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CHAPTER 13

Soundscape research in Malaysia and its potential to support ecosystem conservation and planetary health

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Abstract: The interconnected threats of environmental degradation, climate change, and biodiversity loss pose significant challenges to both human and ecosystem health. To address these challenges, it is critical to understand systemic processes that govern planetary health. Acoustic environments – comprising of sounds from biological (biophony), geophysical (geophony), and anthropogenic (anthropophony) sources – are perceived and interpreted through our hearing sensory system. Recent advancements in digital technologies and spatial data analytics accelerated ecosystems health monitoring, biodiversity assessment and evolutionary ecology studies, where both physiological and psychological aspects of human and non-human living organisms are explored. This chapter presents the status of bioacoustics and soundscape research in Malaysia, and discusses the relationships among soundscapes, biodiversity, and human health. Long-term monitoring of soundscapes is important to understand species occurrences and interactions, which may contribute to understanding ecosystem health. This understanding could be especially important in ecosystems vulnerable to climate change or habitat loss, such as tropical ecosystems in Southeast Asia. Future research should harness the potential of soundscapes as a cost -effective and less intrusive assessment tool for biodiversity conservation that complements other monitoring methods.

INTRODUCTION

The term "soundscape" is described as the relationship between a landscape and the composition of its sound (Southworth 1969). The Oxford dictionary gives a succinct definition of soundscape as 'the sounds heard in a particular location, considered as a whole'. A soundscape can be categorised into three parts: "biophony" (biological sounds produced by organisms, such as the songs, calls, and choruses of birds, frogs, insects, mammals, etc.), "geophony" (geophysical sounds from environmental process, such as wind, rain, thunder, waves, earthquakes, etc.), and "anthropophony" (human or manmade sounds, such as speech, traffic, music, construction, machinery, etc.). Figure 1 summarises the complex relationships between the three components of soundscape and the impact of human activities on natural soundscapes. The field of soundscape ecology concerns not only the study of these individual components but also how they interact with one another across time and space (Schafer 1977; Krause 1987). The human relationship with acoustic environment, or soundscape, is rooted deeply in the inter-connectedness among elements of natural sounds, be it from vocal or non-vocal sources. Thunder announces rain, and one may seek shelter. The perceived loudness of flowing water may indicate the how fast or wide a river is, and one may follow the direction of that sound to locate water source or identify suitable campsite. When arriving on an island, birdsong reveals the species present, from which one may infer the types of resources available to support a given composition of birds. Even a sudden silence or abrupt burst of sounds can be informative to indicate the presence of a predator or the break of dawn, and one may perceive or react accordingly to ensure survival.

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Figure 1. Soundscape is characterised by geophony, biophony and anthropophony sources and directly affected by the changes arising from natural and human-made causes. Illustrated by Nadia Radzif, Sunway Centre for Planetary Health.

Ancestral humans who were more capable of seeking out safe locations within a landscape were more likely to pass on their genes to subsequent generations (Smith and Pijanowski 2014). Consequently, modern humans are genetically hard-wired to prefer natural landscapes and soundscapes that minimise physical risks. Sight and hearing are often considered as primal senses that condition our perception of an environment. Actively listening to the soundscape provides valuable information from the surroundings, especially when visibility is limited by dense canopy, weather, distance, and/or darkness. The perception and evaluation of a soundscape's quality may be inherently subjective, with individual experiences shaping whether an acoustic environment is deemed appealing or aversive (Medvedev *et al.* 2015). With that said, investigations into the beneficial effects of natural soundscapes have revealed multiple underlying mechanisms that can improve health both physiologically and psychologically, suggesting a complex interplay between acoustic stimuli and human responses (Aletta *et al*. 2018; Song *et al.* 2023). Indeed, intact ecological relationships in the wild allowed for the evolution of the perception and use of soundscape by wildlife and people, not only to communicate and to survive (Marler 2004; Podos and Webster 2022). The human perception of and interaction with the soundscape contributes to the evolution of culture, where people are inspired to create music (Schafer 1977), to name something based on the sound it makes (onomatopoeia, see Lim *et al.* 2017), to pass on indigenous and traditional knowledge (Tidemann and Gosler 2011), and to incite imaginative and meaningful stories (Smalley *et al.* 2023).

Humans are intricately connected with the natural or built environment. By understanding these relationships through the soundscape, we can gain valuable insights into our health in relation to the health of ecosystems (Dumyahn and Pijanowski 2011; Farina 2018; Pillay *et al.* 2019; Sethi *et al.* 2022; Wang *et al.* 2024). As one of the three major tropical ecosystems in the world, Southeast Asia is understudied and disproportionately vulnerable to massive changes in climate and biosphere (Sodhi *et al.* 2004). However, Southeast Asia possesses high potential for positive change (Procheş *et al.* 2021). To address these challenges, there is a growing need to understand systemic processes that govern planetary health, a state where both people and the planet thrive together (Horton and Lo 2015; Whitmee et al. 2015; Gupta *et al*. 2024; Muniandy 2024), for which the soundscape

offers a unique and valuable perspective. To understand ecological relationships in large spatio-temporal scales that are timely for conservation action, scientists and practitioners are utilising the rapidly advancing technologies today. These approaches combine both automated collection of environmental data with automated detection systems, with the aim of reducing field labour and time taken to turn raw data to insightful information (Sugai *et al.* 2019), thereby enhancing the capacity to derive critical information on biodiversity and ecosystem health (Farina 2014; Pavan 2017; Johnson *et al.* 2023).

This chapter documents published research on bioacoustics and soundscape ecology in Malaysia, examines the inter-connectedness of people's health and wellbeing with soundscapes through the overlooked impacts of anthropogenic noise pollution, and finally provides an outlook of future directions and recommendations to protect our national acoustic heritage. The main takeaway of this chapter is that: More than being a voice for nature, we need to *listen* to the voices of those we often deem 'voiceless', only then can we learn how to live in harmony with the only planet that keeps us alive.

STATUS OF BIOACOUSTICS AND SOUNDSCAPE RESEARCH IN MALAYSIA

Malaysia is one of the 17 mega-biodiverse countries and possesses high potential for advancing the understanding and conservation of our natural soundscapes. To understand the breadth of research on the acoustic environment in Malaysia, a literature review of original research published up to 2025 was conducted using the keywords: (bioacoustic* OR ecoacoustic* OR soundscape* OR acoustic* OR sound* OR vocal* OR noise* OR call* OR song* OR record*) AND (Malaysia*). After excluding duplicates, reviews and perspectives, and studies conducted outside of Malaysia, the search were able to curate a collection of 69 relevant primary research articles (Figure 2).

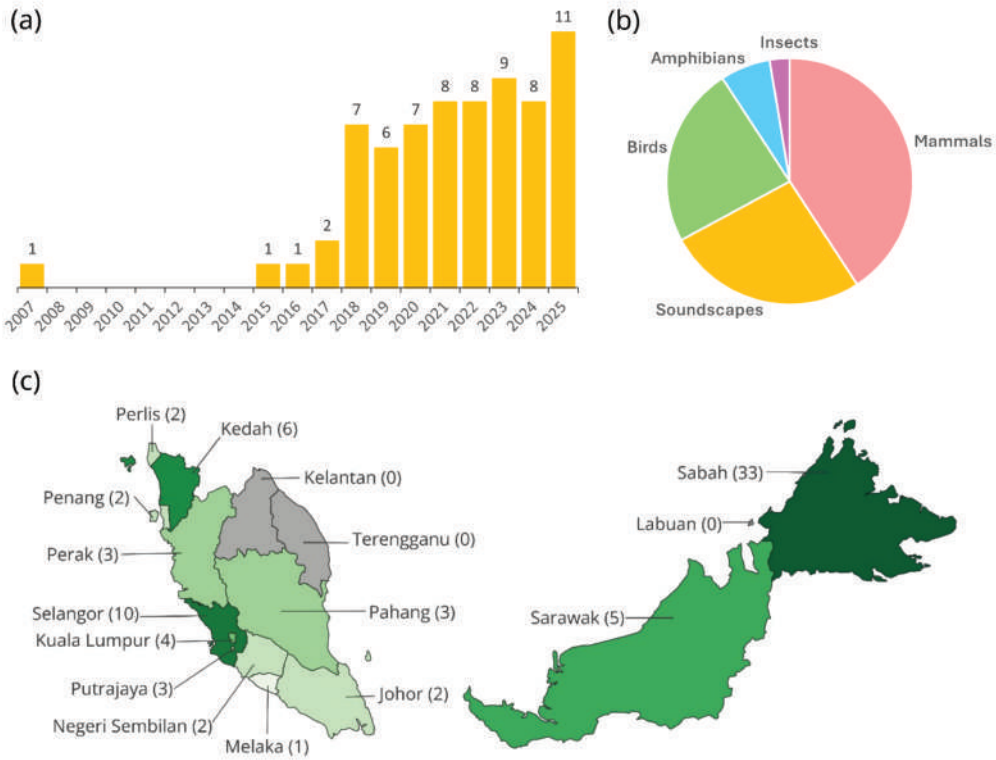


Figure 2. Number of published bioacoustics studies in Malaysia by (a) year, (b) taxonomic group or soundscape level, and (c) state.

Table 1. Reference table of primary research on soundscapes and bioacoustics in Malaysia by state, habitat type, and taxonomic group or soundscape level studies.

State	Habitat Type	Taxonomic group/ Soundscape	References
Sabah	Forest	Mammals	A.R. Lau *et al.* (2018, 2022); Cauzinille *et al.* (2024); Clink (2017); Clink *et al.* (2017, 2019, 2020a, 2020b, 2023, 2025); Clink and Klinck (2019a, 2019b, 2021); Clink and Lau (2020); Clink, Charif *et al.* (2018); Clink, Grote *et al.* (2018); Clink, Zafar *et al.* (2021); Lakdari *et al.* (2024); Tengström (2023)
		Birds	Clink and Ahmad (2025); Clink, Groves, *et al.* (2021); Gwee *et al.* (2019)*; Kennedy *et al.* (2023); Mitchell *et al.* (2020); Tengström (2023); Yusni (2023)
		Soundscapes	B.E. Heath *et al.* (2020, 2021); Mitchell *et al.* (2020); R. Heath (2022); Sethi *et al.* (2019, 2022); Sethi, Ewers *et al.* (2020); Sethi, Jones *et al.* (2020); Tengström (2023)
		Amphibians	Tengström (2023)
		Insects	Holmes *et al.* (2025)
	Plantation	Mammals	A.R. Lau *et al.* (2018); B.E. Heath *et al.* (2021); Clink *et al.* (2019); Tengström (2023)
		Birds	Tengström (2023)
		Soundscapes	B.E. Heath *et al.* (2021)
		Amphibians	Tengström (2023)
Selangor	Forest	Birds	Chang *et al.* (2018); K.K.S. Lau (2018); Mah *et al.* (2023); Nawi *et al.* (2021); Yee *et al.* (2016, 2018)
	Plantation	Birds	Chang *et al.* (2018); Yee *et al.* (2016, 2018)
	Mangrove	Birds	Rahim *et al.* (2025)
		Soundscapes	Rahim *et al.* (2024)
	Built environment	Birds	Hanafi *et al.* (2019)
		Soundscapes	Muniandy (2024)
Kedah	Forest	Amphibians	Ong and Shahrudin (2021, 2022a, 2022b)
		Mammals	Pang *et al.* (2022)
		Soundscapes	Razali *et al.* (2015)
	Marine	Mammals	Bono *et al.* (2022)
Sarawak	Forest	Birds	Gwee et al. (2019)*; Kueffner (2023)
		Amphibians	Arch *et al.* (2007)
		Soundscapes	Yi *et al.* (2021); Harmon and Wahid (2024)

Kuala Lumpur	Urban green space Built environment	Soundscapes Birds	J.S.L. Lee *et al.* (2023a, 2023b) Hanafi *et al.* (2019); Othman *et al.* (2024)
Pahang	Forest	Mammals Soundscapes	Kamaruzaman *et al.* (2023) Muniandy *et al.* (2025); Miza (2025)
Perak	Forest	Mammals Soundscapes	Avicena *et al.* (2025) Loo *et al.* (2024) Nurika *et al.* (2025)
Putrajaya	Urban green space Built environment	Soundscapes Birds	J.S.L. Lee *et al.* (2023a, 2023b) Hanafi *et al.* (2019)
Johor	Forest Lab	Mammals Insects	Loo, Avicena *et al.* (2025) Tan *et al.* (2024)
Negeri Sembilan	Forest Built environment	Mammals Birds	Okuda *et al.* (2022) Hanafi *et al.* (2019)
Penang	Forest Urban green space	Soundscapes Mammals Soundscapes	Loo, Lee, *et al.* (2025) Miard *et al.* (2019) Loo, Lee *et al.* (2025)
Perlis	Forest Marine	Soundscapes Mammals	Razali *et al.* (2015) Bono *et al.* (2021)
Melaka	Marine	Mammals	Bono *et al.* (2021)
Others (with secondary data sources)		Birds	Gwee *et al.* (2019)*; Hing *et al.* (2025)*

Note: Published papers with studies involving multiple sites, habitats and taxonomic groups, are reflected in each relevant category. 'Forest' includes primary, secondary, lowland, and highland forests; Plantation includes any type of cultivated land including oil palm, rubber, etc.; 'Built environment' refers to urban, suburban and rural areas; 'Urban green spaces' refers specifically to urban parks, botanical gardens, recreational parks, and other green spaces that do not qualify as forests. *denotes studies that included xeno-canto recordings from various sites in Malaysia (xeno-canto.org).

The study of soundscapes in Malaysia is advancing in the recent decade, with increased accessibility to equipment and software for analysing sounds, as well as collaborations with international institutions (see Box 1). The two main approaches for studying biological sounds are through passive acoustic monitoring and focal recordings of target species or individuals. Passive acoustic monitoring allows researchers to collect acoustic data at large spatio-temporal scales using pre-scheduled recording units deployed strategically at study sites, while focal recording allows the researcher to follow vocalising individuals and provide behavioural contexts of the sounds recorded. Social studies about the perception of soundscapes were also included in this review.

According to the literature review, bioacoustics and soundscape research from Malaysia covers various habitats, including forests (n = 57), plantations (n = 7), urban green spaces (n = 4), built environments and laboratory studies (n = 4), marine environments (n = 2), and mangroves (n = 2), as well as various states in Malaysia, including Sabah (n = 33), Selangor (n = 10), Kedah (n = 6), Sarawak (n = 5), Kuala Lumpur (n = 4), Pahang (n = 3), Perak (n = 3), Putrajaya (n = 3), Johor (n = 2), Negeri Sembilan (n = 2), Penang (n = 2), Perlis (n = 2), and Melaka (n = 1).

Bioacoustic studies documented the presence, vocal features and behaviours, as well as ecological interactions of animals, such as mammals (n = 31), including both land and marine mammals (see Box 2), birds (n = 17), amphibians (n = 5), and even insects (n = 2) in both wild and urban environments. For example, some notable studies described

novel vocalisations of amphibians (Ong and Shahrudin 2021, 2022b), marine mammals (Bono *et al.* 2021, 2022), and Sunda colugos (Miard *et al.* 2019), and investigated vocal signature patterns and linguistic theories in primates (Clink *et al.* 2017; Clink, Ahmad *et al.* 2020; Clink *et al*. 2021; Clink and Lau 2020). These studies provide new insights and deeper understanding into these vocalising animals and thus aid in identifying potential new species and examining their conservation status. For instance, population densities of wildlife can also be revealed using acoustic methods, such as through acoustic triangulation (Pang *et al.* 2022). The increase of labelled data from passive acoustic monitoring studies enables the training of machine learning models to automate data analysis and provide timely insights for early warning systems that benefit the safety of people in areas where human -wildlife conflicts may occur (Avicena *et al.* 2025; Clink and Klinck 2021; Loo *et al.* 2024).

Box 1.

The Locally-led East Asian Flyway (LEAFA) program is a transboundary collaborative effort that leverages local researchers and practitioners to co-design standardised methods for passive acoustic monitoring projects at key migratory bird sites along the East Asian-Australasian Flyway (EAAF). The EAAF is one of the most diverse flyways in the world with the highest overlap with human population (~2 million), which exacerbates anthropogenic threats such as poaching and habitat degradation. LEAFA is currently led by 17 teams spread across five countries (Philippines, Indonesia, Taiwan, Cambodia, and Malaysia) and has collected sound data for at least one year at the time of writing. To gain insights from the immense amount of data collected, the teams will utilise deep learning technologies for automated detection of bird calls to accelerate the process from research to conservation action. This initiative provides a framework to create partnerships for the transboundary protection of migratory birds that can be adapted to global flyways.

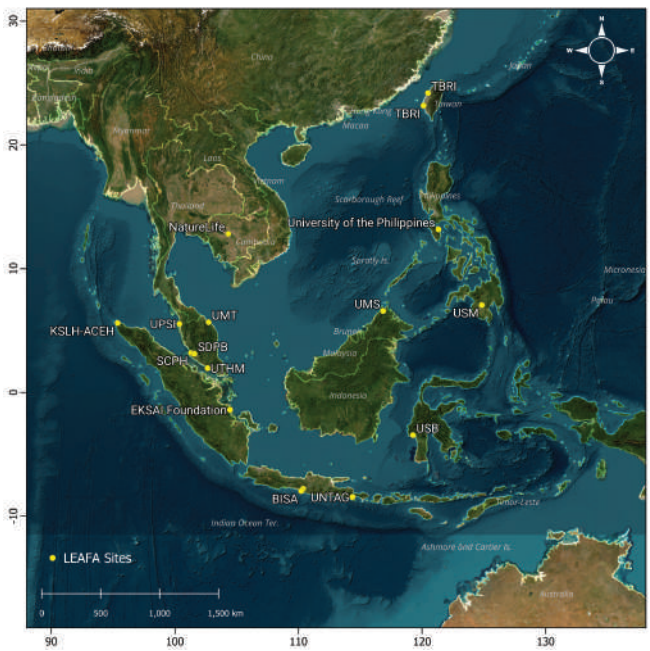






Photo credits: LEAFA

Research on the changes and anthropogenic impacts and perception towards soundscapes (n = 20) were also increasing in recent years, where ecoacoustic indices are used for rapid ecosystem health assessments (Loo, Avicena *et al.* 2025; Mammides *et al.* 2021; Mitchell *et al.* 2020). Ecoacoustic indices, also known as soundscape metrics, features or indices, are mathematically derived numerical representations of the soundscape (Farina

2018; Sueur and Farina 2015). In other words, the diversity of species found in an area can be interpreted through the soundscape, and this relationship has been studied using traditional biodiversity surveys and over 60 types of soundscape indices, such as Acoustic Complexity Index (ACI), Bioacoustic Index (BI), Soundscape Evenness Index (SEI), Normalised Difference Soundscape Index (NDSI), Soundscape Richness Index (SRI), and many others (Stowell and Sueur 2020; Xiang *et al*. 2023; Zhao *et al*. 2022).

Soundscapes offer a holistic approach to enhance conservation efforts in Malaysia. For instance, acoustic monitoring is an effective complementary tool for biodiversity assessment, particularly for vocal taxonomic groups that rely heavily on vocal communication. For instance, Miza (2025) found that rich biophony of birds and insects coincide with high acoustic complexity and diversity with diurnal cycle pattern in key soundscape indices, typical of a healthy tropical highland forest. Monitoring remote habitats such as highlands or deep forests benefits from passive acoustic monitoring approach, which can reduce fieldwork costs while allowing prolonged deployment of recording units. Abd Mutalib and colleagues explore the movement ecology of primates in Kenyir, Terengganu (https://primatesmalaysia.org/home/project-soundskape/). This study, among others (Abd Mutalib *et al.* 2025), demonstrates the scalability of studying home range dynamics of vocally active species using passive acoustic approaches, enabling conservation efforts to align with the needs of vulnerable species.

Box 2.
The MareCet Research Organization has been collaborating with bioacoustics researchers since 2014 to study dugong acoustics in Johor, porpoise echolocations in Langkawi, and Irrawaddy dolphin and Indo-Pacific humpback dolphins in Langkawi and Matang. However, more comprehensive bioacoustics work on the marine mammals in Peninsular Malaysia only began in 2019. MareCet now covers acoustics on cetaceans such as Indo-Pacific humpback dolphins, Irrawaddy dolphins, Indo-Pacific finless porpoises and Bryde's whales, including sirenians such as the dugongs. Other opportunistic studies cover spinner dolphins and bottlenose dolphins that are seen when studying the Bryde's whales offshore. Beyond the species level, research also covers the soundscape of the marine mammal habitat, which include understanding the boat noise impacts to their acoustic behaviour and the absence or presence of these animals for long-term monitoring purposes.

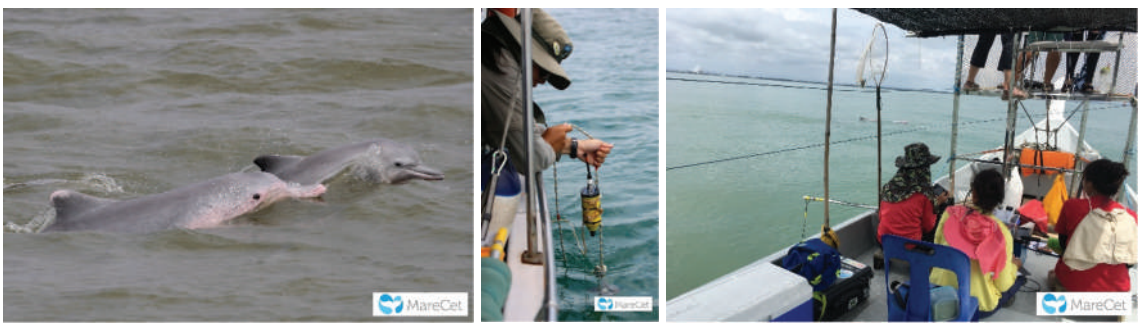


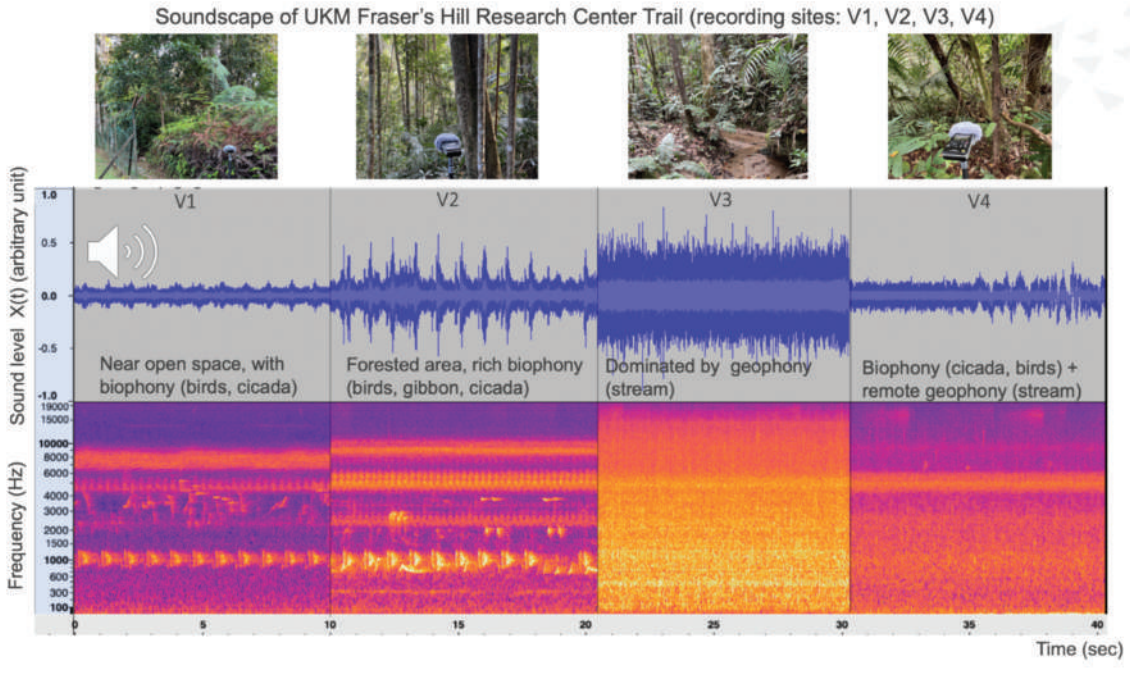
Photo credits: The MareCet Research Organization.

The typical picture of habitat loss is usually visualised through satellite images of fragmenting or displaced landscapes. However, the real impacts are sometimes felt through the silencing of natural soundscapes. Factors like topography, vegetation, and species distribution influence the production and propagation of sounds, making soundscape patterns valuable for understanding ecological integrity across various spatial and temporal scales (Müller *et al*. 2023; Pillay *et al*. 2019; Sethi *et al*. 2022; Wang *et al*. 2024). Soundscapes

vary spatially across habitat, ecosystem, and landscape scales (Mammides *et al.* 2025). They also vary temporally across seconds, days, seasons, years, and aeons (Loo, Lee *et al.* 2025). Taken together, soundscape indices can explain ecosystem integrity indices (Sánchez-Giraldo *et al.* 2021), such as the factors influencing the ability to maintain biodiversity and ecosystem processes in any given habitat (W.H. Lee and Abdullah 2019; McGarigal *et al.* 2018). By analysing the acoustic environment, we can infer the presence, diversity, and interactions of species, as well as their responses to external stressors like climate change, habitat degradation, or anthropogenic noise (Krause and Farina 2016; Sethi *et al.* 2024). For example, the Natural Soundscape Quality (NSQ) indices have been used to quantify the soundscape ecosystem services with deep socio-psychological wellbeing values (Chen *et al.* 2024). NSQ indices are widely used to indicate significant heritage values, especially for planning and management of green spaces with landscape aesthetic quality. Several studies in Malaysia monitored the soundscape characteristics in different habitat types revealed that soundscapes in functioning ecosystems are more diverse than disturbed ones, and are more desirable to urban dwellers (see Box 3) (Loo, Lee *et al*. 2025; Muniandy 2024; Muniandy *et al.* 2025; Othman *et al.* 2024).

Box 3.

Soundscape is a powerful medium to promote action research and ecological empathy given the re-emergence of planetary awareness under the field of environmental humanities. Muniandy (2024) created a sympathetic theme using soundscapes of water bodies originating from the same hill with different paths, one passing through a rewilded urban forest (Rimba Ilmu Botanic Garden, Universiti Malaya) and another stream endured a challenging build environment. This study adopted an Artscience approach by combining robust soundscape signal analysis and eco-philosophy (or ecosophy) to raise awareness for ecological empathy and promote the protection of soundscape heritage, especially that of natural waterbodies and landscape. The figure below shows the time domain representation of the sounds signal sampled for 10 seconds (for illustration) at four different locations along the UKM Fraser's Hill Research Station Trail (N 3.7261, E 101.7165, 1023 m asl) along with the time-frequency spectrogram (Muniandy *et al.* 2025).



HIDDEN COSTS OF ANTHROPOGENIC NOISE POLLUTION

One of the biggest threats to the preservation of natural soundscape is anthropogenic noise pollution, thereafter 'noise pollution'. Noise pollution occurs when sounds are excessively loud and continue for an extended period (United Nation Environmental Programme 2022), while positive soundscapes encompass acoustic environments that individuals perceive as aesthetically pleasing or beneficial to their auditory experience (Aletta *et al.* 2018; Zhu *et al.* 2023). Anthropogenic noise generated from human activities, such as transportation, urbanisation and industrial revolution, is recognised as a significant global pollutant that affects both terrestrial and aquatic ecosystems (Kok *et al*. 2023; Kunc and Schmidt 2019; Shannon *et al.* 2016). It transforms natural acoustic environments by increasing high -intensity noise events and creating consistently high and homogenised background sound levels (Senzaki *et al.* 2020; Shannon *et al.* 2016). This section will explore how changes in the soundscape impact the health and wellbeing of both wildlife and people.

Noise pollution is an underestimated public health risk as the impacts are not always immediately visible or easily quantifiable. Noise pollution is associated with broad spectrum of acute and chronic health issues, manifesting as both auditory and non-auditory health effects (Mohamed *et al*. 2021; The Lancet Regional Health – Europe 2023). These harmful health impacts of noise pollution can be measured by Years Lived with Disability (YLDs) from hearing loss. The safe noise level according to the WHO for humans is less than 70 dB(A) for 24-h exposure (World Health Organization 2010, 2021). Fifteen percent of the global population experiences hearing reduction due to exposure to loud noise from various sources, including occupational, recreational, and mobile phone use (Taneja 2014), as seen from the 73.6% increase in YLDs from hearing loss between 1999 and 2019. By 2050, the burden is anticipated to escalate globally, including Southeast Asia regions (Haile *et al*. 2021).

As cities continue to expand, the increasing intensity and extent of noise pollution from urban activities have construction, transportation, and industrialisation increases the prevalence of stress, anxiety, cardiovascular problems, and impaired cognitive function (Basner *et al.* 2014). For instance, in Kuala Lumpur and Klang Valley, noise from traffic frequently exceeded 70dB due to rapid urbanisation (Halim *et al.* 2017; Halim 2019; Chieng and Chan 2021; Faisal *et al.* 2023; Y.L. Lee *et al.* 2023), surpassing the threshold for safe exposure and putting people's livelihood at risk (Ali Najah Ahmed *et al.* 2019; Ismail *et al.* 2020; Mamat *et al.* 2022).

Beyond hearing loss, chronic exposure to noise pollution can also trigger tinnitus (ringing or buzzing sound in ears), cause stress and anxiety, disrupt sleep and impair cognitive function (Fritschi *et al.* 2011; Thompson *et al.* 2022), all of which can undermine performances in both school and work settings (Basner *et al.* 2014; Di Gennaro *et al.* 2023). When the nervous system is exposed to chronic stress, it can lead to serious cardiovascular issues such as hypertension, ischemic heart disease, and stroke (Fritschi *et al.* 2011; Basner *et al.* 2014). Vulnerability to noise-related health impacts varies by age, gender, income and comorbidities. Unlike air, water, and soil pollution, noise pollution is often overlooked in Asian cities, as 11% of the global cost of hearing loss or US$108 billion (RM 456.46 billion) is attributed to Southeast Asian countries (World Health Organization 2021). This systemic environmental challenge extends beyond mere acoustic measurements, presenting significant implications for public health and urban liveability.

While noise pollution affects people's health, livelihoods and quality of life, its negative impact on wildlife often goes unnoticed. Recently, this field of study has gained traction in the scientific literature. It has been shown that noise pollution interferes with sensory systems and masks the animal's ability to interpret environmental information required for habitat selection, foraging, species recognition, and risk assessment (Dominoni

et al. 2020), altering wildlife behaviour and physiology, with cascading effects on community dynamics (Shannon *et al.* 2016; Kunc and Schmidt 2019; Dominoni *et al.* 2020). Noise can significantly influence community composition through various mechanisms such as masking, misleading and distraction – directly and indirectly, altering interactions among individuals to species within the ecosystem. For instance, direct impacts of noise exposure can result in habitat avoidance, reduced recruitment, and increased mortality (Kok *et al.* 2023), impacting not only acoustics-oriented animals with auditory receptors, such as birds, but also indirectly affect non-acoustic species such as grasshoppers, dragonflies and damselflies (Senzaki *et al.* 2020; Shannon *et al.* 2016). Bird species that rely on songs for territorial defence and mate attraction are especially vulnerable to the masking effects of anthropogenic noise (Hu and Cardoso 2010; Slabbekoorn 2013; Hao *et al.* 2024).

Moreover, noise pollution can disrupt interactions among different species in a community by increasing mortality through predation and reducing foraging success (Phillips *et al.* 2021; Cho *et al.* 2025). In addition, birds may avoid noisy areas more readily than less mobile species such as ground-dwelling insects (Senzaki *et al.* 2016). Species that adjust the frequency, amplitude or timing of vocalisations, or switching to alternative sensory modes to survive can incur high energetic cost (Hu and Cardoso, 2010; Slabbekoorn 2013; Tolentino *et al.* 2018; Hao *et al.* 2024). However, not all species have the behavioural plasticity to adapt to noisy environments. These impacts can cause long-term harm, such as poorer body condition, reproductive success and offspring development (Dominoni *et al.* 2020), albeit their being difficult to attribute directly to noise pollution. Ecosystem services may be disrupted due to noise pollution. By examining the interactions between wildlife and their acoustic environment, we may begin to understand the integrity of ecosystems on a deeper level beyond biodiversity metrices.

Call to Action: Harnessing an "invisible" resource

Establish the linkages between healthy soundscapes and human health

The global imperative to monitor and protect biodiversity and the advancements of passive acoustic monitoring tools provided increasingly rapid assessments beyond single target species, but also broader soundscape patterns such as community integrity and ecosystem functioning (Sugai *et al.* 2019; Bradfer-Lawrence *et al.* 2023; Sethi *et al.* 2024). Strategies informed by local ecological knowledge, including education and community outreach, can help accelerate these efforts (Doran-Sherlock *et al.* 2025). The preservation and therapeutic use of pristine soundscapes in Malaysia offers significant potential for enhancing human wellbeing through non-invasive, nature-based interventions (Jeon *et al.* 2012). Exposure to natural sounds or aesthetically pleasing auditory stimuli has been found to correlate with accelerated recovery rates following stress-inducing events (Alvarsson *et al.* 2010; Medvedev *et al.* 2015) and increased positive mood states, such as comfort and relaxation (Song *et al.* 2023). Growing evidence highlights the effectiveness of healthy soundscapes in healthcare settings, such as improving comfort and physiological responses in dementia care (Sabran *et al.* 2018), reducing pain and agitation in surgical intensive care patients during endotracheal suctioning (Ruan *et al.* 2024), and aiding recovery in patients with myocardial infarction (Fatehimoghadam *et al.* 2023). Practices like Japan's '*Shinrin-yoku*' (forest bathing) further illustrate how immersive natural soundscapes can stabilise mood, boost immunity, and aid stress recovery (Han 2003; Li 2022).

In rapidly urbanising cities in Malaysia, architects, engineers, and township designers can work together to build nature sounds into city landscape and green space design. In green spaces dominated by natural sounds, soundscape diversity can be enhanced by increasing vegetation richness and water features. Diverse tree species in dense vegetation increase the number of sound types, reflecting the multi-layered or closed vegetation structures of tropical ecosystems that can enhance both species diversity and preserve natural soundscapes (Zhao *et al.* 2022; Hao *et al.* 2024). Connectivity within landscapes can

be enhanced by increasing vegetation richness and water features. Diverse tree species in dense vegetation increase the number of sound types, reflecting the multi-layered or closed vegetation structures of tropical ecosystems that can enhance both species diversity and preserve natural be modelled by considering the impact of landscape features on the efficiency of sound propagation for animal communication and the spatial distribution of anthropogenic noise sources (Sánchez-Giraldo *et al.* 2021).

The distribution of acoustically rich zones across a landscape may also have the potential to indicate key connectivity elements such as least-cost corridors, defined as the pathway of preferred movement from one point to another that requires the least amount of energy, or resistance (Balbi *et al.* 2019), especially if these are indicated by habitat structures that can be readily reflected by the properties of the soundscape. Natural soundscape has been incorporated in the design of many well-known parks around the world (e.g., Beijing Olympic Forest Park, Paris Bamboo Garden in Le Parc de la Villette, Shiru-ku Road pocket park in Japan) using diverse plants, water and other landscape elements (Song *et al.* 2023). Sound-borrowing, adapted from "scenery-borrowing" techniques in traditional gardens is used to stimulate more senses by combining the visual and aural experiences associated with associations with water, wind, rain, plants and landscaping. For instance, sounds of plants, water, insects and birds are usually used to mask noises (sound-masking). Future research can utilise sound measurement tools to monitor the impacts of a nature-based soundscape design on human health and wellbeing in cities and rural areas, to explore the connection between human wellbeing and positive conservation outcomes.

Long-term, evidence-based monitoring to enhance and protect soundscape health

Longitudinal research to track how changes in soundscapes over extended periods impact both ecosystems and human health is needed to understand the long-term consequences of soundscape alterations. Additionally, understanding how the soundscape is influenced by climate change or habitat fragmentation may provide a comprehensive view of fundamental ecological questions that are relevant to achieving planetary health. These objectives could be achieved by designing studies that monitor the changes to the different components of soundscapes across seasons, years, and geographic regions including different habitat types and biomes (Zwerts *et al.* 2022; Loo, Lee *et al.* 2025; Mammides *et al.* 2025). Such studies must involve interdisciplinary parties to ensure that the outcomes of the studies are beneficial to all stakeholders. Some examples of existing networks and datasets include the Locally-led East Asian Flyway Acoustics (LEAFA) Program (Abd Mutalib *et al.* 2025), Stability of Altered Forest Ecosystem (SAFE) Project (Ewers *et al.* 2011; Sethi, Ewers *et al.* 2020), and landscape-scale sensor network in Japan (Ross *et al.* 2018).

Well-designed research and monitoring programs will accelerate conservation action through policies to protect pristine natural soundscapes and promote low-noise city soundscapes. At the 16th Conference of the Parties to the Convention on Biological Diversity (CBD COP16 2024), the Global Action Plan on Biodiversity and Health was adopted, with a recommended action to '*promote strategies to reduce light and noise pollution, especially in urban environments, that is harmful to human health and the health of other organisms*' as a strategy for '*mainstreaming biodiversity and health interlinkages into the implementation of the Kunming-Montreal Global Biodiversity Framework.*' Thus, we call on nations to propose and implement policies to preserve natural soundscapes and promote the lowering of anthropogenic noise by developing soundscape status using criteria that reflect ecological function and human health. These categories can include "Pristine Soundscape" for a completely natural and intact soundscape with no detectable anthropogenic noise, "Near Pristine Soundscape" for a mostly intact soundscape with low levels of anthropogenic noise that does not affect wildlife or people in any measurable ways, "Vulnerable Soundscape" for a soundscape suffering from moderate anthropogenic noise which impacts the presence of wildlife and psychological health of people, "Critically Damaged Soundscape" suffering from severe anthropogenic noise which impacts the ecosystem function and physical health of people.

Invest in technological advancements to reduce noise pollution

Human innovation and the growing accessibility of advanced tools to mitigate noise pollution is essential for preserving and restoring natural soundscapes, enhancing public health and conserving wildlife. Existing innovations for quieter technologies, including electric vehicles, noise-reducing road surfaces, and low-noise industrial machinery, have proven effective in reducing urban and transportation-related noise. Urban planners, landscape designers, and architects can integrate noise-reduction measures into city infrastructure, such as green buffers and sound-absorbing materials in building designs. In tourism and park management, adopting sustainable practices such as limiting motorised vehicles in sensitive areas and using low-noise operational equipment, can help protect natural soundscapes while enhancing visitor experiences and wildlife conservation. These efforts collectively improve urban liveability and ecosystem health, ensuring benefits for both people and the planet.

Community involvement is also vital to drive demand for quieter, eco-friendly innovations and ensure the success of noise mitigation efforts. For example, integrating mobile applications and web-based tools (Estrella *et al.* 2024), can enable citizens to monitor and report noise pollution in real time, contributing to localised data collection and awareness. Public campaigns and education initiatives can empower individuals about the importance of mitigating noise pollution and preserving natural soundscapes, encourage them to make environmentally conscious choices such as supporting businesses offering quieter options, and adopt low-noise appliances. Engaging the public in citizen science projects and involving them as testers of noise-reducing interventions fosters a sense of ownership and responsibility while addressing local concerns. These efforts help bridge the gap between technological solutions and practical, community-driven implementation. Collaborative efforts between local authorities, community organisations, and the public could give demand to urban planners and policymakers to prioritise creating quieter and healthier cities. By aligning technological advancements, community action, and sustainable practices, we can preserve the natural soundscapes essential to human wellbeing and ecological resilience.

CONCLUSION

The acoustic environment or soundscape represents the full collection of acoustic activities arising from biological, geophysical, and anthropogenic sources at a particular place and time, thus providing a unique perspective through which we can examine our relationship with the environment (Kong and Han 2024; Aletta *et al.* 2025). Soundscapes enable rapid assessment of biodiversity, as well as monitoring of ecosystem changes and responses to ecological threats. The potential of soundscapes as health indicators is particularly salient in rapidly urbanising regions such as Southeast Asia, where economic growth is reshaping urban ecosystems. However, addressing the acoustic environment in these dynamic settings presents complex challenges. Safeguarding the healing qualities of soundscapes is more than just reducing anthropogenic noise pollution but also making sure we maintain the ecosystems for species that rely on them. Therefore, we call for scientists, policymakers, planetary health actors, and the public to identify the connections between ecosystem and human health, and provide innovative ways to preserve rapidly disappearing natural soundscapes to safeguard people and the planet so that both can thrive.

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