AT THE CROSSROADS BETWEEN ASTRONOMY AND ECOLOGY: EXPLORING LINKS BETWEEN URBAN SKYGLOW AND NOCTURNAL BIRD MIGRATION

C. Villemur[1], J. Milli[1], P. Gaüzère[2], C. Desjonquères[2], B. Drillat[3], F. Malbet[1], P. Deverchère[4] and B. Falque[5]

Abstract. This study investigates the impact of urban skyglow on nocturnal bird migration by combining night sky brightness measurements and acoustic monitoring in the Grenoble basin. Using photometric sensors and bioacoustic recorders, we tracked the spring migration of the Black-crowned Night Heron (*Nycticorax nycticorax*) across two urban sites. Preliminary results show no clear effect of night sky brightness on migratory activity, though temporal patterns linked to night progress and seasonality were evident. Methodological limitations and behavioral biases are discussed, with perspectives for integrating radar data in future works.

Keywords: Light pollution, Skyglow, Nocturnal bird migration, Bioacoustics, Urban ecology, Night sky brightness, Interdisciplinary research, Artificial light at night (ALAN), *Nycticorax nycticorax*.

1 Introduction

1.1 Astronomy and Light Pollution: Scientific Challenges and Interdisciplinary Collaborations

Astronomy has long been confronted with various forms of environmental disturbance, most notably artificial light at night (ALAN), which significantly impairs celestial observations. As early as the 1950s, American astrophysicists blew the whistle, prompting the relocation of major observatories to remote sites by the mid-20th century (Challéat 2018). Moreover, ALAN is affected by atmospheric pollution, notably through enhanced light scattering by particulate matter, including particles smaller than 10 µm (PM10, Sciezor & Czaplicka 2020). Other growing anthropogenic pressures also affect observatories, such as rising global temperatures with consequences on increased dome- or ground-layer seeing (Cantalloube et al. 2020), more variable precipitable water vapour (Böhm et al. 2020) impacting infrared observations, frequent wildfires directly threatening major astronomical sites (Barbuzano 2025) or worsening sky transparency of 0.2%/decade (Steinbring 2022). Therefore astrophysics has an incentive to engage into interdisciplinary collaborations, where it can actively share its expertise in order to tackle common environmental and societal challenges (Moutou et al. 2024).

1.2 Urban Skyglow and Nocturnal Bird Migration: An Exploratory Acoustic Approach

Among such initiatives, the *Institut de Planétologie et d'Astrophysique de Grenoble (IPAG)* has been conducting sky observations and public engagement campaigns both in the presence and absence of public lighting (Milli et al. 2024). In parallel, astrophysics-grade sensors have been deployed to measure night sky brightness (NSB) at various locations across the Grenoble basin, a critical migratory corridor along the Isère river. This work is embedded in a collaborative research initiative involving the *Ligue de Protection des Oiseaux (LPO)*, the *Laboratoire d'Ecologie Alpine (LECA)* and the *Institut des Géosciences de l'Environnement (IGE)* to investigate the effects of light pollution on nocturnal bird migration (Milli et al. 2024). Existing research has already

[1] Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France
[2] Univ. Grenoble Alpes, CNRS, LECA, F-38000 Grenoble, France
[3] LPO Auvergne Rhône-Alpes, délégation territoriale de l'Isère, MNEI, 5 place bir Hakeim, 38000 Grenoble, France
[4] ScotopicLabs, 11 rue Calas, 69004, Lyon, France
[5] AurorAlpes, 2 rue Anthoard, 38000 Grenoble

demonstrated disorientation, attraction, increased collisions, and exhaustion of migratory birds exposed to individual sources of artificial lighting, primarily using radar analysis to capture the impact on large populations (e.g. Van Doren et al. 2017; Day et al. 2015; Ballasus et al. 2009; La Sorte & Horton 2021). Our present study shifts the focus to the effects of skyglow-diffuse night sky brightness caused by multiple urban light sources and modulated by atmospheric conditions-rather than individual lights. Importantly, we employ passive acoustic monitoring (PAM), which enables species-specific identification. Despite the limitations of PAM for quantification, it can be used to evaluate the phenological responses of various migratory bird species to urban skyglow. While our analysis remains exploratory, we outline here the methodological framework and initial results that enable future causal inference modeling and methodological expansion to other seasons, sites, and bird species.

2 Methodological Framework: Integrating Passive Acoustic Monitoring and Skyglow Measurement for Studying Nocturnal Bird Migration

2.1 Passive Acoustic Monitoring and Species Selection

Since 2024, acoustic recording devices (Song Meter Mini 2 Li-ion, Wildlife Acoustics) have been deployed at six sites across the Grenoble basin during spring (pre-nuptial migration) and autumn (post-nuptial migration). These devices continuously record stereo sound from dusk to dawn. One of the two microphones is located at the focus of a 40 cm parabolic reflector oriented toward zenith to amplify bird sounds flying above the device. Two of these stations are colocated with Ninox photometric sensors (Sky Quality Meters), which measure sky luminance in mag/arcsec^2 over a 20° field of view, or with FRIPON (Fireball Recovery and Inter-Planetary Observation Network) fish-eye cameras (see Milli et al. 2024, for details on instrumentation and site installation). The latter has been calibrated to estimate night sky brightness (Boribon 2024). Acoustic analysis was conducted using BirdNET, a neural network developed by the Cornell Lab of Ornithology (Kahl et al. 2021). The tool is widely used in bat and bird bioacoustics research. Our parameters were set to maximize detection sensitivity, accepting a higher number of false positives, which were filtered during manual post-processing. Specifically, we used the following BirdNET settings: a sensitivity value of 1.5, a confidence threshold of 0.1, and a 2-second overlap (Funosas et al. 2024). To ensure reliable species identification, approximately 120 BirdNET detections per site and season were manually validated and calibrated using a fixed accuracy threshold of 90% specific to each site, season, and species (Wood & Kahl 2024). We focused initially on the Black-crowned Night Heron (*Nycticorax nycticorax*), a member of the Ardeidae family, which favours wetlands. This species is notably vocal at night, easily recognizable by ear, reliably identified by BirdNET even in urban areas, and known to migrate along the Isère river.

2.2 Integrating Light Pollution Metrics and Environmental Filtering for Bioacoustic Analysis

Given the variability in public lighting infrastructure by location, day, and time of year, we chose to use NSB as a proxy for light pollution. This approach is well justified, as sky brightness is predominantly caused by ALAN in urban environments (Jechow et al. 2017; Leng et al. 2019). Additional environmental and anthropogenic factors influencing skyglow were documented to support future causal inference modeling. The Directed Acyclic Graph (DAG) shown in Fig. 1 represents these factors and their causal relationships, providing a structured visual framework for subsequent analysis. Astrophysical data were obtained from Ninox, meteorological data from the IGE automated weather station (except cloud cover, which came from the binary cloud mask computed using Meteosat data*, and PM10 concentrations from the Geodair platform. For this exploratory analysis, we focused on two sites approximately 3 km apart: one in central Grenoble (rooftop of the city council) and the other within the campus of Université Grenoble-Alpes (in St-Martin d'Hères). Due to poor detectability at the city council site in spring 2025, only the summer 2024 campaigns at both sites and the summer 2025 campaign at the campus were retained. All environmental data were sourced within 3 km of the recording locations. We used 30-minute time bins to maintain temporal resolution and account for rapid changes in lighting, weather, and moon conditions (e.g., moon altitude). Importantly, we included both detections and absences of birds in the dataset, removing time bins with extreme wind or precipitation that could impair acoustic detectability. Validated detections were filtered to retain only those at least one minute apart, interpreted as different individuals.

*GEO-CMA product of NWC SAF

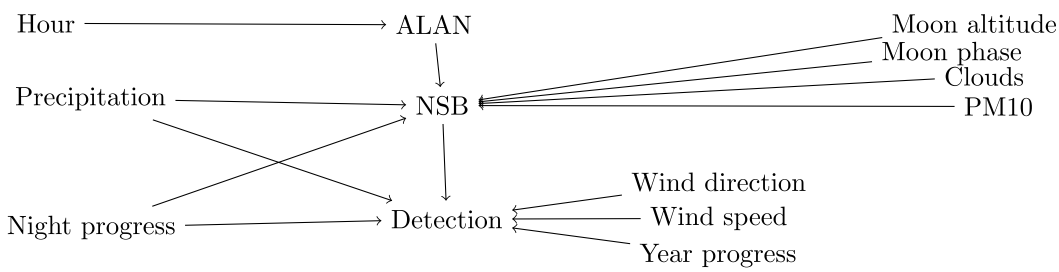

Fig. 1. Directed Acyclic Graph representing relationships among environmental variables.

3 Preliminary Results from Two Urban Sites During Spring Migration

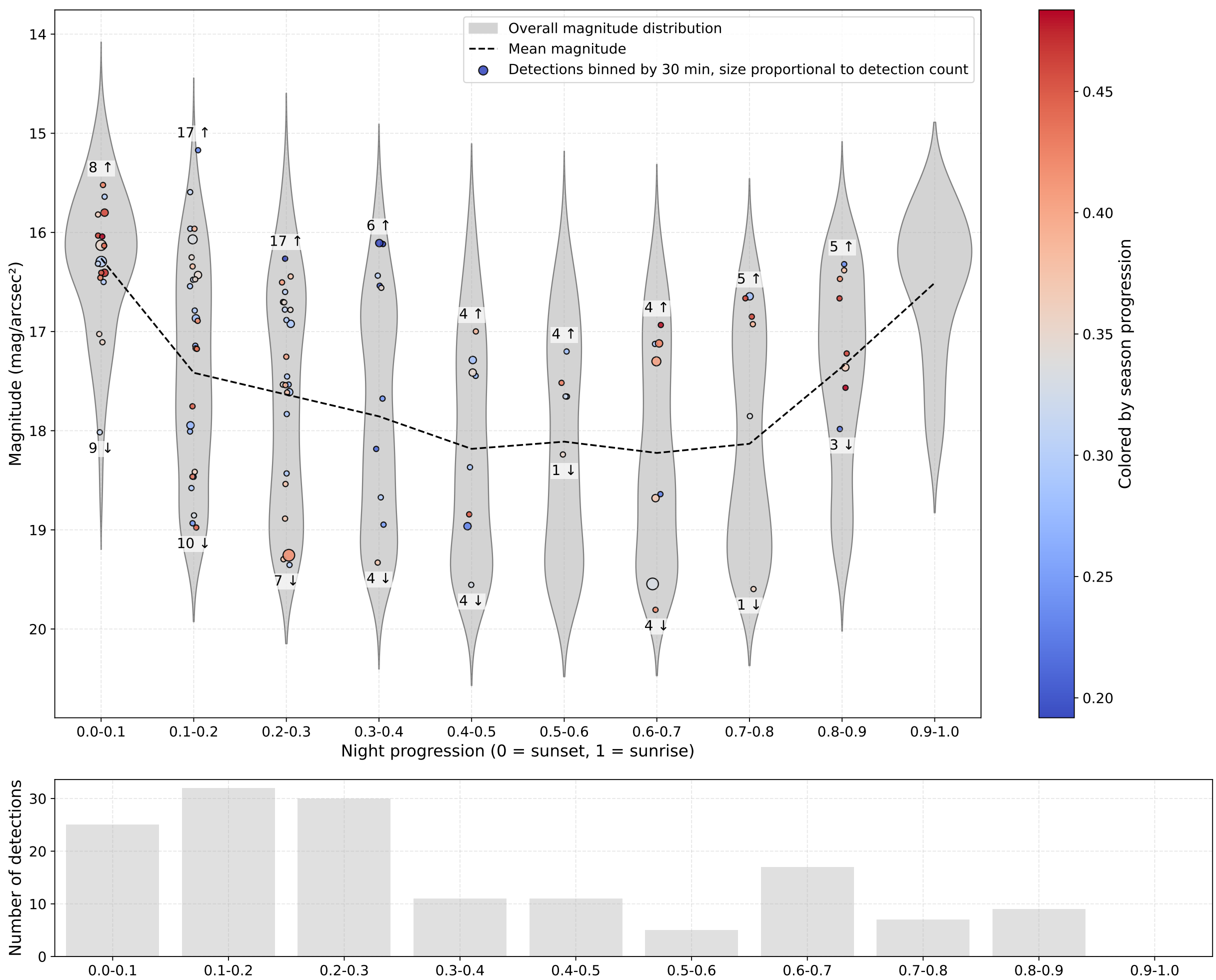

Fig. 2. Passages of Black-crowned Night Herons on campus over the season (spring 2024-2025). The x-axis bin represents 10% of the night's duration (0 = sunset, 1 = sunrise); consequently, time intervals do not correspond to fixed clock times across seasons. Because nights are longer earlier in the season, the temporal resolution varies slightly. The top panel shows the magnitude (NSB) of each detection relative to night progression and season (0 = January 1, 1 = December 31). Numbers with an upwards (respectively downwards) arrow indicate the counts of individuals detected with a NSB above (resp. below) the mean NSB in that time bin, shown as a dashed line. The bottom panel shows the number of Night-Heron detections across night progression.

Across the spring season of 2024 and 2025, 118 detections were retained from the campus and downtown sites, based on a 90% identification threshold and following the application of meteorological filters. Preliminary analyses indicate that both the time of the night and the date strongly influence bird passages. First results, as shown in Fig. 2, suggest a balanced distribution of points above and below the median NSB values, indicating no clear effect of NSB on migratory activity. The use of color to represent seasons effectively on this figure highlights temporal variation, but no distinct pattern emerges: early and late migrants do not appear to show any consistent preference relative to NSB levels. At this stage, results do not indicate any significant effect of sky brightness, and by extension of the light halo, on the spring migration phenology of the Black-crowned Night Heron (see Fig. 2). However, given that statistical analyses (Generalized Additive Models, GAMs) are still ongoing, this possibility cannot be ruled out yet.

4 Discussion and Perspectives

4.1 Potential Biases Related to Species Behavior and Migration Patterns

Several known sources of bias may account for the lack of observed influence of light pollution. First, the species studied is known to migrate at low altitudes and may therefore be less sensitive to skyglow compared to species that migrate at higher altitudes such as thrushes. Furthermore, this species-like others in the same family-may temporarily settle in the Isère region. Consequently, some detections may not reflect active migration but rather local stopover behavior, resulting in the inclusion of stationary individuals in migration counts.

4.2 From Proxy Limitations to Methodological Improvements

In this study, we assumed that a detection indicated the passage of at least one individual, and that the number of vocalizations was proportional to migratory activity. However, night migrating birds do not consistently vocalize in flight, potentially leading to false negatives. These false negatives have not yet been quantified but may represent a substantial bias in analyses that rely on presence-absence data. Additionally, Van Doren et al. (2017) reported that artificial lighting may increase the vocal activity of nocturnal migrants, introducing another potential bias in our acoustic proxy. This highlights the value of incorporating radar data into such studies. In future work, the use of radar would be essential to quantify migration fluxes more accurately and potentially assess flight altitudes. Such data would complement acoustic monitoring as the only way to reliably identify the species.

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