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Bioacoustic Baselines for Intact Forests

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ABSTRACT

Forests are at the frontline of both climate and biodiversity crises: forests are fundamental to the regulation of Earth's atmospheric carbon dioxide levels, and tropical forests alone harbour over half of all terrestrial species. Consequently, forests are at the centre of global efforts to both prevent extinctions of species and sequester carbon to mitigate climate change. Most carbon sequestration initiatives do not measure how effective they are in terms of biodiversity protection, largely because it is expensive, complex and often not required. Compounding this problem is the lack of reliable biodiversity baselines, against which positive changes due to conservation and negative changes due to human pressure could be measured. The Soundscape Baselines Project is a global initiative to collect and analyse bioacoustic baselines in some of the world's remaining intact forests. The baseline data are collected using a modular system of passive acoustic monitoring and ancillary data that can be expanded and integrated with other technologies. It is managed by local teams of scientists, conservation practitioners and community members. Emphasis is on the usability of data and equipment beyond the project, community engagement and building an interconnected network of scientists across forested countries, particularly historically underexplored partnerships between tropical forest countries. In this paper, we describe the initiative and share initial results to demonstrate how the project could be used for biodiversity conservation purposes in the future and outline steps towards operationalization. We also draw a list of priority areas for additional baseline locations across remaining intact forests. We discuss how bioacoustic baselines established now and in the future will become invaluable in a rapidly changing climate and the resulting unprecedented change in Earth's forests. Establishing rigorous biodiversity baselines using bioacoustics and other technologies and approaches through collaborative science is fundamental to ground biodiversity conservation in evidence, equity and transparency.

RESUMEN

Los bosques se encuentran en primera línea tanto de la crisis climática como de la de la biodiversidad, siendo fundamentales para regular los niveles de dióxido de carbono en la atmósfera terrestre; además, los bosques tropicales, por sí solos, concentran más de la mitad de todas las especies terrestres. Por consiguiente, los bosques ocupan un lugar central en los esfuerzos mundiales tanto para prevenir la extinción de especies como para capturar carbono con el fin de mitigar el cambio climático. La mayoría de las iniciativas de secuestro de carbono no miden su eficacia en términos de protección de la biodiversidad, en gran medida por su alto coste, su gran complejidad y porque frecuentemente no es un requisito. A este problema se suma la falta de líneas de base fiables sobre la biodiversidad, con las que se pudieran medir tanto cambios positivos debidos a la conservación como cambios negativos asociados a la presión humana. El Proyecto Soundscape Baselines es una iniciativa global para recopilar y analizar líneas de base bioacústicas en algunos de los bosques intactos que aún quedan en el mundo. Estos datos de línea de base se recopilan mediante un sistema modular de monitoreo acústico pasivo además de datos complementarios que pueden ampliarse e integrarse con otras tecnologías. El proyecto está gestionado por equipos locales de científicos, profesionales de la conservación y miembros de comunidades. Asimismo, se pone especial énfasis en la utilidad de los datos y los equipos más allá del proyecto, en la participación de las comunidades y en la creación de una red interconectada de científicos en países con bosques, en particular en colaboraciones históricamente poco exploradas entre países con bosques tropicales. En este artículo, describimos esta iniciativa y compartimos los resultados iniciales para demostrar cómo el proyecto podría utilizarse en el futuro con fines de conservación de la biodiversidad, y esbozamos los pasos para su puesta en marcha. También elaboramos una lista de áreas prioritarias para establecer nuevas líneas de base en los bosques intactos restantes. Analizamos cómo las líneas de base bioacústicas establecidas ahora y en el futuro resultarán inestimables en un clima en rápida evolución y el consecuente cambio sin precedentes en los bosques de la Tierra. Establecer líneas de base rigurosas de biodiversidad utilizando la bioacústica, junto con otras tecnologías y enfoques a través de la ciencia colaborativa, es fundamental para asentar la conservación de la biodiversidad en la evidencia, la equidad y la transparencia.

1 | Introduction

There are nine planetary boundaries that humans must not cross if we are to ensure the sustainable use of natural resources on Earth (Steffen et al. 2015). Of these, six have already been crossed, including Biosphere integrity (Richardson et al. 2023). Biodiversity is being rapidly lost, with approximately 25% of animal and plant species known to science—equivalent to a million species—now threatened with extinction (Díaz et al. 2019). This ongoing crisis, often described as the sixth mass extinction (Ceballos et al. 2020), is driven primarily by habitat loss and fragmentation, overexploitation and more recently, climate change (Barlow et al. 2016; Jaureguiberry et al. 2022).

Forests are central in both the biodiversity and climate crises (Griscom et al. 2017; Buřivalová et al. 2023). First, forests play a fundamental role in the Earth's carbon cycle, absorbing carbon dioxide and thereby helping to stabilize the climate (Malhi et al. 2002; Schimel 2014). Given the rapid progression of anthropogenic climate change, forests have become the central focus of Natural Climate Solutions (NCS)—actions that aim to conserve, restore or improve the management of ecosystems in order to mitigate greenhouse gas emissions or sequester CO_2 from the atmosphere (Griscom et al. 2017). Second, forests harbour over half of terrestrial vertebrate species (Pillay et al. 2022; Kass et al. 2022). Recognizing the importance of forests to both climate and biodiversity, the international community has made ambitious commitments to halt deforestation and degradation, as well as to restore forest lands (Gasser et al. 2022; Nasi 2022).

Despite widespread recognition of the importance of biodiversity, most conservation and climate initiatives focused on forests do not measure directly how effective they are in terms of biodiversity protection. This is because monitoring biodiversity is expensive, difficult and often not required (Buřivalová et al. 2023). Many initiatives may, instead of measuring biodiversity directly, employ proxies such as forest cover, deforestation and forest degradation, which can be quantified using satellites at planetary scale (Hansen et al. 2013; de la Sancha et al. 2021). Whereas such proxies estimate broad biodiversity benefits (Gibson et al. 2011), they suffer from large uncertainties. Threats less readily visible on satellite images (e.g., unsustainable hunting, some types of logging, understory fires, diseases, chemical- and heavy metal contamination and climate change) can lead to severe faunal declines, resulting in defaunated forests or drastically altered communities (Redford 1992; Burivalova et al. 2014; Ghazoul et al. 2015; Benitez-Lopez et al. 2017; Sagar et al. 2026).

Where direct biodiversity measurements are required, guidelines or specific targets are at best vague, and at worst missing entirely. Often, it is simply prescribed that biodiversity must be monitored (Lindenmayer et al. 2013). In the case of carbon offset markets, detailed biodiversity reporting has not yet become a standard requirement. Despite these inconsistencies, there is an exponential growth in projects that aim to monetise biodiversity protection through credits (Antonelli et al. 2024). Regardless of other potential controversies, if biodiversity credit projects are to become widely implemented, they must be referenced against robust biodiversity baselines to ensure meaningful impact monitoring for biodiversity conservation (Antonelli et al. 2024).

A lack of reliable biodiversity baselines complicates efforts to quantify positive effects of conservation and negative impacts of human extraction. Baseline biodiversity data for global forests are either missing, patchy, focused on limited taxonomic groups or collected with variable and idiosyncratic methodologies and sampling designs (Hillebrand et al. 2018; Christie et al. 2020; Kuczynski et al. 2023). There is no global

consensus on what constitutes a biodiversity baseline. Without reliable baselines, projects can carry out equivalent measurements at control sites, but finding an appropriate control and then gaining access to these sites is often very challenging. Alternatively, projects may rely on measuring relative change over time or using space-for-time substitutions, both of which are susceptible to the shifting baselines phenomenon and confounding factors.

Shifting baseline is a concept originally described in fisheries (Pauly 1995; Papworth et al. 2009), and it can be described as observers perceiving relatively little change in their environment despite substantial changes occurring over time because their reference point goes back only to the beginning of their career or life, or their 'cognitive baselines' (Lozano-Montes et al. 2008). For example, a person born in the 2000s may view a population of certain animals as stable, even though it was much larger in the 1960s. Such 'shifting baselines' can also be present in formal, scientific observations, such as when used to 'describe changes to a system that are measured against earlier reference states that themselves differ significantly from the original state' (Corlett 2013). We note that the definition of 'original state' itself is highly complex and dependent on the observer's subjective decision of timescale, heavily biassed by (often false) western conservation narratives of where 'pristine' nature occurs (Ellis et al. 2021). The impact of shifting baselines on conservation has already been demonstrated in British, South American and North American bird communities (Jones et al. 2021; Luther et al. 2022; Rittenhouse et al. 2010; Stouffer et al. 2021).

Suitable reference sites for terrestrial baseline biodiversity data are becoming increasingly scarce. For example, Intact Forest Landscapes, as defined by Potapov et al. 2017, decreased by 1.5 million km^2 or 12% of their total remaining area between 2000 and 2020. In addition, even the most 'intact' habitats are seeing changes in biodiversity under climate change (Wolfe et al. 2025). Therefore, there is an urgent need to document biodiversity baselines before it is no longer possible (Corlett 2013). Such baselines could be used to support future conservation and restoration projects, particularly where individual projects no longer have access to suitable control sites.

To be effective, the method for characterizing baselines and monitoring changes in biodiversity must be both rapid, cost-efficient and ideally include multiple taxonomic groups (Swann and Perkins 2014; Beng and Corlett 2020; Teixeira et al. 2024). Acoustic monitoring has emerged as a tool that can be rapid, robust and cost-effective, offering a solution for tracking biodiversity across several taxonomic groups (birds, amphibians, mammals, invertebrates), including elusive, rare, threatened and even unknown species, in near real-time across large and remote areas (Teixeira et al. 2019; Rumelt et al. 2021; Vega-Hidalgo et al. 2021; Somervuo et al. 2025). The development of passive acoustic monitoring, along with advances in computing infrastructure and machine learning now allow ecologists, community members and conservation practitioners to collect, store and analyse large amounts of biodiversity-relevant data in the form of soundscapes (Servick 2014). Analysing soundscapes using acoustic indices is one approach to assess broad, structural changes in soundscapes, such as diel or seasonal patterns, particularly where individual species are poorly known. Such whole soundscape approaches can help target the detection and classification of the sounds of individual species, communities or sounds associated with human disturbance, using for example, machine learning approaches, to understand changes in occupancy, presence and even proxies of abundance and composition (Somervuo et al. 2025; Winiarski et al. 2026; Rumelt et al. 2021). In this regard, soundscapes of a given environment can serve as bioacoustic baselines, which have the potential to be used as important components of biodiversity baselines, against which biodiversity changes can be measured over time (Pijanowski et al. 2024), complementing methods that measure non- or weakly-vocalizing taxa. In this study, we define a bioacoustic baseline as a continuous, high-resolution recording of soundscapes in relatively intact ecosystems, capturing the full range of diel and seasonal variation in acoustic activity, including both biotic and abiotic acoustic components. The purpose of such a baseline is to generate a multidimensional reference profile against which other sites, time periods or management interventions can be compared. This includes acoustic indices, temporal patterns therein (e.g., diel cycles), and, where available, taxon-specific activity. Variation in these profiles is an indicator of changes in soundscape structure that can subsequently guide investigations of direct measures of biodiversity loss or gain.

Soundscape analysis has been successfully used to understand how degradation and deforestation of tropical rainforests are affecting vertebrate communities in Malaysian Borneo (Mitchell et al. 2020; Sethi et al. 2022), Panama (Bradfer-Lawrence et al. 2020) and the Amazon (Furumo and Mitchell Aide 2019; Rappaport et al. 2022). Likewise, this method has been used to address questions such as how animal communities change with wildfires (Duarte et al. 2021), how biodiversity changes with the age of forest stands and logging (Pekin et al. 2012; Burivalova et al. 2019; Burivalova et al. 2021; Müller et al. 2023), or to assess habitat-animal associations in particular sites or ecosystems (Ribeiro Jr et al. 2017; Rappaport et al. 2022). While soundscapes do not capture all aspects of biodiversity, they offer an objective and cost-effective means of documenting multiple taxa (Chen and Wiens 2020) and changes over time (Izquierdo-Tort et al. 2024; Somervuo et al. 2025). Importantly, soundscapes and changes therein can be analysed even before all vocalizing species are known and described in terms of their vocalizations, enabling the measurement of understudied aspects of biodiversity while allowing future species identifications.

With the unprecedented investment in Natural Climate Solutions, the global decline of biodiversity and the shifting baselines phenomenon, it is important to establish rigorous biodiversity baselines in all ecosystems, and particularly forests. Here, we introduce the Soundscape Baselines Project, a global initiative to collect and analyse bioacoustic baselines in some of the world's remaining intact forests. Specifically, we (1) describe the initiative and (2) share initial results from pilot bioacoustic baseline locations to demonstrate how such results could be used for biodiversity conservation purposes. Additionally, we (3) draw a list of priority areas for additional baseline locations across the remaining intact forests. We emphasize that soundscape analysis is a developing field with much ongoing work on analytical methods, both in terms of individual species classification and broad soundscape analyses. Developing such methodologies,

for example, to identify all vocalizing species, which may vary for different regions and habitats, will take time. In the meantime, this project seeks to create a time capsule of the world's remaining intact forest soundscapes, to be available for such methodological advances, and as a permanent record that can be reanalyzed once optimal methods are developed.

2 | Methods

2.1 | Location of Bioacoustic Baselines

In the first phase of the Soundscape Baselines Project, the six pilot baseline locations were chosen non-randomly (Figure 1). We opportunistically sought partners such as individual research groups, communities, Indigenous Peoples, research stations and conservation areas that manage or own intact forests and were interested and able to participate in the project (Supporting Information S1). Intact forests were defined as forests with minimal human influence, limited to low levels of hunting and no commercial timber extraction in at least the last 40 years, such that recorded soundscapes are expected to be minimally influenced by anthropogenic noise. The six pilot baseline locations included sites in (i) Andulau Forest Reserve (Brunei); (ii) Tiputini Research Station (Ecuador); (iii) Ibola Dja Bana Ba Massaha (Gabon); (iv) the Bavarian Forest National Park (Germany); (v) Manu Biological Station (Peru); and (vi) Baraboo Hills, Wisconsin (USA) (Figure 1, Tables S1 and S2).

In the next stage, the project aims to include intact forest sites in each forested biome within each realm, and eventually in each ecoregion. Therefore, we have combined several spatial layers to identify future priority site areas by identifying where 'intact' forests are, using the Intact Forest Landscapes data (IFL) (Potapov et al. 2017), in forested realms and biomes (Olson et al. 2001; Dinerstein et al. 2017).

2.2 | Data Collection Protocol

At each of the six biaocoustic baseline pilot locations, we collected data from six sites. The sites were chosen based on a combination of a predetermined protocol and local ecological knowledge. The local teams (co-authors living or working at baseline locations, Supporting Information S1) chose sites that they considered representative of their forest and its variation. Each site was at least 1 km distant from all other sites for acoustic independence. Although there are certain species whose calls may travel further than 1 km (e.g., forest elephant, orangutan, howler monkey), most sound emitting species do not vocalize at amplitudes and frequencies that can be recorded at 1 km distance with the equipment we used (Winiarska et al. 2024). Importantly, this design (6 sites, > 1 km apart) was established as a trade-off to enable local teams to revisit all baseline sites within 1 day on foot. While increasing site numbers and distances would improve broader-scale biodiversity assessments, it would also limit participation in this project, which requires monthly revisits.

At each site, we deployed one bioacoustic recorder (BAR-LT, Frontier Labs), at ~1.5 m above ground on a tree trunk, with one omni-directional microphone pointing down. Within a radius of 10 m from the bioacoustics recorder, we also deployed one camera trap (Reconyx Hyperfire 2 Professional White Flash Camera OD Green), at 30–40 cm above ground, pointing in the direction of the most likely animal travel, as determined by local teams.

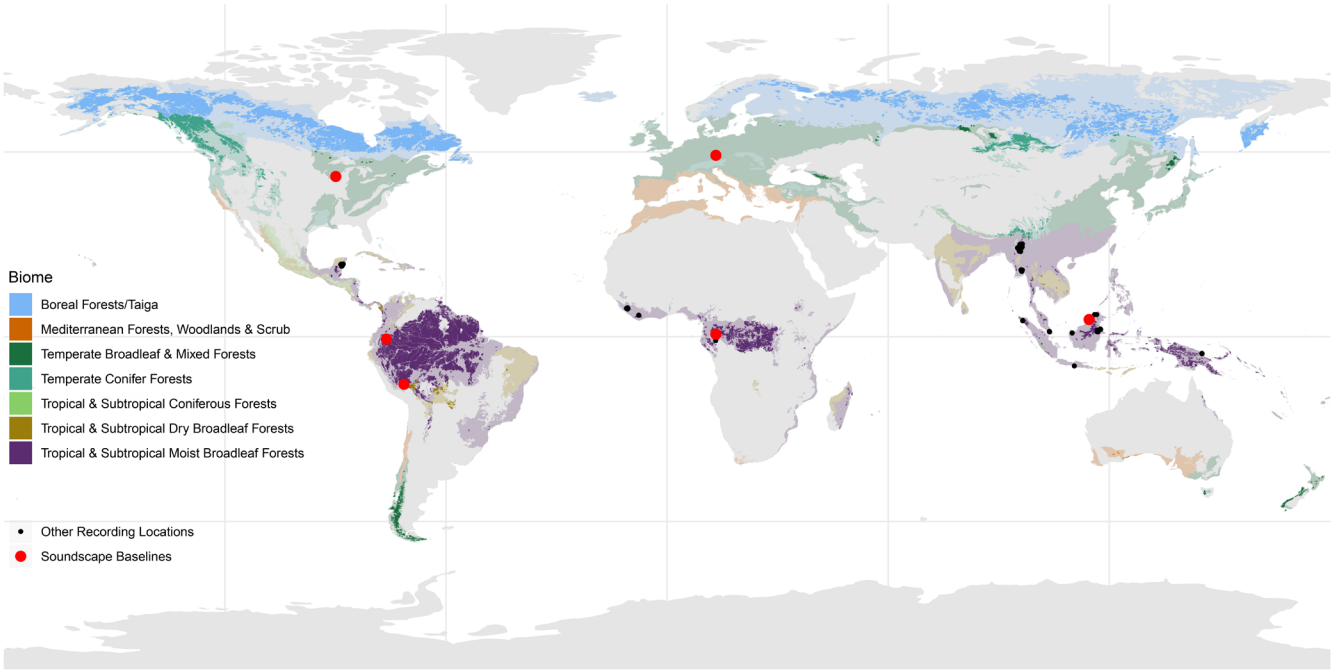

FIGURE 1 | Pilot bioacoustic baselines locations (large red circles) and additional shorter-term recordings (small black dots, not analysed here), in different biomes. For each forested biome, colours are dark in Intact Forest Landscapes (Potapov et al. 2017), representing priority areas for future baselines locations and pale where forests are no longer intact. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

The bioacoustic recorders were pre-programmed to record all sounds at 40 dB gain and at a frequency between 0 and 22.05 kHz (44.1 kHz sampling rate; Landau 1967), which represents a range accessible to a well-hearing human, and it excludes species that make sounds at ultrasonic frequencies. The sampling rate was selected as a trade-off between taxonomic coverage of vocalizing species (e.g., many species of invertebrates make sounds above 10 kHz) and data storage and battery life, which in turn determined the revisit frequency. Sampling at higher rates requires more storage and uses more energy. Recordings happened continuously (24 h a day, for at least 365 continuous days). The collection of continuous year-long recordings will allow acoustic patterns to be interpreted across a wide range of environmental conditions, rather than being driven by short-term weather variability. The recorded sounds were saved on SD cards as 30 min WAV files. The recorders had an integrated GPS for location and time synchronization. The camera traps were pre-programmed to capture three consecutive photos when triggered by movement, with 30 s 'quiet time' between triggers and 30 s videos, with a high sensitivity setting. At each site, we collected meta-data (Supporting Information S2). All sites were revisited monthly by the local teams, who exchanged batteries and memory cards, and addressed any hardware problems. In the case of equipment failure, new devices were installed at the same locations. In one case, a camera trap was moved several metres due to an initial problem with the angle of the camera. The deployment strategy described above generates approximately 5.85 GB per recorder per full day of recording time, or 250 GB per recorder per monthly visit: in the context of our six recorders per site networks, this yielded 1.5 TB of acoustic data generated per month in addition to the metadata files for each site. Whereas such dense sampling may not be needed for all bioacoustic projects, our dataset may be used to answer questions about subsampling. Here, we provide illustrative analyses of only the bioacoustic data, but describe the camera trap and meta-data protocols so that such data can be used by other researchers.

Resulting data (soundscapes, images, videos, meta-data) were stored on external hard drives at a secure location within the country of each baseline site (e.g., Universidad San Francisco de Quito, Ecuador, for the Tiputini Biodiversity Station), on external hard drives at the University of Wisconsin-Madison, USA, and in a S3 data storage system owned by the University of Wisconsin-Madison. The local team members are considered the data collectors, and the entire project team is considered the data steward, in the sense that they are included in data sharing agreements. Leads in each location (Supporting Information S1) reviewed and had a chance to edit a project description, which included a description of how collected data will be publicly available for non-commercial use. Future scaling up of the Soundscape Baselines Project will include a more standardized process for engaging different types of landowners in Free, Prior and Informed Consent (FPIC).

2.3 | Analysis

We have analysed parts of the full dataset using several different approaches, including acoustic indices and species recognition algorithms. All analyses were conducted on full soundscapes, which include both biotic (e.g., animal vocalizations) and abiotic (e.g., rain, wind) components, without attempting to isolate purely biological signals. Abiotic components can be intermittent but nevertheless contribute to a site's bioacoustic baseline.

2.3.1 | Acoustic Indices

Soundscape data were processed by calculating a standard set of acoustic indices using the QUT Ecoacoustics Analysis Programs (Towsey et al. 2018). Acoustic indices are calculations that summarize various aspects of the acoustic environment. Indices were calculated for each minute of the recordings and for each ~43 Hz frequency band. Acoustic indices can be used either individually or in combination through false colour spectrograms (Berman et al. 2026). Many commonly used indices are strongly correlated with each other. Therefore, we first calculated and plotted a pairwise correlation matrix to understand to what degree different indices may provide overlapping information (Figure S1). Next, we ranked the indices in terms of their correlation with all other indices and chose an index that was the most correlated with others overall, and the most orthogonal one (details in Supporting Information). Based on this, we chose the acoustic indices Power Minus Noise (PMN), Background Noise (BGN) and Soundscape Saturation (SS, see below) to avoid redundancy while retaining ecological interpretability, rather than to demonstrate the superiority of one index over others.

PMN is the difference between the maximum decibel of each acoustic frequency bin and the corresponding decibel of the background noise profile (mean decibel level for that acoustic frequency bin; Towsey et al. 2014). Therefore, it provides a measure of the sound intensity for each acoustic frequency bin absent of background noise, essentially measuring acoustic activity. BGN reflects the consistent acoustic background of an environment, including both abiotic sounds (e.g., wind, rain) and some sustained biological signals such as insect choruses (Supporting Information S3). While BGN is intended to capture relatively stable background conditions, it does not fully separate abiotic and biotic contributions, particularly when environmental sounds are temporally or spectrally heterogeneous. As a result, transient or variable events such as rainfall may still influence PMN values (see Figure S4 for an example). We chose PMN (together with BGN) because it is one of the simplest and therefore one of the most transparent ways to show overall acoustic activity. PMN is the basis for several other more complex acoustic indices, and this is likely why it has overall the strongest correlations with other indices (Figure S1). When summed for each minute, such as here, it approximates how loud the soundscape was during that minute. Despite its relative transparency, this index can be biassed by loud sound sources close to the sensor. This is why we also illustrate the use of the index Soundscape Saturation (SS), which mitigates this potential bias by giving each frequency bin a value of either 0 or 1. In other words, each frequency bin has an equal chance to contribute to the overall value of the index. SS is defined as the proportion of frequency bins that are acoustically active in a given minute (Burivalova et al. 2018), whereby acoustic activity is defined as PMN crossing a threshold theta, chosen so that the SS data are roughly normally distributed. Here, our threshold was 1.5 dB for all sites. SS was

chosen also because it is the only index known to us that has been validated in limited contexts (Burivalova et al. 2018; Yoh, Mbamy, et al. 2024; Yoh, Haley, and Burivalova 2024; Zwerts et al. 2022) against proxies of *all* vocalizing diversity (the number of unique sonotypes or sound types). The majority of other studies that correlate indices with biodiversity metrics focus on birds alone or other narrow taxonomic groups (reviewed in Alcocer et al. 2022). Although this is a reasonable approach to establish whether indices can be used to estimate for example, bird richness in cases where soundscapes are dominated by birds, this is not our aim, and most soundscapes in this data set are not dominated by birds. Here, we interpret changes in acoustic indices as indicators of shifts in soundscape structure, not direct measures of biodiversity loss.

2.3.2 | Spatial Variation

To illustrate variation in indices over space, we modelled 5 continuous days of PMN at each site using generalized additive models (GAMs). A 5 day recording duration was selected as it was shown by previous studies to be representative of a particular soundscape within one season (Bradfer-Lawrence et al. 2019), and was short enough to check manually that it did not contain significant rain events. We used the 'bam' function from the *mgcv* R package (version 1.9.1; Wood and Wood 2015) to handle large datasets efficiently. The response variable, PMN, was modelled as a function of time of the day, a continuous variable representing the temporal resolution of the dataset. We used a cyclic cubic regression spline (bs = 'cc') to capture the effect of time, accounting for the cyclic nature of daily patterns and ensuring smooth transitions between the start and end of the time series. To allow for site-specific variations in daily acoustic patterns, the smooth term for time was stratified by site across baseline locations. Additionally, 'site' was included as a fixed effect to account for overall differences across locations. We fitted GAMs using a Gamma-poisson (negative binomial) distribution, which is often more appropriate for non-normal and overdispersed data, and estimated using fast restricted maximum likelihood (fREML) to optimize smoothness selection. The number of knots ($k = 12$) was chosen to ensure sufficient model flexibility while avoiding overfitting. To confirm the number of knots and assess model adequacy, we used the 'gam. check()' function to evaluate residual patterns and smoothness diagnostics. To account for temporal autocorrelation, we incorporated a first-order autoregressive (AR(1)) process by specifying the *rho* parameter in the 'bam' function. *Rho* values ranged from 0.93 to 0.97 across models, indicating strong dependency in the time series, and were informed by inspecting autocorrelation function (ACF) plots of residuals from initial GAMs fitted without autocorrelation terms.

2.3.3 | Forest Management

To illustrate how bioacoustic baselines could be used to measure the difference associated with different types of forest management, we modelled Soundscape Saturation at three types of site (baseline and two treatments), all within the same ecoregion (Northwest Congolian lowland forest) and during the same season (dry) in Gabon. Using data from the dry season minimized the role of rain in the data. The 5 control sites were within the Proposed Community Conservation Area (PCCA), Ibola Dja Bana Ba Massaha (Ibola Dja Bana Ba Massaha et al. 2026), within the same general location (but not identical sites) as the 6 subsequent bioacoustic baseline sites in Gabon, which were established in the following year, at slightly different sites, due to the preferences of the local community's paraecologist and local scientist lead (SEK, WM). The 4 non-certified logging (treatment 1) and 12 Forest Stewardship Council (FSC) certified logging (treatment 2) sites had undergone selective logging ~1 year prior to soundscape sampling (2021), at a reported logging intensity of ~35 m^3/ha, without and with sustainability certification, respectively (logging concessions anonymized). The full description of these sites is available in Yoh, Mbamy, et al. (2024); Yoh, Haley, and Burivalova (2024).

We used generalized additive models (GAMs) to estimate how Soundscape Saturation varied between the two treatments and the baseline, with the following equation: Index ~ Forest Use + s(Minute of the day, by = Forest Use, $k = 50$). We included a smoothing term to model the time of the day (Minute of the day). The model was fitted with a Gaussian distribution with an identity link function and employed restricted maximum likelihood for smoothness estimation. The model was fit using the *mgcv* R package. The error bars in the plots represent the lower and upper Gaussian confidence limits based on the t-distribution of observed data.

2.3.4 | Species Temporal and Spatial Variation

To illustrate the use of bioacoustic baselines through identifying individual species' vocalizations and assessing patterns of spatial and temporal heterogeneity, we used the BirdNET Convolutional Neural Network (Kahl et al. 2021) to detect and identify bird vocalizations from two bioacoustic baselines locations: approximately 3 months of continuous recordings (12 October 2022 to 19 Jan 2023) at the six Gabon baselines sites (Table S2), and approximately 6 months of continuous recordings (15 May 2023 to 25 October 2023) at the six Peru baselines sites (Table S2). These detections are used to illustrate patterns of community composition and activity, rather than to estimate absolute abundance, occupancy or population trends.

In Gabon, our goal was to assess *diel activity patterns* for bird species most commonly detected by BirdNET. We note that these species may not necessarily correspond to the most abundant or commonly vocalizing species in the region, as BirdNET may have other biases which make it more likely to detect certain species compared to others (e.g., due to the nature of the vocalizations, degree of overlap with other sounds). We used BirdNET-Analyzer v2.2 with sensitivity = 1, minimum confidence threshold = 0.25 and overlap = 0 to detect species filtered by location at lat = 1 and lon = 13, with a location filter threshold of 0.03 during 335 total days of recordings at all six Gabon baseline sites. A total of 210 species were detected. We selected the 16 most commonly detected species for logistical reasons: many species were not detected a sufficient

number of times to establish robust thresholds or robust diel activity curves. We estimated the detection precision of the 16 most commonly detected species by manually reviewing 200 three-second segments for each species with confidence scores ranging from 0.25–1.0, with 0 s of overlap, following the protocol outlined in Symes et al. (2023). This enabled us to establish species-specific thresholds via fitting a logistic regression (Symes et al. 2023). After filtering out detections with less than 90% certainty, 13 of the 16 most commonly detected species remained. Next, to visualize diel patterns of vocal activity, we binned call occurrences into 10-min intervals based on the time of day (minutes since midnight). For each species, we calculated the relative frequency of calls within each bin to estimate the probability of calling over the 24-h period. We then applied locally weighted regression smoothing (LOESS) with a span of 0.25 and quadratic polynomial fitting (degree = 2) to the binned data to generate continuous probability curves of vocal activity.

In Peru, our goal was to illustrate how to assess patterns of *spatial heterogeneity* among the six Peru sites, as these were spread across an elevational gradient from ~600 m to ~1200 m, and at a transition between Peruvian Yungas and Southwest Amazon moist forest, referred to also as lowland to premontane tropical forest (Table S2). To do so, we used the CLI implementation of BirdNET-Analyzer v.2.4 with sensitivity = 1, minimum confidence threshold = 0.3 and overlap = 1. During preliminary assessment, we found that the metadata model used to generate BirdNET's location-specific species lists performed rather poorly in this region, supplying a number of species that do not occur in Cuzco province or occur above the treeline. To account for this, we used a custom species list that included all species detected by several comprehensive surveys of the region (Walker et al. 2006; Jankowski et al. 2013; Freeman et al. 2022) containing 913 bird species. We used a validation procedure adapted from Wood and Kahl (2024) to remove probable false positive detections from the database. This procedure involved creating two sets of sample detections for each species, one spanning a BirdNET confidence score range of 0.3–1 and the other spanning a confidence score range of 0.8–1, stratified such that up to 30 samples were taken from each 200 m interval of elevation across the gradient. Sample detections were manually reviewed in Raven Pro, classified as true or false and used to create a function which mapped confidence scores to probabilities on a per-species basis by fitting a logistic generalized additive model (family 'binomial' with REML optimization) with logit confidence score (linear term) as a predictor, true/false label as the response, and site elevation (smooth term, cubic regression spline) as an environmental covariate to account for possible spatial variation in classifier performance due to the presence of similar-sounding organisms across certain sections of the gradient. For each species, the threshold for accepting detections was calculated as the lowest (e.g., most permissive) threshold that kept the false positive rate (*fpr*) as evaluated on each species' annotated sample set below 5%. After this filtering step, we retained all species with ≥ 3 detections across all sites and assessed spatial heterogeneity by calculating pairwise Sørensen Distance-based beta diversity metrics using the *betapart* R package (Baselga and Orme 2012).

3 | Results

3.1 | Prioritization of Future Bioacoustic Baselines

All realms with forests had some remaining Intact Forest Landscapes, and our pilot locations were spread across five out of six forested realms. A first level of priority for future bioacoustic baseline sites would be to represent each of the 30 forested biomes in different realms (e.g., Tropical & Subtropical Dry Broadleaf Forest in the Neotropic, Oceania, Nearctic, Indomalay, Afrotropic and Australasia realms). Of the 30 combinations of biomes and realms, only 20 still have Intact Forest Landscapes, and these are the most urgent priority for future bioacoustic baselines efforts (Table S1). At the regional level, the next layer of prioritization would include ecoregions. Current pilot locations represented the following ecoregions: Napo moist forest (Ecuador), transition between Peruvian Yungas and Southwest Amazon moist forest (Peru), Northwest Congolian lowland forest (Gabon), Borneo lowland rainforest (Brunei), Western European broadleaf forest (Germany); and Upper Midwest US forest-savanna transition (USA).

The following results are presented to illustrate the types of patterns that can be derived from bioacoustic baselines, not providing definitive tests of biodiversity change or management recommendations.

3.2 | Spatial Variation

To illustrate the spatial variation in soundscape structure (as captured by acoustic indices) at and across baseline sites, we plotted the acoustic index PMN and BGN (Figures S1 and S2), and modelled PMN variation using GAMs (Figure 2). In general, the highest peak in PMN occurred in the early morning, followed by a less consistent second-highest peak in the later afternoon. The magnitude and consistency of these peaks varied among locations.

In Brunei, Ecuador and the USA, the morning peak was narrow and occurred at a very similar time of the day (~7:00, except one site each in Brunei and Ecuador). In Gabon and Germany, the morning peak occurred earlier (~5:00 and ~6:00, respectively), and the precise timing of the maximum varied by ~0.5–1 h across sites. In Peru, the morning peaks happened at a variable time, between 6:00 and 9:00. The second, evening peak was prominent in Brunei (~20:00–22:00), Germany (~19:00), and to a lesser extent in Ecuador (~21:00), Gabon (19:00–21:00), Peru (16:00–17:00). In the USA, the evening peak was only prominent at two out of the six sites, around 21:00. In Ecuador and Gabon, and to some extent in Peru and the USA, we also observed a midday peak. In Germany and the USA (the two temperate locations), PMN remained high during the day, and was low at night, with one exception in the USA. At the tropical locations, PMN was high at night.

Baseline areas varied in their within-location consistency (Tables S3 and S4). Gabon's and Brunei's sites were very homogeneous, with estimates fluctuating only slightly around the intercept, suggesting a high degree of consistency. In contrast,

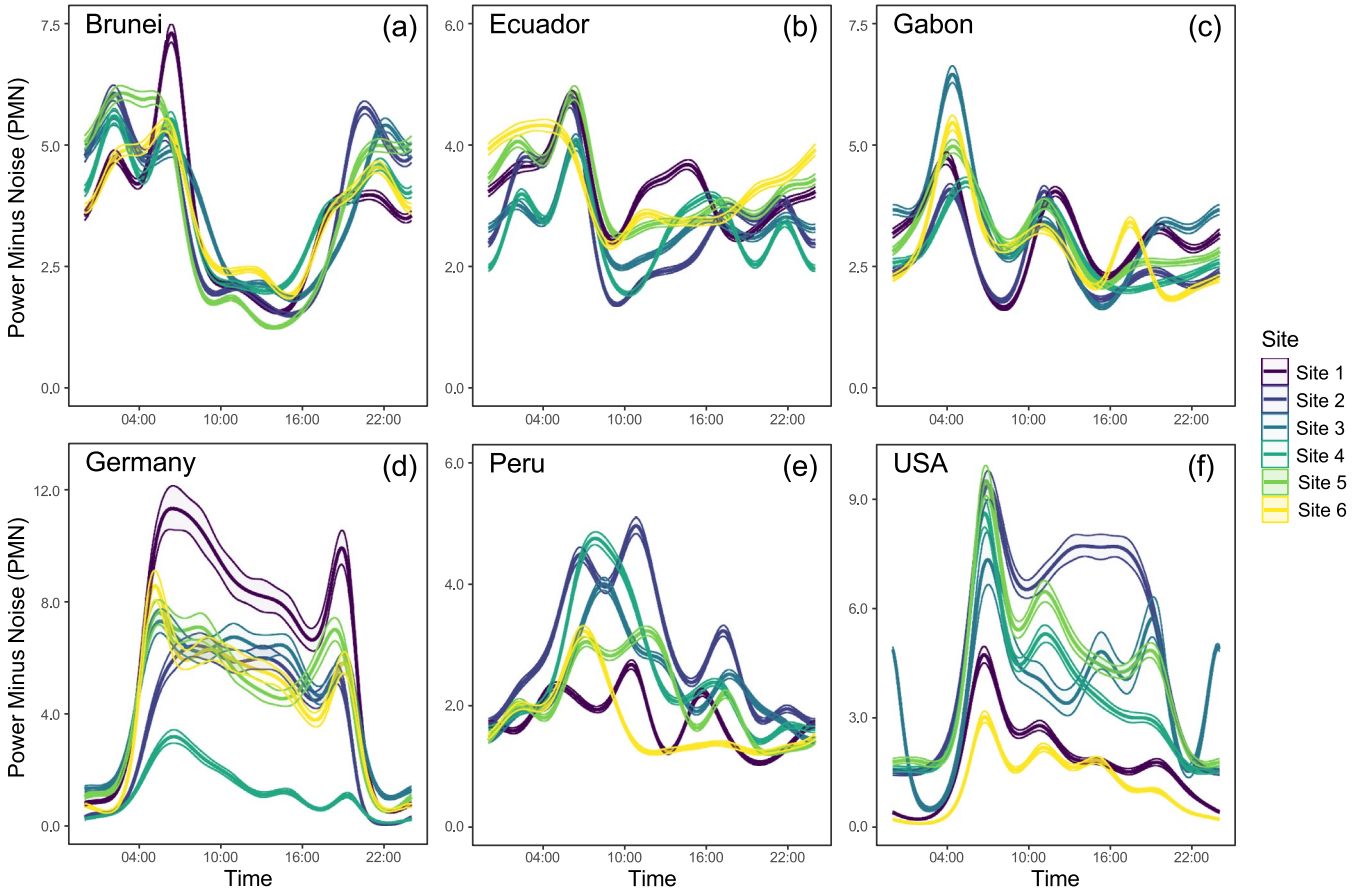

FIGURE 2 | Between site variation across space in the acoustic index Power Minus Noise (PMN) at existing bioacoustic baseline locations during 5 consecutive days. Y axes display the predicted PMN using a generalized additive model (GAM) with cyclic smoothers for time and site-specific effects across existing bioacoustic baseline locations. Shaded areas indicate confidence intervals, reflecting site-specific diel trends in PMN. See Figures S1 and S2 for raw data and BGN.

Peru exhibited substantial heterogeneity, with site PER2 showing the highest PMN estimate (estimate = 0.492, $p < 0.001$) and site PER6 the lowest (estimate = −0.057, $p < 0.001$), likely due to more variation in the elevation across sites. The temperate locations displayed the greatest within-location variability in terms of PMN magnitude. In Germany, site DEU4 had a markedly lower PMN estimate than site DEU1 (Estimate = −1.609, $p < 0.001$), whereas sites DEU3 and DEU5 showed more moderate decreases. The USA baseline sites showed a spread across PMN magnitude (e.g., site USA2: Estimate = 1.184, $p < 0.001$; site USA6: estimate = −0.587, $p < 0.001$; Tables S3 and S4).

3.3 | Variation From Baseline State With Forest Management

Across the day, baseline sites in Gabon had a mean Soundscape Saturation (SS) of 66.2% (±0.08 SE) during the dry season. Overall, FSC-certified selective logging sites (66.5 ± 0.05 SE) had a marginally higher SS than the baseline sites (0.30 ± 0.10 SE, $t = 3.02$, $p = 0.003$), whereas non-certified selective logging sites were substantially less saturated across the day (−6.38 ± 0.13, $t = -50.94$, $p < 0.001$). The SS across all forest types exhibited strong, nonlinear temporal trends (edf values ~40–48, p values < 0.001). These temporal trends were most pronounced in FSC-certified sites (edf = 43.8, $F = 208.1$), followed closely by the baseline sites (edf = 40.7, $F = 184.0$). Non-certified sites exhibited the least pronounced fluctuations in SS across the day (edf = 40.4, $F = 63.1$) (Figure 3). However, both logging concession types had lower morning and evening peaks compared to baseline sites (Figure 3). The morning peak also occurred earlier in baseline sites (approx. 05:00, SS ~78.4% [observed range 68.0%–93.0%]), compared to FSC-certified sites (approx. 06:25, SS ~68.1% [31.6%–95.7%]), and non-certified sites (approx. 06:20, SS ~62.4% [29.7%–85.2%]). At night, baseline sites had similar SS to FSC-certified sites, whereas non-certified selective logging sites had much lower SS (Figure 3). During mid-day, SS at all types of sites was variable and not substantially different from each other. We note that differences in Soundscape Saturation among management types reflect differences in soundscape structure, not direct measures of biodiversity loss or gain. They should be interpreted as shifts in acoustic activity across diel periods that may be associated with changes in ecological communities (Kümmet et al. 2025), but are not assumed to map directly onto species richness.

3.4 | Species-Level Temporal Variation

To illustrate species-level analyses possible with our dataset, we analysed temporal patterns in acoustic activity at Gabon's baseline sites, for the 13 most commonly detected bird species

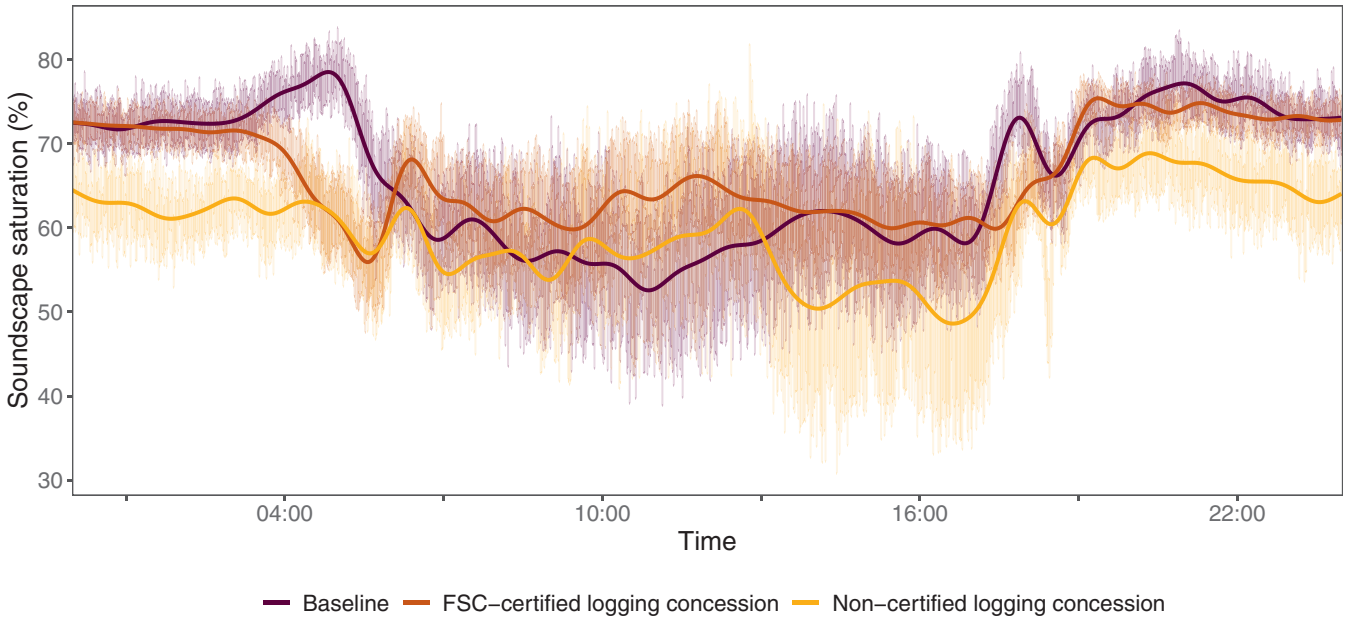

FIGURE 3 | Comparison of bioacoustic baseline sites in Gabon with selectively logged forest during dry season (Non-certified and FSC-certified logging concession), in terms of Soundscape Saturation, which is an acoustic index derived from Power Minus Noise. Thicker lines represent the GAM model, and thin vertical lines represent lower and upper Gaussian confidence limits based on the t-distribution of observed Soundscape Saturation per minute.

(Figure 4). During the three-month period that we analysed, Red-chested Cuckoos (*Cuculus solitarius*), the most commonly detected species of our set of 13 species, were detected with confidence on average 76 times per day or a total of 25,612 times, while Eastern Bearded-Greenbuls (*Criniger chloronotus*), the least commonly detected of our 13 most common species, were detected on average only 6 times per day, or a total of 1887 times. At Gabon's baseline sites, all 13 of our focal species were primarily active during the day (Figure 4), following one of several temporal patterns: some had only a morning peak (e.g., Western Black-headed Oriole, *Oriolus brachyrynchus*; Rufous Flycatcher-Thrush, *Stizorhina fraseri*), some species had two daily peaks in vocalizations (Red-tailed Greenbul, *Criniger calurus*; Red-chested Cuckoo, *Cuculus solitarius*; Lesser Bristlebill, *Bleda notatus*), some had only an evening peak (Black-casqued Hornbill, *Ceratogymna atrata*; Great Blue Turaco, *Corythaeola cristata*) and a few species had a similar level of activity throughout the day (Yellow-throated Tinkerbird, *Pogoniulus subsulphureus*; African Emerald Cuckoo, *Chrysococcyx cupreus*). These results illustrate patterns in detected vocal activity, not estimates of species abundance or occupancy, which can however be done with our dataset by future studies (Winiarski et al. 2026; Rumelt et al. 2021).

3.5 | Species-Level Spatial Variation

At the six baseline sites in Peru, over 6 months, we detected a total of 329 species. The most commonly detected species (Tawny-bellied Screech Owl, *Megascops watsonii*) had 657,254 detections and the 10 least commonly detected species had three detections. The species composition showed a substantial beta diversity gradient, with the two sites at ~600 m elevation and the two ~700 m sites forming clusters and the 800 m and 1100 m sites being increasingly more divergent. In keeping with existing literature on avian diversity gradients on tropical mountains (e.g., Jankowski et al. 2009), we find that most of this beta diversity gradient is due to turnover between sites with elevation, with the highest site being particularly distinct (Figure 5). By contrast, there is very little evidence that the species composition at higher elevation sites is a nested subset of the diversity at low elevations.

4 | Discussion

The Soundscape Baselines Project is a global initiative that aims to document and understand the natural variation in soundscapes and vocalizing biodiversity over time and space in the world's remaining intact forests (Figure 1, Table S1). In 2025, the Soundscape Baselines Project encompassed one baseline location in six countries (Brunei, Ecuador, Gabon, Germany, Peru, USA), each comprising six recording sites (Figure 1). At each site, we aimed to record soundscapes continuously for at least a year. Here, we illustrate the potential of the Soundscape Baselines Project by showing four types of analyses on subsets of the dataset.

By understanding the normal (baseline) variation in a soundscape in terms of acoustic index values over space and the diel cycle (Figure 2) and in future analyses throughout the year, we can measure deviations from the baseline state at degraded, managed, conserved or restored sites, such as under different types of forest management (Figure 3), biodiversity credit schemes or Natural Climate Solution project sites. Such deviations from a baseline index value can then be further investigated for example by identifying a subset of species whose vocalizations make up a considerable part of the soundscape (Figures 4 and 5). Beyond providing insights into whether and how degraded, altered or managed habitats support biodiversity,

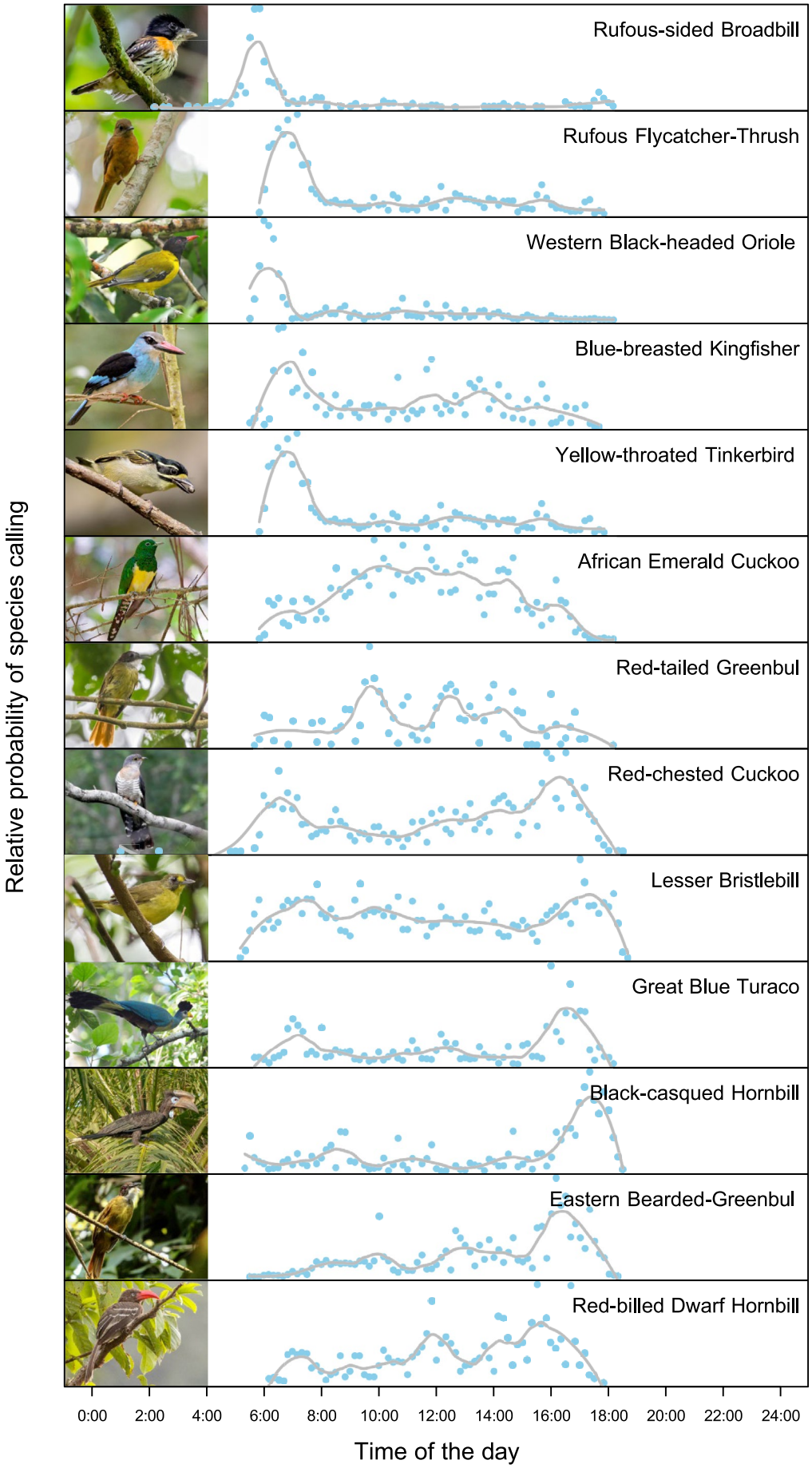

FIGURE 4 | Legend on next page.

FIGURE 4 | Temporal patterns in vocal activity of 13 bird species at Gabon's six bioacoustic baselines sites. Based on 3 months of recordings from 12th October 2022 to 19th January 2023. Blue dots represent the relative probability of a species calling over a 24 h period, calculated for each 10 min period. Grey lines represent locally weighted regression smoothing (LOESS). Species are arranged by vocal activity patterns. Please see acknowledgement for photograph sources.

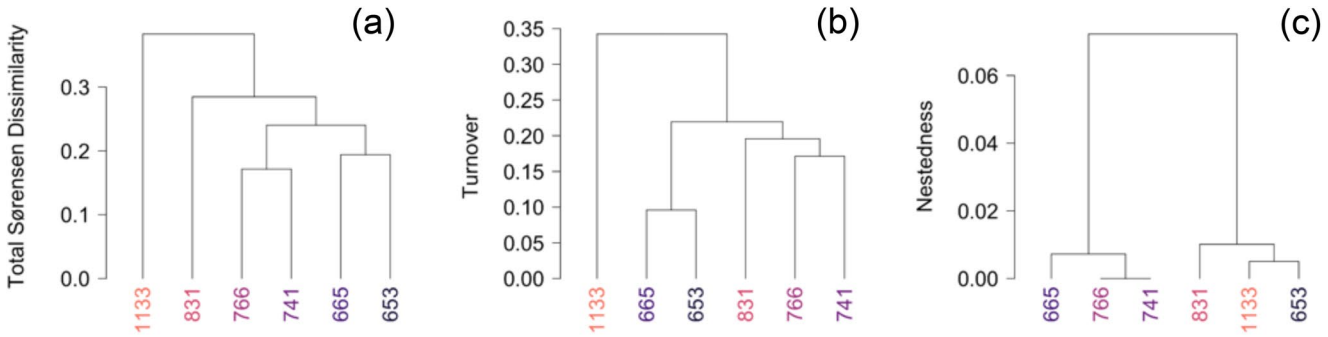

FIGURE 5 | Patterns of spatial heterogeneity for 329 species of birds at Peru's six bioacoustic baselines sites based on 6 months of recordings (May 2023–October 2023). Sites are labelled with their elevation in metres; lighter colours indicate higher elevation sites. A substantial beta diversity gradient exists between the six sites, likely primarily as a result of high levels of turnover with elevation.

through providing a baseline, this initiative also creates a 'time capsule' in light of ongoing dramatic forest loss, enabling humanity to study biodiversity retrospectively and possibly guide restoration efforts.

The bioacoustic baseline concept is grounded in two ecological principles. First, soundscapes in relatively intact forests exhibit structured temporal and spectral patterns, shaped by faunal communities and environmental conditions, through biotic and abiotic sounds (Pijanowski et al. 2011; Berman et al. 2026; Somervuo et al. 2025). Second, anthropogenic pressures can alter these patterns, through changes in species composition, behaviour or the introduction of novel acoustic sources (Ross et al. 2023; Wood et al. 2024; Hopping et al. 2021; Somervuo et al. 2025).

4.1 | Unique Acoustic Signature of Forests

Our illustrative analysis from 36 sites across six countries provides evidence that intact forests do exhibit specific soundscape patterns. Even within 5 days, a recording duration determined to be representative of a particular soundscape within one season (Bradfer-Lawrence et al. 2019), we observe significant differences between individual sites (typically in terms of the magnitude and timing of various peaks), but also consistencies between sites within one baseline location (typically in terms of the shape of the daily pattern). For example, Gabonese sites showed a consistent temporal pattern across sites, but this temporal pattern differs from those observed in other locations such as Germany, which is similar to findings of a related study on the same dataset, using Principal Component Analysis (Berman et al. 2026).

Such differences in the acoustic index profile across sites, even those within the same forest type with 100% forest cover, demonstrate how relying on remote sensing alone can miss important differences in biodiversity patterns (Figures 2 and 5). Mismatches between fauna and habitat state have already been noted in the literature (Sagar et al. 2026). Several recent long-term studies show that species are declining even in habitats unaffected by industrial extraction of resources, such as the Amazon rainforest, Central African rainforests, African tropical mountains, and the Mojave desert of North America (Bush 2020; Stouffer et al. 2021; Riddell et al. 2019; Neate-Clegg et al. 2021; Wagner et al. 2021; Blake and Loiselle 2024). Collecting bioacoustic baselines over the long term could help identify mechanisms underlying such changes; some types of threats are even audible within the soundscapes (gunshots), and others can be derived from remote sensing (e.g., thermal stress). Combined with insights from other global biodiversity observatories (Supporting Information S3) and remote sensing, bioacoustic baselines could help achieve global and local conservation goals by generating an understanding of what is at stake, the magnitude of change and the effectiveness of solutions.

The significant differences between sites within a single location (e.g., between two sites in the Tiputini Biodiversity Station's forest in Ecuador, or across an elevational gradient in Peru) suggest that spatial variation within the area may influence its soundscape heterogeneity. Although six sites are not enough to encompass the full breadth of environmental heterogeneity at each location, we can make several qualitative observations. For example, baseline sites at similar elevations (Gabon) exhibited similar patterns in an acoustic index, whereas sites spread over an altitudinal gradient (Peru) had much more variability, as documented by prior studies as well (Jankowski et al. 2009). Other soundscape studies suggest that environmental variables, beyond anthropogenic degradation, influence patterns in acoustic indices. For example, in Papua New Guinea, sites at higher elevation had relatively higher Soundscape Saturation during most of the day (Burivalova et al. 2018). More research is needed to better understand the relationships between environmental variables and corresponding soundscapes, across realms and biomes (Berman et al. 2026). Meanwhile, bioacoustic baseline sites should only be used as a reference for sites with similar

environmental conditions, for example, the same ecoregion and elevation.

Our preliminary results demonstrate that it is equally important to compare sites at the same time of the day, due to strong circadian patterns across all surveyed sites. Averaging soundscape index values over larger time bins is not recommended as the sole metric of change, as this approach will obscure differences (e.g., see similarities in overall SS value in Gabon's baseline and FSC-certified site, and clear differences when temporal trends are shown, Figure 3). This finding aligns with a study from Gabon (from different sites), which showed that averaging even for 1-h time bins leads to a significant information loss (Yoh, Haley, and Burivalova 2024). Instead, comparing sites using GAMs or other time series methods (Yoh, Mbamy, et al. 2024; Yoh, Haley, and Burivalova 2024; Rothacher et al. 2025) is more suitable, as these methods do not require averaging over time. Future analyses will determine the role of seasonality in the consistency of soundscape patterns, known to be prominent from other studies (e.g., Persche et al. 2024; Zwerts et al. 2022; Lai et al. 2025). Until then, comparing sites during the same season is strongly recommended (Yoh et al. 2024B).

4.2 | Bioacoustic Baselines Can Inform Conservation Efforts

Acoustic index analyses can help identify spectral and temporal regions of change in soundscape structure, which can then be pursued through a targeted species-level analysis (Figures 4 and 5). For example, comparing baseline sites in Gabon to logged sites highlighted higher Soundscape Saturation during dawn and dusk at baseline sites (Figure 3). Subsequent species-level analysis suggested that these differences could be associated with shifts in activity patterns of some species, while the activity of others remains the same (Figure 4). In another example, a discovery of substantial variation of daily patterns in soundscape indices in Peru, likely due to elevation, can prompt conservationists to monitor for potential future homogenization in beta diversity gradients of avian species across sites, compared to a 2024 baseline status (Figure 5). Such changes could in the future occur due to species loss at the top of an elevational gradient coupled with thermalization at lower elevations, as a result of anthropogenic mean annual temperature increases. Our results show a strong distinction in bird community composition at higher elevations, further adding to the evidence of conservation peril for mountain-top species (Elsen and Tingley 2015).

Acoustic indices—including PMN and Soundscape Saturation—do not provide direct estimates of species richness (Alcocer et al. 2022). This is due to the fact, amongst others, that not all species vocalize, different species have vocalizations spanning a variable number of frequency bins, some vocalize in nearly identical ways (e.g., mimics) and many differ in how often and how long they vocalize. Not assuming a direct mapping between acoustic indices and biodiversity metrics, our approach treats soundscape structure itself as an emergent ecological signal that can be compared across space, time and management contexts, along with individual species analyses. The soundscape structure inherently includes both biotic and abiotic components, which together reflect ecosystem function and environmental conditions. The strength of acoustic index analysis in this context lies in enabling scalable, integrative comparisons and in guiding targeted species-level analyses where needed and possible. Being able to prioritize soundscape regions of interest for species-level analyses is important. Current classifiers for species detection and classification, while advancing rapidly, are resource-intensive and unlikely to be available for all sound emitting species within the next decade (e.g., by the Kunming-Montreal Global Biodiversity Framework targets for 2030) due to our incomplete knowledge of species overall, and incomplete sound libraries for those species that are described (Bradfer-Lawrence et al. 2025). These limitations are especially pronounced for invertebrates, whose sounds are less well studied (Symes et al. 2022; Gindhart et al. 2025). At the same time, recording bioacoustic baselines may help with the development of new Artificial Intelligence methods. The recorded 'time capsules' can also be re-analysed with future, currently unavailable methods (Hillix 2007). Additionally, due to the high-resolution nature of the dataset, it will become possible to answer questions on optimal temporal sampling density, through stepwise reduction of the full dataset.

4.3 | Caveats and Limitations

Under the current project design, we cannot answer questions based on species abundance and movement (Rhinehart et al. 2020), however, it is possible to extract incidence frequencies that can be used statistically in a similar way to abundance (Kortmann et al. 2025). Since our sensors are deployed in the midstory, the soundscapes captured may potentially underestimate canopy specialist species, however, a study from Ecuador shows that even bird canopy specialists' sounds can be captured in the midstory (Kortmann et al. 2025). The deployed sensors did not span the entire frequency spectrum at which terrestrial animals are known to vocalize, therefore many bat species and invertebrates are excluded. Our case studies represent rare examples of continuous acoustic data across a year. However, at this stage, these data represent a snapshot in time that cannot capture interannual variation. The Soundscape Baselines Project aims to continue to collect data in order to characterize the natural heteroscedasticity observed across multiple year cycles, driven by environmental oscillations (such as El Niño and La Niña cycles, masting) or anthropogenic pressures (e.g., hunting pulses), to quantify such natural variation in baseline conditions. While bioacoustic baselines enable meaningful comparisons across sites and interventions, translating these differences into decision thresholds (e.g., restoration success or biodiversity credits) will require project-specific calibration, integration with additional data sources and stakeholder-defined objectives (Bradfer-Lawrence et al. 2025). The Soundscape Baselines Project provides the empirical foundation upon which such operational frameworks can be developed.

5 | Conclusions

The existing pilot network of six baseline locations provides a foundation for our goal of achieving a comprehensive global coverage of Intact Forest Landscapes across forested biomes in different realms, and ultimately across ecoregions and multiple years.

The Soundscape Baselines Project could act as a time capsule for sound emitting forest biodiversity, creating a record of acoustic species communities as they exist today across global biogeographic realms, biomes and ecoregions. Creating this record is essential to prevent conservation efforts from being misinformed by the shifting baselines phenomenon when using acoustic data, act as reference points for how anthropogenic and climatic changes may alter global ecological communities and their corresponding soundscapes in the coming decades, and support global biodiversity conservation goals. By establishing globally distributed, high-resolution bioacoustic baselines, this initiative provides a critical reference framework for detecting and interpreting ecological change in an era of rapid environmental transformation.

Author Contributions

E. Chaboteaux: investigation, project administration, data curation, writing – review and editing. **A. Lopera-Toro:** investigation, supervision, project administration, resources, writing – review and editing. **Z. Buřivalová:** conceptualization, methodology, investigation, formal analysis, supervision, funding acquisition, visualization, project administration, resources, writing – original draft, writing – review and editing. **H. S. S. C. Sagar:** conceptualization, methodology, investigation, resources, writing – review and editing. **G. Ingram:** data curation, project administration, writing – review and editing. **N. Yoh:** methodology, formal analysis, visualization, writing – review and editing. **C. Mere-Roncal:** investigation, data curation, project administration, resources, writing – review and editing, supervision. **S. Perea:** data curation, formal analysis, visualization, writing – review and editing. **T. M. Maeda:** methodology, data curation, writing – review and editing. **M. Persche:** methodology, investigation, writing – review and editing. **L. M. Berman:** data curation, formal analysis, visualization, writing – review and editing. **R. Rumelt:** methodology, formal analysis, visualization, writing – review and editing. **P. Alonso-Alonso:** validation, writing – review and editing. **U. Grafe:** investigation, data curation, resources, writing – review and editing. **W. Mbamy:** investigation, data curation, supervision, project administration, writing – review and editing. **C. Valle-Piñuela:** investigation, data curation, writing – review and editing. **C. Wirth:** project administration, resources, writing – review and editing. **H. H. Ahmad Sah:** investigation, project administration, resources, writing – review and editing. **I. J. Moreno-Buitrón:** investigation, data curation, writing – review and editing. **L. Ganchozo:** investigation, data curation, writing – review and editing. **F. Macanilla:** investigation, data curation, writing – review and editing. **G. Rivas-Torres:** project administration, resources, writing – review and editing, methodology. **J. Müller:** methodology, investigation, data curation, funding acquisition, resources, writing – review and editing. **E. Game:** conceptualization, methodology, writing – review and editing. **J. Macanilla:** investigation, data curation, writing – review and editing. **A. Calhoun:** investigation, resources, writing – review and editing. **R. Sanmiguel:** data curation, investigation, writing – review and editing. **N. Zapata:** investigation, data curation, writing – review and editing. **J. Schlüter:** investigation, data curation, writing – review and editing. **D. Luther:** conceptualization, methodology, writing – review and editing. **S. Ekazama Koto:** investigation, data curation, writing – review and editing. **G. Z. L. Froese:** investigation, data curation, project administration, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Datasets underlying the individual analyses are available at DOI https://doi.org/10.6084/m9.figshare.32159550.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Pairwise correlation plot of acoustic indices calculated on a per minute basis, for 5 continuous days, at 6 sites at each of the 6 countries. The indices PMN and CVR have the highest absolute levels of correlation with other indices. BGN has the highest negative correlation with other indices. **Figure S2:** Between site variation across space in the acoustic index Power Minus Noise (PMN) at existing sound-scape baseline locations during 5 days. Y axes display the raw PMN, averaged over 5 days on a per minute basis. See Figure 2 for modelled PMN. **Figure S3:** Between site variation across space in the acoustic index Background Noise (BGN) at existing soundscape baseline locations during 5 days. Y axes display the raw BGN, averaged over 5 days on a per minute basis. BGN is subtracted during the calculation of PMN (Figure 2 and S2). **Table S1:** Realms and biomes with Intact Forest Landscapes (IFL; Potapov et al. 2017) and existing Soundscape Baselines Project locations. See Table SI2 for details on existing locations. **Table S2:** Details on existing bioacoustic baselines locations. Please see Table S1 for relevant biomes and ecoregions. **Table S3:** PMN estimates for each site at each Soundscape Baseline location. Sites 1 are the reference levels for each location. GAM formula: PMN ~ s(Time, bs = 'cc', $k = 12$, by = Site) + Site, family = negative binomial and method = fREML. **Table S4:** Smooth terms (temporal variation by site) for each site at each Soundscape Baseline location. Estimated degrees of freedom (edf), reference degrees of freedom (Ref df), F values and p values included.