Ohio Department of Transportation Research Project Fact Sheet

Ecological Design Rules for Roadway Lighting

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The Problem

Artificial lighting at night (ALAN) that alters natural patterns of light and dark in ecosystems can have serious implications for ecological systems, such that it is increasingly referred to as "ecological light pollution". Current knowledge relative to the ecological impacts of ALAN is extremely limited, but critical in order to design appropriate best management practices (BMPs) for ecologically sensitive areas, such as riparian areas along roads and bridges over waterways.

Research Approach

This project included a comprehensive literature search on the ecological impacts of ALAN and roadway lighting, as well as field studies aimed at quantifying the effects of roadway lighting on insects, fish, and wildlife and sensitive aquatic ecosystems including streams, rivers, reservoirs, and wetlands. Our research was conducted in the Columbus Metropolitan Area (CMA), Ohio, and included urban, suburban, and peri-urban sites, as well as a control site on protected Nature Conservancy Land. To identify potential mechanisms driving ALAN-effects on aquatic organisms, controlled experiments were performed at OSU's Shiermeier Olentangy River Wetland Research Park (ORWRP).

Findings

The body of ALAN literature continues to grow, with some clear messages.

- ALAN can have strong and consistent effects on animal behavior such that animal activity onset and offset are significantly shifted against sunrise and sunset.
- ALAN has negative effects on cognition, animal navigation, hormone levels (specifically the sleep-wake cycle hormone melatonin), and number of offspring.
- Predation rates are significantly increased in the presence of ALAN.
- Effects of ALAN on populations, communities, and ecosystems are less documented in the literature, although some studies suggest ecosystem-level effects on, for example, food-web and pollinator-plant interactions.

Lighting across the CMA ranged in intensity and spectral composition. Lighting across the CMA was primarily a mixture of light-emitting diode (LED) and high pressure sodium (HPS), and intensity (lux) in riparian and aquatic ecosystems varied broadly based on light source, distance, and other mitigating factors such as natural shielding (e.g., vegetation). Across our stream-riparian study sites, we observed lighting levels from 0.1-11.2 lux. At our river-reservoir sites, lighting intensity ranged from 0.01 at unlit reaches to 6.9 lux at the water surface near bridges. Our experimental work in wetlands and mesocosms tested ecological responses of LED lighting up to 12-20 lux.

The impact of ALAN ranges across ecosystem types and organisms.

Insects. The abundance and diversity of benthic macroinvertebrates are key indicators of healthy stream ecosystems. Surveys of benthic macroinvertebrates did not detect effects of ALAN on benthic macroinvertebrate diversity. In the wetland system, we observed an increase in emergent aquatic insect density, but no impact on richness (i.e., number of taxonomic groups). Additionally, family-level emergent aquatic insect community composition in the wetland system was significantly different under LED lighting, implying species-specific responses to lighting types. In experimental mesocosms, we used mosquitoes as an insect model to compare oviposition (egg-laying) rates in habitats exposed to LED

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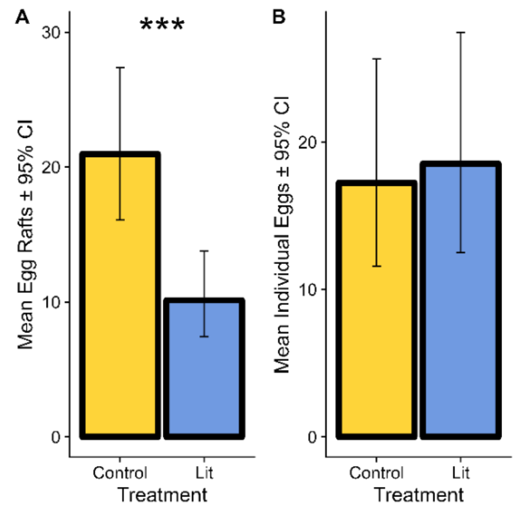
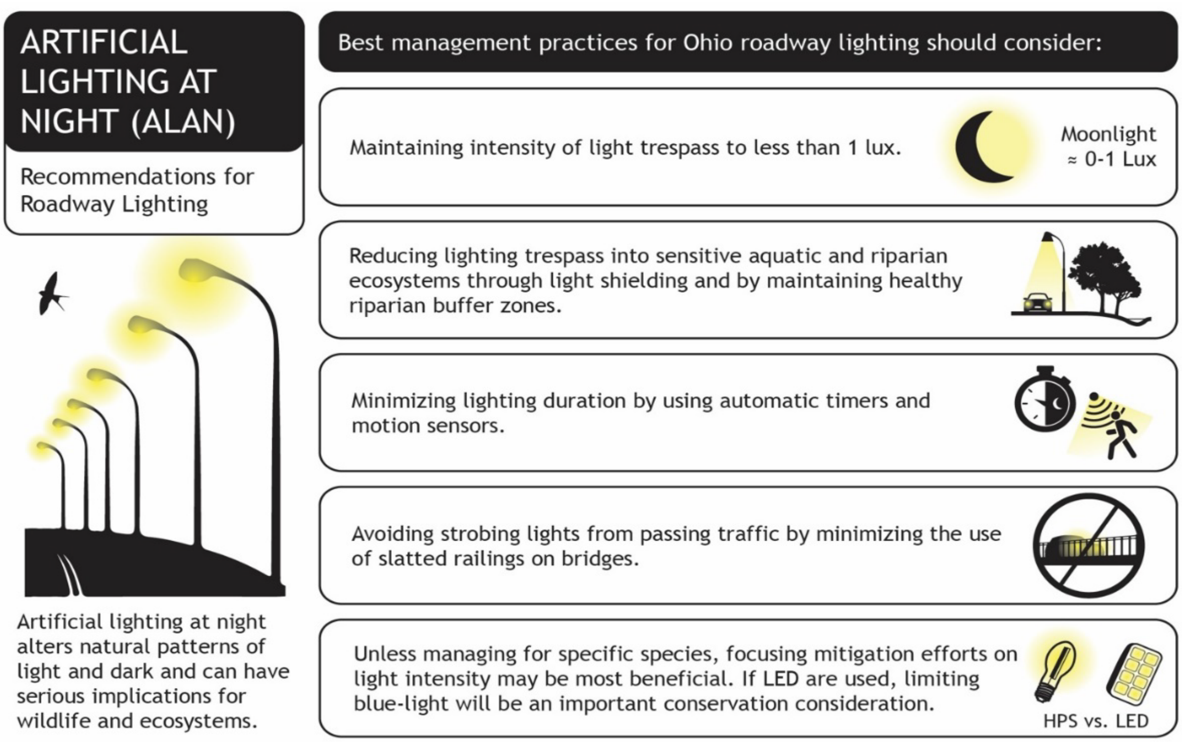
luminaires (3000K, ~13 lux) and dark controls. Mosquitoes had species-specific responses to ALAN. Mean cumulative *Culex* egg raft oviposition was greater in control pools (20.97 ± 2.85) than in ALAN pools (10.13 ± 1.58). We observed no response of *Ochlerotatus*, potentially reflecting the risk associated with the alternative oviposition strategies of the two species (eggs rafts vs. skip oviposition).



(A) Mean cumulative egg rafts per mesocosm oviposited Culex restuans on surface water of the two treatments groups over the course of the entire experiment. (B) Mean cumulative individual eggs per mesocosm oviposited by Ochlerotatus japonicus on filter paper of the two treatment groups over the course of the entire experiment. Error bars represent 95% confidence intervals.

Fish. Our results imply that the relatively low-levels of ALAN observed in canopied streams may exert only subtle effects on small stream fish assemblages, which are difficult to detect amongst the multiple, confounded stressors impacting these relatively species-poor systems. In rivers and reservoirs, there were no differences in fish species richness, α-diversity, species evenness, or assemblage structure between lit transects under bridges and nearby unlit transects. We observed initial evidence that species evenness decreased with increasing lux, but this finding would to be investigated further. In a mesocosm experiment, we found that fish predation was negatively impacted by strobing lighting effects, such as the lighting environment created by vehicles crossing bridges with railings.

Wildlife. We did not find evidence that ALAN was associated with ground-dwelling mammal space use or community composition in the riparian areas of this study. However, ALAN was related to trophic and food-web interactions of small mammals, suggesting that ALAN may have community to ecosystem-level effects. For bats, initial analyses suggest greater bat activity in unlit vs. lit wetland habitats.



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