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# SOUND COMMUNICATION INTERFERENCE WEIGHTING FOR TERRESTRIAL ANIMALS

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## ABSTRACT

In epidemiological research on the effects of noise on terrestrial animals (primarily birds and mammals), A-weighted sound levels are often used for convenience. However, A-weighting is based on human loudness perception and is not well-suited for this purpose. The plan-B project explored alternatives, as assessing perceived loudness across multiple species is impractical. Two alternatives used in humans are hearing level weighting and communication interference weighting. These could also be applied for terrestrial animals. The former is a conservative approach covering all sound uses, while the latter can be easily extracted from the vast database of recorded animal communications. Different weightings were applied to two-week recordings at 40 suburban and urban locations, where traffic is the dominant noise source. The Spearman correlation between 15-minute equivalent levels with different weightings was very high. Thus, for a Europe-wide assessment, the specific weighting applied may not be critical. However, for specific locations, sources, or particular (endangered) species, the chosen weighting may affect conclusions.

**Keywords:** *weighting curves, bird communication interference, biodiversity*

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## 1. INTRODUCTION

The effects of noise on terrestrial biodiversity have become a critical area of ecological research. Anthropogenic noise, stemming from urbanization, industrial activities, and transportation, poses a significant threat to the persistence of many species [1] [2]. Studies have shown that noise pollution can influence physiology [3], increase costs of communication, and disrupt various biological functions, leading to changes in species interactions and altering community structures [4] [5].

Sound plays vital roles in the lives of many organisms, similar to its functions in humans. It serves as a tool for passive monitoring, enabling situational awareness by detecting danger, confirming safety, and identifying opportunities for food and water. Additionally, sound facilitates active communication, essential for mate finding, establishing territorial boundaries, and sharing experiences. However, task-irrelevant sounds can interfere with these primary functions, causing masking effects or making auditory scene analysis more challenging.

To measure the interference caused by noise, various strategies have been developed. One approach focuses on what can be heard being disturbing, while another emphasizes the impact on active communication. In humans, the former approach led to the adoption of A-weighting, a method that adjusts sound measurements to reflect the relative loudness perceived by the human ear [6]. Historically, speech interference weighting has also been used to assess how background noise affects speech communication.

This study investigates the potential to calculate communication interference weights for terrestrial animals using analysis of recordings in 1/3 octave band spectra. By clustering these spectra, we can decrease the diversity of variants and simultaneously exclude recordings contaminated by extraneous sounds. In Section 3, the derived weighting curves are utilized on a variety of noise recordings from suburban and urban areas, while Section 4 provides a discussion of our key results.

## 2. DERIVING SOUND COMMUNICATION INTERFERENCE WEIGHTING

For deriving communication interference a representative amount of bird sounds had to be collected. For this, we used one of the primary sources for bird song recordings, Xeno-canto, a collaborative website dedicated to sharing wildlife sounds from around the world. For deriving a weighting curve, only the spectral content of the song is relevant. Hence, 1/3 octave band spectra are calculated for each recording and normalized to obtain an rms-value of one for the highest 1/3 octave band while ignoring temporal structure.

However, several bird species produce songs with comparable spectra. This similarity can be explored to reduce the number of weighting curves that one could obtain. Hence, the spectra in the frequency range 160 Hz to 10000 Hz were mapped to two dimensions using UMAP (Uniform Manifold Approximation and Projection) [7] and subsequently clustering based on DBSCAN( Density-Based Spatial Clustering of Applications with Noise) [8] was applied. This procedure also allows to identify outlier spectra that could be caused by noisy recordings. the resulting mapping to two dimensions is shown in Figure 1. In this figure, different symbols refer to automatically identified clusters while colors are related to species. The prevalence of species in each cluster is further analyzed in Figure 3.

Figure 2 illustrates the mean spectral data grouped by bird clusters, revealing three prominent classifications: the extensively populated cluster 5 along with its numerous variants, cluster 4, and cluster 0. As depicted in Figure 3, cluster 5 and its variants encompass recordings of songbirds, cluster 0 is characterized by doves and pigeons, while cluster 4 includes species such as the mallard, grey heron, Eurasian jay, Eurasian coot, and common buzzard. The birds in this last group utilize vocalizations not for marking territories but for interactions such as mutual communication, signaling danger, or expressing aggression. Notably, the coot is recognized for its high-pitched

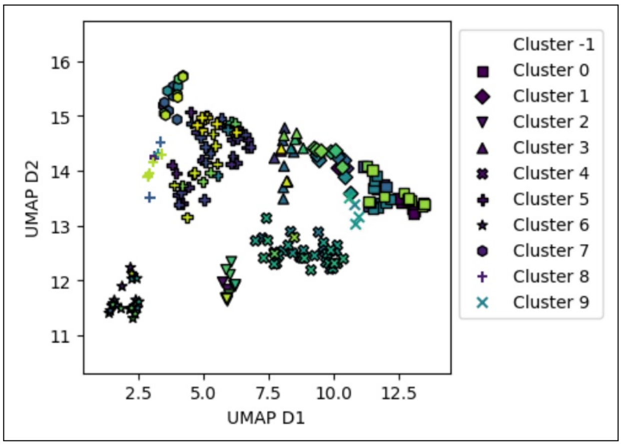


**Figure 1**. Clusters of bird song spectra based on 250 recordings from 25 bird species, mapped in 2 dimensions.

vocalizations at elevated pressure levels. A shared feature within this group may be their body size, which influences the ability to produce sound at lower frequencies [9]

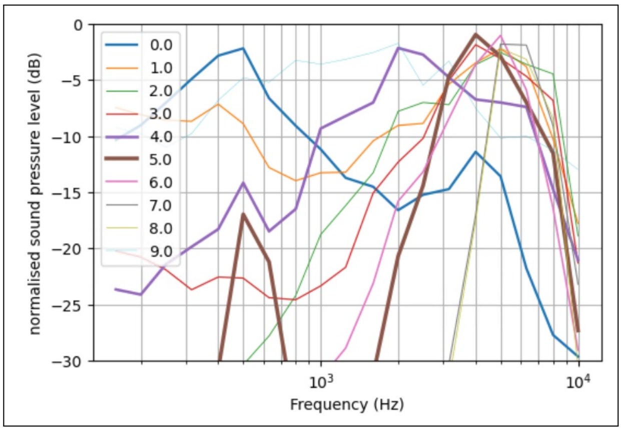


**Figure 2**. Song spectra averaged over each cluster; line width is proportional to the number of exemplars in the cluster thus thinner lines may refer to clusters of noisy or poor quality measurements.

Based on the communication spectra, three different weighting curves are proposed: CI1, CI2, CI3 (Figure 4). They are described by analytical functions similar to the ones used for describing A, B, and C-weighting. These functions correspond to filters with sets of complex conjugate poles and zeros, and can thus be implemented easily

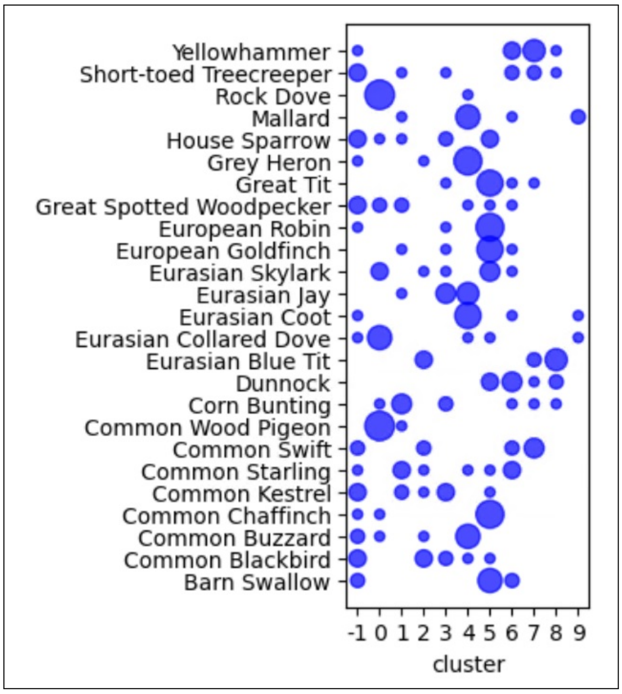


**Figure 3**. Distribution of the species over the clusters; the size of the circle is proportional to the number of recordings of that species in that cluster; cluster -1 refers to recordings that do not fall in one cluster

in measurement equipment.

## 3. INTERFERENCE WEIGHTED NOISE LEVELS

### 3.1 Effect of weighting on biodiversity surveys

To investigate how the selection of weighting curves could influence large-scale biodiversity studies, this research compares 15-minute equivalent noise levels using both A-weighting and CI-weighting. Approximately two weeks of data were gathered from 40 sites within the broader Ghent (Belgium) area. Each measurement was taken at the facade of a building, with environments varying from suburban to urban.

In Figure 5, a scatter plot is depicted illustrating the comparison between A-weighted and CI1-weighted levels (for songbirds) and A-weighted and CI2-weighted levels (for doves). To assess the monotonic relationship within these data points, we have determined Spearman's correlation coefficients: 0.898 for A-weighted vs. CI1-weighted, 0.928 for CI2-weighted, and 0.965 for CI3-weighted. The substantial correlation values suggest that on a broad scale, such as biodiversity surveys across an entire continent, using existing A-weighted noise maps could be an acceptable approach, particularly given the prevalence of anthropocentric noise mapping. With traffic being a primary contributor to anthropogenic sounds, especially in the suburban and urban areas examined here, either weighting scheme would indeed effectively highlight these human-induced auditory disturbances.

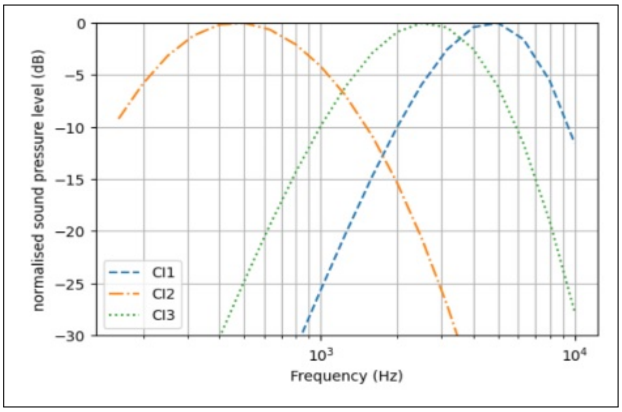


**Figure 4**. Communication Interference weighting curves proposed for three groups of bird species.

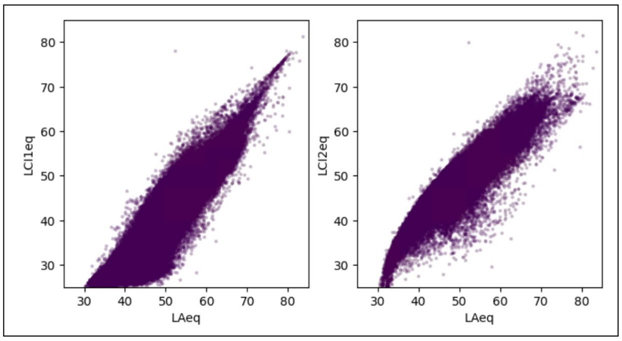


**Figure 5**. Scatter plot of 15-minute CI1 and CI2 weighted Leq versus A-weighted Leq; each dot represents a single observation at any time during the day at any of the 40 locations.

### 3.2 Temporal patterns

When examining specific situations, communication interference weighting can highlight differences between recording sites. Figure 6 illustrates the effect of weighting by comparing measurements at two suburban gardens. At the first measurement location (until day 115), the CI1-weighted levels exhibit a pattern over the day that is clearly influenced by the light/dark cycle. On certain days (depending on the weather), the CI1-weighted level shows a distinct increase in the early morning, linked to the morning bird chorus, which is the primary communication interference for songbirds. This pattern is not as evident in the A-weighted level plot (left part of the figure). At the second location (after day 115), a clear diurnal anthropogenic noise pattern is visible in A-weighted levels, including typical daily and weekly variations. The CI1-weighted level shows a more uniform pattern throughout the day. Interestingly, the highest CI1-weighted levels at this second location are lower than the levels observed during the morning chorus at the first location.

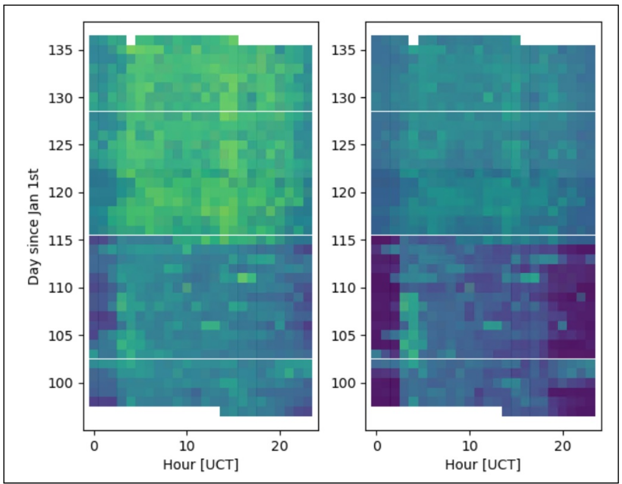


**Figure 6**. Heat map of noise levels at two suburban gardens (location change on day 115); left: A-weighted, right: CI1-weighted.

## 4. DISCUSSION

Communication interference weighting curves extracted in this publication are extracted from recordings of the communication of several bird species. These species were selected based on their estimated abundance in Belgium, hence the resulting weighting curves might not be applicable in different climatological zones and different continents. The database used for collecting the sounds was Xeno-canto. This sound collection contains contributions from lay persons and is not carefully checked for origin of the data nor the recording conditions are carefully checked. It can be expected that most recordings originate from suburban neighborhoods and thus song bird frequencies may already have been shifted to higher frequencies because of the presence of anthropogenic sounds [5].

The importance of appropriate frequency weighting is explored based on measurements in the Ghent area, Belgium. Belgium is situated at the crossroads of Europe, with two major roads, E40 and E17, intersecting near Ghent. Several air corridors pass over the measurement area, and although the nearest airport is 60 km away, aircraft noise is often clearly audible in the more tranquil areas. Within this context, and considering measurements at different hours of the day, a monotonous relationship was observed between A-weighted levels and CI-weighted levels. Thus, at times and locations with significant noise, whether anthropogenic or natural, a high noise level will be obtained regardless of the weighting. From this, one could conclude that for identifying zones with high disturbance, A-weighting might still be an acceptable alternative for assessing effects of noise on wildlife and biodiversity, even though it lacks a logical foundation. Although we would not advise doing so, it could be a cost-effective alternative for lengthy calculations when A-weighted noise maps are available.

More detailed analysis of the diurnal pattern of CI1-weighted noise level reveals the relative importance of other bird sounds compared to anthropogenic noise. Indeed, not only anthropogenic environmental noise has to be considered as a source of disturbance but also natural soundscapes can be noisy because of wind, waves, or other species, e.g. such as frogs [10]. Animals have adapted to noisy environments by selecting a specific window of opportunity for singing. This can include optimal meteorological conditions for acoustic transfer [11], diurnal pattern of other bio-phonic sounds, or waiting for a specific short time window [12]. Based on the above, one could expect that some birds have the ability to select optimal singing strategies to avoid anthropogenic noise as well as bio-phonic sound. Literature on birds adapting their singing behavior to urban sound environment [3] has gained a lot of attention, also in lay literature. Some experimental work is not so univocal [13] and point at the role of overlapping spectra. Observed pitch changes might not be the adaptive strategy but rather a side effect of singing louder in noisier environment [14], comparable to the Lombard effect in humans.

As a general conclusion, both theoretical considerations and measurement examples show that using a specific weighting curve for assessing communication interference in animals could be beneficial. This could allow for a more targeted impact assessment of new initiatives and interventions, in particular if the species of interest are known. This could also lead for more efficient noise mapping as the frequency range that needs to be modeled is usually less extended than for human-related A-weighting. Hence, for new biodiversity-related noise mapping the use of CI-weighting should be preferred.

## 5. ACKNOWLEDGMENTS

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## 6. REFERENCES

[1] R. Sordello, O. Ratel, F. Flamerie De Lachapelle, C. Leger, A. Dambry, and S. Vanpeene, "Evidence of the impact of noise pollution on biodiversity: A systematic map," *Environmental Evidence*, vol. 9, pp. 1–27, 2020.

[2] M. M. Sander and D. T. Tietze, "Impacts of traffic infrastructure on urban bird communities: A review," *Sustainability*, vol. 14, no. 24, p. 16805, 2022.

[3] R. Amjad, T. Ruby, K. Ali, M. Asad, A. Imtiaz, S. Masood, M. Q. Saeed, M. Arshad, S. Talib, Q.-t. A. Alvi, A. Khan, and M. M. Sharif, "Exploring the effects of noise pollution on physiology and ptilochronology of birds," *PLOS ONE*, vol. 19, p. e0305091, June 2024.

[4] A. Kok, B. Berkhout, N. Carlson, N. Evans, N. Khan, D. Potvin, A. Radford, M. Sebire, S. Shafiei Sabet, G. Shannon, *et al.*, "How chronic anthropogenic noise can affect wildlife communities. front ecol evol. 2023; 11: 1130075."

[5] Z. Hao, C. Zhang, L. Li, B. Gao, R. Wu, N. Pei, and Y. Liu, "Anthropogenic noise and habitat structure shaping dominant frequency of bird sounds along urban gradients," *Iscience*, vol. 27, no. 2, 2024.

[6] D. S. Houser, W. Yost, R. Burkard, J. J. Finneran, C. Reichmuth, and J. Mulsow, "A review of the history, development and application of auditory weighting functions in humans and marine mammals," *The Journal of the Acoustical Society of America*, vol. 141, no. 3, pp. 1371–1413, 2017.

[7] L. McInnes, J. Healy, and J. Melville, "Umap: Uniform manifold approximation and projection for dimension reduction," *arXiv preprint arXiv:1802.03426*, 2018.

[8] E. Schubert, J. Sander, M. Ester, H. P. Kriegel, and X. Xu, "Dbscan revisited, revisited: why and how you should (still) use dbscan," *ACM Transactions on Database Systems (TODS)*, vol. 42, no. 3, pp. 1–21, 2017.

[9] J. I. Friis, J. Sabino, P. Santos, T. Dabelsteen, and G. C. Cardoso, "The allometry of sound frequency bandwidth in songbirds," *The American Naturalist*, vol. 197, no. 5, pp. 607–614, 2021.

[10] H. C. Gerhardt, "Sound pressure levels and radiation patterns of the vocalizations of some north american frogs and toads," *Journal of Comparative Physiology*, vol. 102, no. 1, pp. 1–12, 1975.

[11] A. Guibard, F. Sèbe, D. Dragna, and S. Ollivier, "Influence of meteorological conditions and topography on the active space of mountain birds assessed by a wave-based sound propagation model," *The Journal of the Acoustical Society of America*, vol. 151, no. 6, pp. 3703–3718, 2022.

[12] L. M. Chronister, T. A. Rhinehart, and J. Kitzes, "When birds sing at the same pitch, they avoid singing at the same time," *Ibis*, vol. 165, no. 3, pp. 1047–1053, 2023.

[13] E. Bermúdez-Cuamatzin, M. López-Hernández, J. Campbell, I. Zuria, and H. Slabbekoorn, "The role of singing style in song adjustments to fluctuating sound conditions: a comparative study on mexican birds," *Behavioural processes*, vol. 157, pp. 645–655, 2018.

[14] E. Nemeth and H. Brumm, "Birds and anthropogenic noise: are urban songs adaptive?," *The American Naturalist*, vol. 176, no. 4, pp. 465–475, 2010.