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Bat guano as a non-invasive indicator of environmental pollution with heavy metals

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Heavy metals are persistent, bioaccumulating pollutants, and their spatial heterogeneity is central to environmental quality assessment. We evaluated fresh bat guano as a practical, non-invasive matrix for monitoring multi-element heavy-metal "fingerprints"across roost locations. Fresh guano was collected from eight sites (five replicates per site). Concentrations of Mn, Fe, Ni, Cu, Zn, Cd and Pb were quantified by Atomic Absorption Spectroscopy (AAS), and Hg by an AMA-254 mercury analyser. Analyses were conducted on the log10 scale. We computed descriptive statistics and a Metal Pollution Index (*MPI*; geometric mean, reported as log10(*MPI*)) to rank site-level overall metal burden. Within-species spatial differences were tested using Welch ANOVA. Mixture patterns were summarised using hierarchical clustering ("fingerprints"), Spearman correlations and Principal Component Analysis (PCA).
Log10(*MPI*) showed pronounced spatial heterogeneity (0.995–1.47; ≈ threefold range between least and most affected sites). In *Rhinolophus hipposideros*, site effects were significant for Mn, Fe, Cd, Pb, Hg and Ni, while in *Myotis myotis* the location effect persisted across all metals. The strongest positive correlations were Cu-Zn (ρ=0.958) and Mn-Ni (ρ=0.786). PCA separated a Zn-Cu-Cd-Pb axis from Fe-Mn-Ni variance relative to Hg, supporting site-specific pollution signatures from guano.

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