navigation, or the lighting equipment used to achieve this purpose.

horizontal illuminance: illuminance measured on a horizontal plane (i.e., the amount of light that lands on a horizontal surface), such as a sidewalk or flat ground. See illuminance.

illuminance: a measurement of the amount of light falling onto (illuminating) and spreading over a given surface area. Illuminance is a measure calculated at a surface, such as the ground (horizontal illuminance) or a wall (vertical illuminance). The metric (SI) measure of illuminance is the lux (footcandle in the Imperial System). Also known as incident light or brightness. See lux and lumen.

impact: a change which is the result of an action or other cause. Synonymous with effect. See effect.

land use plan: a set of decisions that establish management direction for land within an administrative area, as prescribed under the planning provisions of the Federal Land Policy and Management Act of 1976, as amended (Public Law 94-579; 90 Stat. 2743); a document containing an assimilation of planning decisions developed through the planning process outlined in 43 CFR Part 1600, regardless of the scale at which the decisions were developed. Synonyms include resource management plan and management framework plan.

light clutter: a type of light pollution caused by excessive groupings of lights, such as are seen in typical urban environments where there are large numbers of lights of different types.

light-emitting diode (LED) lighting: a semiconductor device that emits visible light when an electric current passes through it.

light loss factor: a multiplier that is used to predict future performance (maintained illuminance) of a lighting system based on the initial properties of the system. The light loss factor accounts for the decline in lumen output over time. Light loss factor = 1 (initial output of the system) minus expected depreciation.

light pollution: any adverse effect of manmade lighting, such as excessive illumination of night skies by artificial light. Light pollution is an undesirable consequence of outdoor lighting that includes such effects as skyglow, light trespass, light clutter, over-illumination, and glare. See astronomical light pollution and ecological light pollution.

light spill: see light trespass.

light trespass: a type of light pollution in which light is cast where it is not wanted or needed. Also referred to as light spillage or light spill.

lighting zone: a zoning system establishing recommended performance standards for lighting for particular areas (IDA-IES 2011).

lumen: the unit of measure used to quantify the amount of light produced by a lamp or emitted from a luminaire (as distinct from "watt," a measure of power consumption). Technically, the amount of light emitted per second in a unit solid angle of one steradian from a uniform source of one candela. See candela.

lumen depreciation: the loss of the original light output of a lamp or fixture that occurs over time.

luminaire: a complete lighting unit (fixture), consisting of a lamp or lamps and ballast(s) (when applicable), together with the parts designed to distribute the light (reflector, lens, diffuser), to position and protect the lamps, and to connect the lamps to the power supply. It does not include the pole or other mounting hardware. Sometimes referred to as a light fixture.

luminance: the intensity of light emitted from a surface per unit area in a given direction.

luminescent: emitting light not caused by heat.

luminosity: the brightness of a light source of a certain wavelength as it appears to the eye.

lux (lx): the SI (International System of Units) unit of illuminance. One lux is one lumen per square meter (lm/m^2). 1 lux = 1 lm/m^2 = 0.093 footcandles (1 footcandle = 10.76 lux). In photometry, lux is used as a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface. See lumen and illuminance.

melanopic/photopic ratio (M/P ratio): a metric for evaluating the biological effects of light for humans and most wildlife, by comparing the proportion of melanopic light (light that affects biological function such as circadian effects) to photopic light (light that supports vision) for a given light source.

melatonin: a hormone secreted by the pineal gland especially in response to darkness that has been linked to the regulation of circadian rhythms.

mesopic vision: a combination of photopic vision and scotopic vision activated in low but not quite dark lighting situations and characterized by poor visual acuity and color discrimination. Most nighttime outdoor and traffic lighting scenarios are in the mesopic range. See photopic vision, scotopic vision, and visual acuity.

Model Lighting Ordinance (MLO): the "Joint IDA-IES Model Lighting Ordinance" is a publication designed to help municipalities develop outdoor lighting standards that reduce light pollution. The MLO uses lighting zones to classify land use with appropriate lighting levels, limits the amount of light used for each zone, and uses the IES TM-15-20 BUG (backlight, uplight, and glare) classification. See BUG rating system.

M/P ratio: see melanopic/photopic ratio.

national conservation area: an area that is part of the National Conservation Lands that is managed to conserve, protect, and restore the exceptional scientific, recreational, cultural, historical, and ecological values for which it was designated.

National Conservation Lands: an organized system of public lands managed by the Bureau of Land Management that have received special designation for their scientific, cultural, educational, ecological, and other values. This system was formally established as the National Landscape Conservation System by Title II of the Omnibus Public Land Management Act of 2009 and includes national monuments, national conservation areas, wilderness areas, wilderness study areas, national wild and scenic rivers, national scenic and historic trails, and other units.

national historic trail: a trail that is part of the National Conservation Lands. These trails follow, as closely as possible, the original trails or routes of travel of national historic significance and are managed to preserve the remnants of nationally significant pathways and the settings in which they are located.

national monument: an area that is part of the National Conservation Lands that is designated to protect objects of scientific and historic interest by proclamation of the President under the Antiquities Act of 1906 or by Congress through legislation. Designation provides for the management of these features and values.

national scenic trail: a trail that is part of the National Conservation Lands. These trails are established by an act of Congress and are intended to provide for maximum outdoor recreation potential and for the conservation and enjoyment of nationally significant scenic, historical, natural, and cultural qualities of the areas through which these trails pass. National scenic trails may be located to represent desert, marsh, grassland, mountain, canyon, river, forest, and other areas, as well as landforms that exhibit significant characteristics of the physiographic regions of the nation.

natural darkness: the illuminance experienced in the absence of outdoor artificial light at night.

natural lighting: natural lighting is light that arises from natural sources (i.e., light that occurs in the natural environment without action by humans). There are many types of natural lighting, including, but not limited to, sunlight, moonlight, starlight, and light from other celestial objects, and also lightning, fire, and bioluminescence.

niche partitioning: the process by which competing species use the environment differently in a way that helps them coexist. See temporal niche partitioning.

night sky impact: an interference with enjoyment of dark night skies or an effect on wildlife resulting from light pollution.

nocturnal: done, occurring, or active at night.

over-illumination (also over illumination): the use of lighting intensity higher than that which is appropriate for a specific activity.

photometric diagram: a diagram that shows the expected spatial distribution of light from a given luminaire.

photoperiodism: the physiological reaction of organisms to the length of day or night.

photopic vision: vision of the eye under well-lit conditions. In humans and many other animals, photopic vision allows color perception, mediated by cone cells, and a higher visual acuity than available with scotopic vision. See visual acuity and scotopic vision.

phototaxis: the directional movement of an organism in response to light. The movement may either be towards the light source (positive phototaxis) or away from the light source (negative phototaxis).

reflective: capable of physically reflecting light.

reflectivity: the fraction of radiant energy that is reflected from a surface.

renewable energy: energy derived from resources that are regenerative or that cannot be depleted. Renewable energy resources include wind, solar, biomass, geothermal, and moving water (e.g., dams, tidal bores, ocean current, wave energy devices).

retroreflective: a descriptive term for surfaces that reflect light back toward the light source with a minimum scattering of light.

scotopic vision: vision of the eye under low light conditions. In the human eye, cone cells are nonfunctional in low light. Scotopic vision is produced exclusively through rod cells. Scotopic vision does not discriminate between colors and has low visual acuity. See visual acuity and photopic vision.

skyglow (or sky glow): the brightening of the nighttime sky that results from scattering and reflection of light by moisture and dust particles in the atmosphere. Skyglow is caused by light directed or reflected upwards or sideways and reduces one's ability to view the night sky.

sodium vapor lamp: a gas-discharge lamp that uses sodium in an excited state to produce light. Low-pressure sodium vapor lamps are an energy-efficient form of outdoor lighting in which a lamp contains neon gas that lights at a relatively low temperature. As the temperature increases, sodium in the lamp begins to vaporize and creates a monochromatic yellow light.

special recreation management area (SRMA): an area designated by the BLM and managed as an administrative unit where the existing or proposed recreation opportunities (e.g., activities, experiences, and benefits derived from those experiences) and recreation setting characteristics are recognized for their unique values, importance, or distinctiveness, especially compared to other areas used for recreation.

specular reflection: the reflection of electromagnetic rays without scattering or diffusion. In specular reflection, the angle at which the wave is incident on the reflecting surface is equal to the angle at which it is reflected from that surface. Also known as direct reflection, regular reflection, or mirror reflection. See diffuse reflection.

substation: an electrical system used to switch generators, equipment, and circuits or lines in and out of a system. It is also used to change alternating-current voltages from one level to another. A substation consists of one or more transformers and associated switchgear.

temporal niche partitioning: the partitioning of various species' activity periods over time based on varying levels of light. See niche partitioning.

transmission (electric): the movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer. Also, the interconnected group of lines and associated equipment that performs this transfer.

transmission line: a set of electrical current conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances (e.g., between a power plant and the communities that it serves).

tunable CCT lighting: tunable spectral distribution or correlated color temperature (CCT) lighting is a programmable solid-state lighting technology that enables users to adjust the color temperature and brightness of a light source in real time. See correlated color temperature (CCT).

unshielded luminaire: a luminaire capable of emitting light in any direction including downwards. See luminaire and fully shielded luminaire.

uplight: light cast in an upward direction; light directed (in angle) above a plane perpendicular to the local direction toward nadir (straight down).

vertical illuminance: illuminance measured on a vertical plane (i.e., the amount of light that lands on a vertical surface), such as a wall. See illuminance.

visual acuity: the clarity of vision. Technically, a measure of the spatial resolution of the visual processing system.

wilderness area: an area of undeveloped federal land retaining its primeval character and influence, without permanent improvement or human habitation, that is protected and managed so as to preserve its natural conditions and that (1) generally appears to have been affected primarily by the forces of nature, with the imprint of human work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least 5,000 acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value.

wilderness study area (WSA): an area of public land that is a candidate for official wilderness area designation by Congress. A parcel of undeveloped and undisturbed land that meets wilderness qualifications which Congress can later designate as wilderness. The Federal Land Policy and Management Act of 1976 directs the Bureau of Land Management to inventory and study its roadless areas for wilderness characteristics.

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