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BEST MANAGEMENT PRACTICES FOR BATS AND ARTIFICAL LIGHTING

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BACKGROUND

Bats comprise nearly a quarter of all the planet's mammals, with over 1,300 known species. Bats are also one of the slowest-reproducing mammals for their size, averaging just one young per year, with some species living up to 30 years in the wild.[1] Bats are ecologically and economically vital to ecosystems and human economies. They are primary predators of insect pests that cost farmers and foresters billions of dollars annually and bats pollinate and disperse the seeds of hundreds of economically important plants.[2,3] Unfortunately, bats are also one of the most imperiled taxa worldwide, with more than half of all species known or suspected to be in decline; the primary causes being habitat loss, overharvest, disease, and impacts from energy development.[4,5]

Two of the major stressors facing bats in the U.S. are White Nose Syndrome and wind power, also a threat globally. Another stressor increasing in prevalence and recognition both globally and in the U.S. is light-pollution.[6.7] Considerable physiological and behavioral evidence suggests that bats are sensitive to and avoid bright light. Cones are the receptor in the eye that are sensitive to bright light, and most bats have no cones at all. The species that do have cone-like structures emerge early to forage, and several studies have shown that bat vision works better in dim light than in bright light.[8,9] The sensitivity to different light levels however varies considerably between the different families and species.[10]

Life evolved over millions of years with predictable daily, monthly, and seasonal patterns of light and dark, and these patterns underlie the natural rhythms of nearly all living organisms.

Increasing urbanization has resulted in a corresponding increase in artificial lighting for roads, bridges, housing, recreational facilities, and other developments. Increased lighting on the landscape has reduced dark sky availability, resulting in impacts to bats and many other light-sensitive animals.[7] These impacts include changes in activity patterns, behavior, and habitat loss and fragmentation.[11] Forty three of the 46 species of U.S. bats feed exclusively on insects, which are also significantly affected by artificial light.[12,13,14] Impacts to bats may be direct or indirect, vary between species, affect bat behaviors differently (i.e. roosting, foraging, commuting, etc.), occur over different time and spatial scales, and be cumulative. Estimating and measuring the precise impact of lighting on bats is difficult as this is an emerging and complex issue with many knowledge gaps.[6,11,15,16,17,18,19,20, 21]

The direct effects of artificial lighting on bats include changes to roost emergence times, existing and potential roost quality, foraging and commuting patterns, and endogenous rhythms.[11,16,18,19,20] Indirect effects include changes in prey abundance and availability, habitat quality, and predation risk.[6, 11,12,17] Although the overall effect of artificial lighting on bats is decidedly negative, some species appear to benefit by increased foraging opportunities at lights, although these benefits can be counterbalanced by adverse impacts at the population scale.[6,11,14,17,22,23]Fortunately, the effects of lighting on wildlife can be reduced, and in some cases, eliminated completely.

2.0 GENERAL BMPS FOR BATS AND LIGHT POLLUTION

The primary management actions that can reduce, eliminate, or mitigate the negative effects of light pollution on bats fall into five basic strategies: 1) *Need;* avoid the use of lighting when not absolutely necessary; keeping dark areas dark, especially those areas deemed important for bats; 2) *Spectrum*; choose the correct color spectrum; avoid lights with shorter wavelengths; 3) *Intensity*; reduce lighting intensity; 4) *Direction;* shield and direct lighting to reduce light spill-over and illumination of important habitat components (incudes the use light screening; i.e. berms, hedgerows, etc.; and 5) *Duration*; use timers and motion detectors to reduce the time that lighting is used.

Because there will be variation in suites of species and habitat quality between sites, biologists with knowledge of local or regional bat ecology should be consulted to determine if light pollution is an issue that needs to be addressed, and if so, the best way to do so.

The following general BMPs should be considered for any new or existing developments where bats or bat habitat may be present, however, natural resource managers should review all bat and light pollution BMPs to ensure the conservation of local and regional bat populations.

2.1. Conduct pre-development bat surveys and habitat analysis whenever possible to ensure that light related disturbance reduction and mitigation are appropriate and effective.

2.2. The project team should start at an early stage of development planning to inform the design and installation of lighting schemes to increase the effectiveness and efficiency of bat conservation measures. This information is important for informing management direction and improving the effectiveness of post-development mitigation, monitoring and evaluation.

2.3. Collect baseline data, including standardized light-level (lux) surveys as well as bat surveys and habitat analyses (i.e. denote high-quality foraging habitat, existing or potential roosting habitat, etc.), especially at the early planning/pre-development stage.

3.0. LIGHTING TECHNOLOGY

Light intensity, wavelength, and configuration are major factors affecting bats response to lighting.[6,14,15] Some bat species may require very low light levels to have little/no impact on bat behavior. Lights with shorter wavelengths, especially in the ultraviolet spectrum (UV), attract insects and should be avoided. Yellow light that does not contain blue, violet, or UV (i.e. short, visible) wavelengths does not attract substantial numbers of insects, nor does red light.

3.1. Consider light levels at the site in the context of pre-development lighting (lux data), and where possible, post-development light levels should be as close to the mean naturally-occurring light levels recorded pre-development at key areas of bat use.[6,15,17,21]

3.2. Use bat-compatible lighting at the lowest intensity possible while still meeting other lighting objectives.[6,15,17.21]

3.3. In general, avoid broad-spectrum blue-white lights with high UV content such as high-pressure sodium, metal halide, and mercury lamps, which have the greatest negative impacts on bats and insects and use narrow-spectrum lights with no UV content such as low-pressure sodium and amber LEDs. Warm-white LEDs still have a peak in blue emissions which attracts insects and some bat species, and generates avoidance behavior in light-sensitive species.[13,14,23]

3.4. If the use of high-UV content lighting such as metal halide or mercury light sources can't be avoided, reduce/completely remove the UV content of the light with UV filters or glass housings.[6,15,21]

3.5. Consider low-intensity lighting options that minimize light spill and reduce illumination such as ground-level foot lights and or illuminated handrails or posts for pedestrian footpaths, biking, trails, service roads, etc. .[6,7,15,21]

4.0. LIGHT PLACEMENT, INTENSITY, AND CONTROL

Artificial light has been demonstrated to impede or fragment bat foraging and commuting routes (e.g., between roosts and foraging areas) and alter foraging patterns for several species. Many bats follow linear landscape features such as riparian corridors/water courses, linear forest strips/patches, hedgerows, and forest roads. Interrupting these flight paths can increase commuting times and decrease foraging efficiency, increasing energy expenditure and causing an overall reduction in fitness. [6,11,24] Artificial light was also shown to reduce roost quality, including forced changes in roost entrance use, significant decreases in colony size, and site abandonment[18,19,20]

No artificial light is almost always better for bats than artificial light, however, where human needs for lighting (e.g. safety, recreation, etc.) is important, both human and bat conservation objectives can be met through management actions such as strategically placing lights, reducing light spillage, combining motion sensors with low-impact lighting, and designating light-exclusion (dark zones) in or adjacent to important bat habitat.[6,15,17,21]

4.1. Plan and design light intensity and configuration, i.e., spacing, height, and directionality, to reduce the intensity and spillage of light to minimize overall illumination and provide dark habitats for bats. .[6,15,21]

4.2. Many bat species are sensitive to even low-intensity light. Every effort should be made to use the minimum amount of light required to meet other management objectives. [6,10]

4.3. Plant or use existing vegetation, berms, walls, or other structures to act as a light barrier to screen and prevent light spillage into important bat habitat including foraging and commuting routes. [6,7,21]

4.4. Design and integrate dark corridors to encourage/guide bats away from or around illuminated areas (such as roads). Corridors should be created relative to other landscape features and along likely commuting routes for bats (i.e., along hedgerows, heavily-vegetated low-volume roadways, stream courses, etc.).[6,15,21]

4.5. Consider leaving dark gaps to facilitate bat crossing when roads with streetlights bi-sect linear landscape or other features that are known or potential bat foraging or commuting routes such as water courses, hedgerows, rights-of-ways, etc.[6,15,21]

4.6. Avoid directing light into important bat habitats such as wetlands, riparian areas, etc. [6,15]

4.7. Use motion sensors to illuminate areas where light is needed, only when it is needed. [6,15,21]

4.8. Use lighting control systems to reduce or eliminate illumination during important bat activity periods, especially the first two hours after sunset and the last two hours before sunrise.

4.9. Reduce the height of lights to keep the lighted area as close to the ground as possible, reducing the volume of illuminated space and allowing bats to fly in the dark space above the lights (if the light doesn't spill over the vertical plane). [6,15,21]

4.10. Avoid the upward spread of light near to and above the horizontal plane; avoid the use of upward pointing lights (e.g., ground-recessed luminaires or ground-mounted floodlights up-lighting trees, buildings and vegetation), keeping light ideally below 90º to horizontal. [6,15,21]

4.11. Never illuminate bat roosts with security or other lighting. If a building known to be used by bats must be illuminated, the lights should be positioned to avoid the sensitive areas. Low wattage (<70W) lamps are preferable as they reduce glare and energy consumption and minimize impacts on bats. Lights can be fitted with movement sensors which turn the light on when the sensor is triggered. [6,19,20]

4.12. Install directional accessories such as hoods, baffles, and louvres on existing light units to direct light away from sensitive areas and minimize light spill. [6,15,21]

4.13. Remote developments, such as oil and gas facilities, are often brightly illuminated at night, and may be the only source of light for miles. Using the full suite of mitigation, i.e. shielding lights, using narrow spectrum and low intensity lighting, and controlling the timing of use should be considered in these situations.[7]

Light Types	Wavelength	Color	Effect on Bats/Insects
Low-pressure sodium lights	No UV/one wavelength	Yellow	Low-insect attraction
Warm-white LED	Little UV/long wavelength	White	Medium insect attraction
White LED	UV/short wavelength	White	Strong insect attraction
High-pressure sodium lights	Broad-spectrum UV	Pinkish Yellow	Strong insect and bat attraction
Mercury lamps	Very broad, incl. UV	Bluish White	Strong attraction for insects/some bat species; strong avoidance by some bat species

5.0 RESOURCES

Artificial Night Lighting and Protected Lands. *Ecological Effects and Management Approaches*

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