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**Research Article****Comparative assessment of avian diversity in Gilgit city using acoustic monitoring (BirdNET) and conventional point count surveys****Mufeed Hussain¹, Saeed Abbas^{1,3}, Nasir Mehdi¹, Atif Hussain¹, Rahila Tabassum²**¹Department of Animal Sciences, Karakorum International University, Gilgit-15100, Pakistan.²Department of Zoology, University of Karachi, Pakistan.³Centre for Biodiversity Conservation and Natural Resources Management, Karakoram International University, Gilgit-15100, Pakistan.**ABSTRACT**

The process of urbanization tends to streamline bird communities, favouring generalist species. The present acoustic survey is the first of its kind in Gilgit City (Pakistan), aiming to describe the urban bird community using BirdNET (a deep-learning sound identification tool) alongside the parallel point count method. We deployed a portable recorder at 32 selected points across urban, suburban, peri-urban, and riverine environments over ten months (winter, spring, and summer). We processed the recordings using BirdNET, while point-count surveys were subjectively verified. BirdNET identified 47 species, while point counts recorded 45. Both approaches revealed a rich but biased assemblage: a few ubiquitous generalists dominated (e.g., House Sparrow, Streaked Laughing Thrush, Rose-ringed Parakeet), whereas many species were detected only once. Species diversity was moderate overall but declined from peri-urban areas (highest richness: ~31 species) to the urban core (highest richness: ~19 species). Richness peaked seasonally, with winter migrants (e.g., White Wagtail) increasing diversity, and post-breeding flocks causing surges in late summer. Our results corroborate existing evidence that BirdNET-based acoustic monitoring can effectively complement traditional field surveys, while demonstrating its applicability in the high-altitude urban and riverine landscapes of Gilgit City, particularly for detecting nocturnal or cryptic species (e.g., owls, night jays, etc.). These findings align with global evidence of urban avifaunal homogenization and highlight the role of peri-urban green spaces as key biodiversity reservoirs. The current effort is the preliminary comparative quantitative analysis of urban avifauna of Gilgit city and sets crucial data to be used in urban conservation planning.

Keywords: Urbanization; bird diversity; Gilgit; community structure.**Correspondence**Saeed Abbas
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INTRODUCTION

There are almost 11,000 extant species of birds all over the world (Gill et al., 2023), considered as indicators of the well-being of the ecosystem. Urbanization has threatened the survival of birds by disrupting habitats, bringing noise and promoting a handful of synanthropic species that are tolerant (McKinney, 2006). According to various studies conducted in urban centers across the globe, usually generalist species dominate as compared to the specialists (McKinney, 2006; Aronson et al., 2014). Although biodiversity is generally reduced by urbanization, urban green areas can hold large quantities of local species diversity of importance, thus making it impossible to clearly evaluate the net conservation costs of urban development (Pérez-Granados, 2023). It is thus important to monitor avian responses along urban gradients so as to control the urban ecosystems. Passive acoustic monitoring (PAM) has developed as a powerful, non-invasive survey technique of birds, particularly in

complicated or noisy environments (Symes et al., 2022); (Blumstein et al., 2011). Recent developments in recording technology and automated acoustic classifiers have dramatically increased the scale and efficiency of biodiversity monitoring, allowing continuous passive acoustic data to be collected and allowing the large-scale processing of large datasets in a matter of seconds using deep learning and other machine-learning techniques (Yingying et al., 2024). (Maithripala et al. 2024) Specifically, BirdNET, an audio neural network based on convolutional neural networks, trained on thousands of bird calls, can detect hundreds of species automatically (Wood et al., 2022; Kahl et al., 2021). Millions of bird observations have already been made by citizen scientists all over the world using BirdNET app (Wood et al., 2022). Passive acoustic monitoring (PAM) is particularly useful in areas where there are few surveyors or difficult landscapes; devices can record constantly, capturing cryptic or nocturnal species, which are often difficult to escape other techniques (Blumstein et al., 2011; Depraetere et al., 2012).

Although it is globally used, the use of acoustic monitoring is not commonly used in South Asia, and previous research has not evaluated BirdNET in urban bird surveys in the Mountain urban centers. The rapidly growing capital of Gilgit-Baltistan, Gilgit City (35.9 0 N, 74.3 0 E; elevation-1,500 m), is a distinctive crossing of both the Central and South Asian avifauna flyways. The city is a diverse mosaic of gardens, orchards, residual forests, and city structures, which are likely supporting a variety of avifauna, but the diversity of these communities has not been documented.

Objectives:

This research aims at achieving the objectives below.

- Conduct a pilot study to undertake an urban-scale avifaunal census in Gilgit using both acoustics and the conventional point count method and subsequently compare the outcome to data.
 - The second objective was to evaluate community structure in an urbanization gradient comprising urban core, suburban regions, peri-urban regions and riverine regions.
 - The third objective was to determine seasonal differences in the abundance of species and richness of avian species.
- We hypothesized that (i) BirdNET would yield species richness patterns comparable to point counts, (ii) avian richness and evenness would increase with decreasing urbanization intensity, and (iii) urban cores would be dominated by generalist feeding guilds.

Through this approach, we provide the first quantitative analysis of bird diversity in Gilgit's urban landscape, offering valuable insights into biodiversity in an underrepresented Himalayan city.

MATERIALS AND METHODS

Study area

Gilgit city lies within the Indus valley (35.9°N, 74.3°E; ~1,500 m elevation; ~1.5 km wide) and is bordered by irrigated orchard land and the Karakoram–Himalaya ranges. The climate is cold-temperate, with sparse forests and patchy green spaces (Khan et al., 2020). For this study, we classified sampling sites into four habitat strata as classified by Sun et al. (2025): Urban Core (densely built-up core areas of Gilgit city, characterized by high building density, paved surfaces, commercial and administrative infrastructure, and intense human activity. Vegetation in these areas was sparse and largely restricted to ornamental trees, roadside plantings, home gardens, and small green patches, Suburban (residential areas surrounding the city core, with moderate building density and comparatively lower human disturbance than urban zones. These sites contain mixed vegetation that consists of fruit trees (e.g., apricot, apple), shade trees, shrubs and small cultivated plots. The vegetation in the peri-urban sector, which is comprised of the outer areas of Gilgit City and lies as the interface between urban settlements and the rural or natural landscape, was described as having low housing density, agricultural land, fallow land, open scrub and isolated plantations. Farther downstream on the Gilgit river and its related floodplains, riparian vegetation, gravel bars, sandbanks and seasonal water channels were found in the riverine zone. Dominant vegetation consisted of willow (*Salix* spp.), poplar (*Populus* spp.), reeds, and grasses, with minimal permanent infrastructure.

Acoustic monitoring

We deployed a total of 32 portable recorders at 32 selected points across the study area (8 per habitat stratum) over ten months (November to August). Recorders were spaced ~500 m apart and operated on 3 to 4 days each month during dawn and early morning (1–4 hours after sunrise), and occasionally at dusk. The Continuous full spectrum of recordings gained from the field is ~150 audio files, out of which 135 were analyzed using BirdNET. As a process of cleaning data, we have removed the nonsensical or overly noisy recordings manually after listening to them, without analyzing them using BirdNET. Recordings were processed using the BirdNET analyzer (web version). BirdNET applies convolutional neural networks to spectrogram slices, producing species identifications with confidence scores.

Ambiguous detections were manually verified against reference sonograms, and non-avian or anthropogenic sounds were excluded. Only species confirmed with high confidence (based on spectrogram inspection and observer expertise) were retained. (Figure 1; Figure 7; and Figure 8) depict the detected species with their confidence scores, the sonogram, and the waveform of the detected species, respectively.

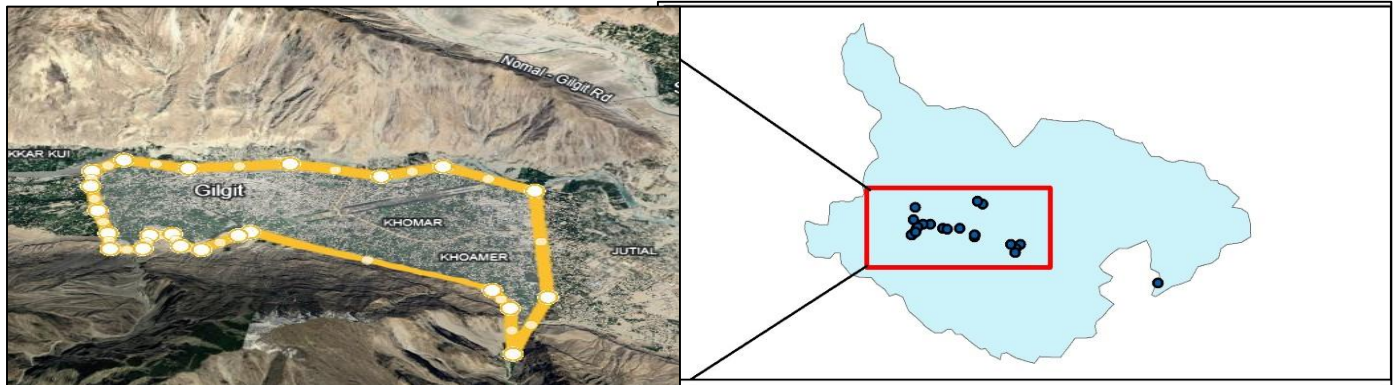


Figure 1. Study area.

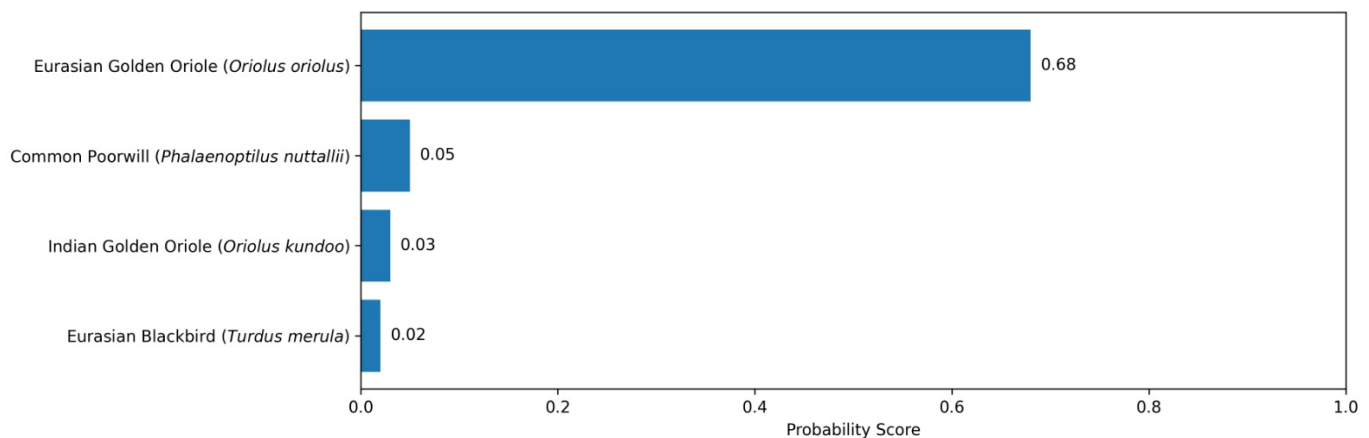


Figure 2. Species probability score for one species using BirdNET (The classifier identifies Eurasian golden Oriole (*Oriolus oriolus*) as the dominant species with a high confidence score (0.68). All alternative Candidates-Common Poorwill (0.05), Indian Golden Oriole (0.03), and Eurasian Blackbird (0.02)-have very low probabilities, indicating weak support and making them unlikely matches. This clear separation in scores supports a robust identification of (*O. oriolus*)

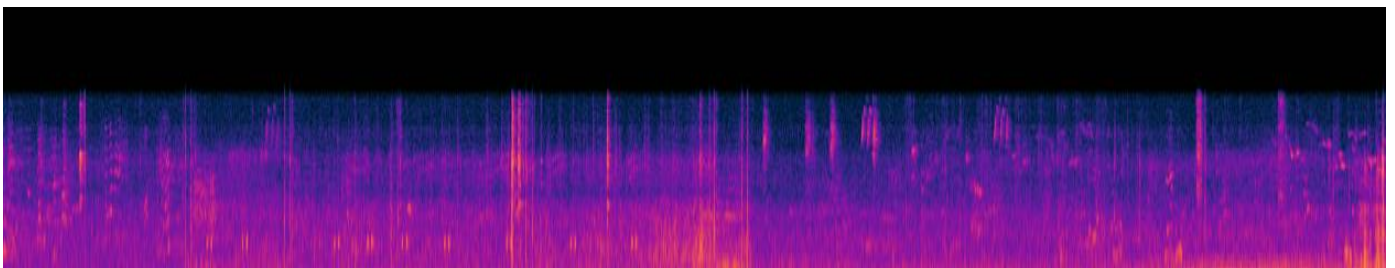


Figure 3. Sonogram of the figure 2 species.

Point counts

Simultaneously, the same 32 sites were surveyed using fixed-point counts. Each survey lasted 10 minutes within a 50 m radius and was conducted shortly after dawn. Each point was surveyed 3 to 4 times per month across seasons (November to August). All birds heard or seen were recorded, and species were captured with a Canon D5200 camera as a source of identification and proof later, and abundances were approximated. The author (trained in ORNIS methods) led all surveys to ensure consistency. In total, 960+ point counts (32 sites \times 3 times per month = 96-point counts in a month for the selected study site, and since this survey lasts for 10 months, $96 \times 10 = 960$ -point counts for the whole survey study time and area) were conducted. Abundance and presence data were aggregated by site and

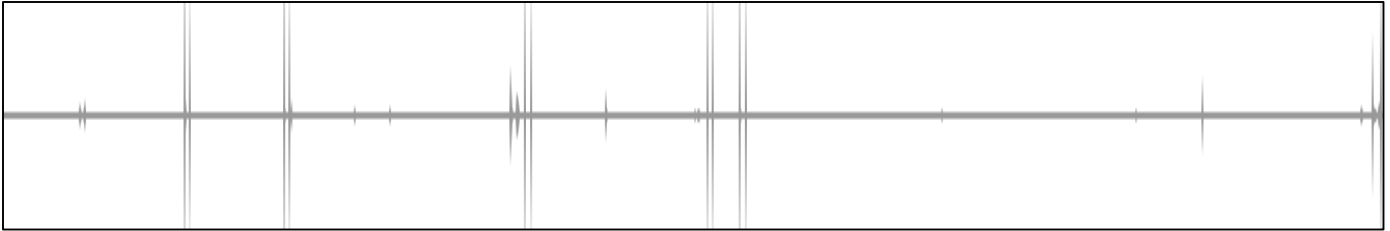


Figure 4. Waveform of the detected species in figure 2 (The waveform exhibits regular, moderate-amplitude peaks corresponding to discrete call notes, without excessive background noise or clipping. The consistent amplitude and spacing indicate clear vocal output rather than incidental noise, supporting the reliability of the detection).

month.

Data analysis

Cumulative species richness (S) was estimated by pooling BirdNET detections across all recordings. Rank–abundance plots were generated separately for BirdNET and point-count data. Diversity indices (Shannon H, Simpson D, and Pielou's evenness J) were calculated for each dataset and for each habitat stratum. Differences in richness and diversity across habitats were tested using one-way ANOVA depending on data distribution. Seasonal patterns were analyzed by plotting monthly totals of species richness and bird abundance. Data collected analyses were conducted in R (version 4.2.0) using standard ecological packages (Kahl et al, 2021).

RESULTS AND DISCUSSION

Species richness and community structure

Both surveys documented a diverse urban avifauna in Gilgit city. BirdNET detected 47 species from 135 analyzed recordings, of which 98 detections were validated. Point counts recorded 45 species and 11,430 individual birds across all survey sites.

Comparative species abundance

The five most abundant species differed substantially between methods (Figure 5). BirdNET acoustic detections were dominated by Indian White-eye (*Zosterops palpebrosus*, 10 detections, 10.2%), Streaked Laughingthrush (*Trochalopteron lineatum*, 8 detections, 8.2%), Cinereous Tit (*Parus cinereus*, 6 detections, 6.1%), Himalayan Bulbul (*Pycnonotus leucogenys*, 6 detections, 6.1%), and Eurasian Tree Sparrow (*Passer montanus*, 5 detections, 5.1%). These five species collectively comprised 35.7% of all validated BirdNET detections.

In contrast, point counts revealed markedly different abundance patterns. The five most abundant species were House Sparrow (2,060 individuals, 18.0%), Streaked Laughingthrush (1,510 individuals, 13.2%), Great Tit (1,387 individuals, 12.1%), Himalayan Bulbul (1,318 individuals, 11.5%), and Rose-ringed Parakeet (984 individuals, 8.6%). These species collectively accounted for 63.4% of all individuals recorded during point counts.

Only two species, Streaked Laughingthrush and Himalayan bulbul, appeared among the top five for both methods, though their relative rankings differed. The conspicuous absence of House Sparrow from acoustic detections, despite comprising 18.0% of point count observations, highlights methodological biases in detection. Similarly, the acoustic method's preference for detecting Indian White-eye and the visual method's superior detection of Rose-ringed Parakeet suggest that vocalization frequency, calling behavior, and visual conspicuousness influence species detectability across survey approaches.

The high skewness of distributions in both methods, and the identities of species detected acoustically and visually, are illustrated below by rank–abundance plots (Figure 6). The acoustic dataset contained many rare species, including 29 singletons (species recorded only once) and 6 doubletons, producing a long tail of infrequent taxa. BirdNET diversity indices were Shannon $H' = 2.7$, Simpson $1-D = 0.92$, and evenness $J' = 0.79$. Similarly, point-count data showed dominance by a few common species: the five generalists mentioned earlier accounted for ~58% of all individuals. Both methods, therefore, characterized the bird community as moderately diverse but strongly skewed toward a small number of abundant taxa. Overall, 39 species were shared between methods, with 8 detected only acoustic (e.g., nocturnal migrants) and 6 only visually (e.g., cryptic water birds at river sites).

Habitat-wise testing of hypotheses

Avian diversity varied markedly across habitat types (Figure 7), providing clear support for the proposed hypotheses. H1: Patterns of species richness and diversity were consistent across acoustic detections and point-count observations, indicating that BirdNET-based monitoring detected avian richness comparable to conventional field

surveys across all habitat types.

H2: Species richness and diversity were highest in less-developed habitats. Peri-urban sites supported the richest and most diverse communities (31 species; $H' = 2.72$; $J' = 0.79$), followed by suburban habitats (24 species; $H' \approx 2.45$). In contrast, the urban core hosted fewer species (19 species), while riverine habitats exhibited the lowest richness and diversity (16 species). These results confirm that avian richness and evenness increase with decreasing urban intensity, supporting the second hypothesis.

H3: Although the urban core exhibited moderate evenness ($J' \approx 0.72$), its bird community was numerically dominated by a small number of generalist species, notably House Sparrow (*Passer domesticus*), Rose-ringed Parakeet (*Psittacula krameri*), and Streaked Laughing Thrush (*Trochalopteron lineatum*), supporting the hypothesis that generalist granivores and omnivores dominate highly built-up environments. ANOVA confirmed that species richness and Shannon diversity differed significantly among habitats ($P < 0.01$).

The House Sparrow was truly pan-urban, occurring evenly across all strata. Laughing Thrushes and parakeets favored the city core and suburbs, while insectivores such as the Great Tit and Blue Whistling-thrush were concentrated in peri-urban green areas.

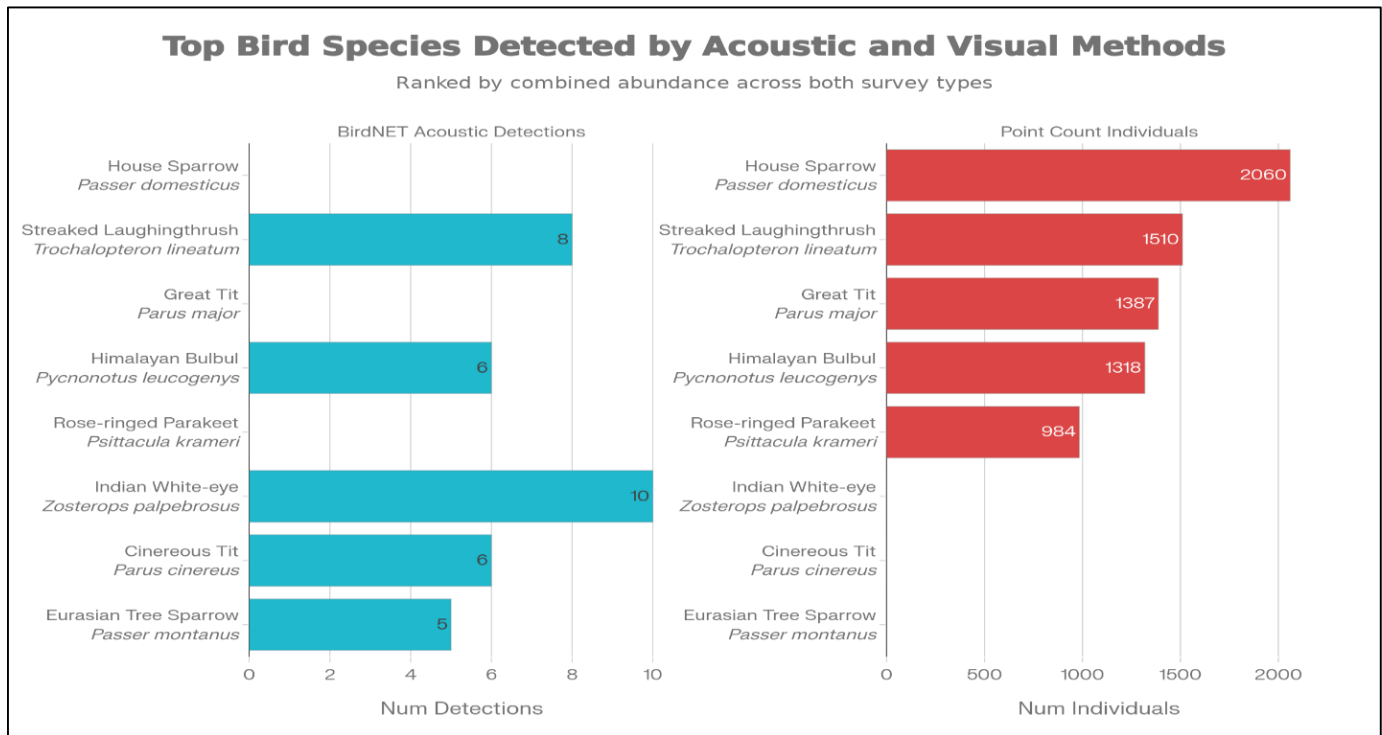


Figure 5. Comparison of top bird species detected by BirdNET acoustic monitoring (left panel, n=98 validated detections) and point counts (right panel, n=11,430 individuals) in Gilgit City. Species are ordered by combined detection frequency across both methods. Note the different scales: BirdNET shows number of detections while point counts show number of individual birds observed.

Seasonal dynamics

Clear seasonal trends were observed (Table 1; Figure 8). Species richness peaked in winter (December to January; ~28 species), driven by migrants such as *Motacilla alba* and *Turdus* spp. Richness declined during spring but rose again in August with the appearance of post-breeding flocks and fledglings (e.g., sparrows and bulbuls). Point-count abundance (total individuals per month) was also highest in August, with consistently high values from January to July (1,200–1,400 individuals/month), followed by a mid-winter trough. These patterns resemble temperate urban dynamics, where winter migrants increase species diversity and breeding periods boost overall abundance (Van-Doren et al., 2023; Fuller et al., 2007).

Methodological complementarity

Our study provides the first comprehensive picture of the avian community of Gilgit city and demonstrates the utility of modern acoustic techniques in a rapidly urbanizing Himalayan setting. Both methods yielded comparable richness (47 vs. 45 species) but revealed different aspects of the community, with point counts better capturing visually conspicuous

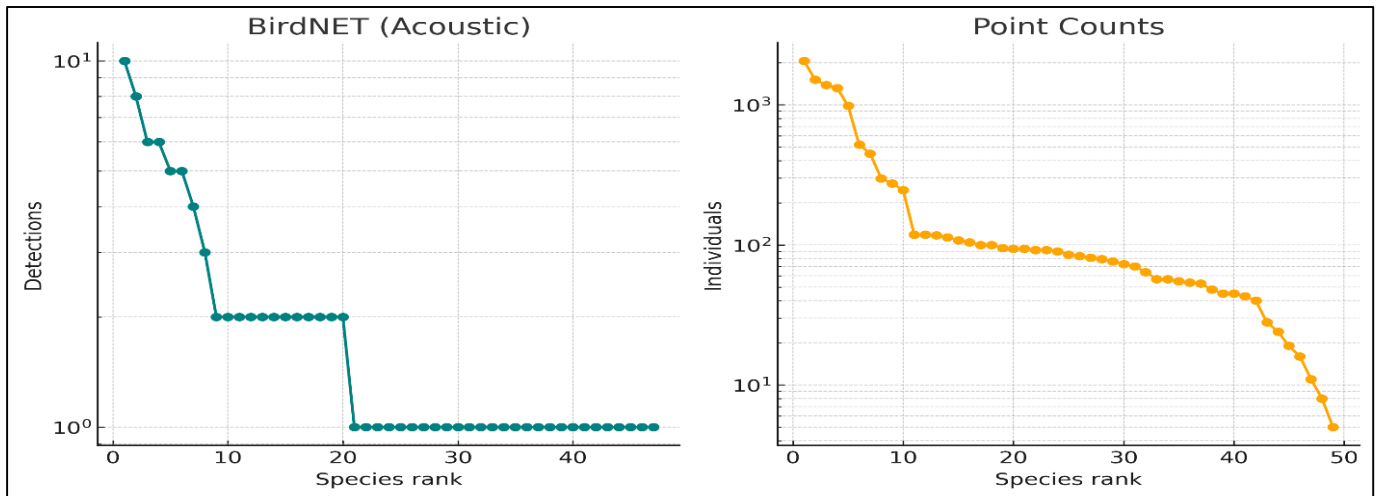


Figure 6. Rank–abundance plots for both methods (BirdNET vs. Point counts).

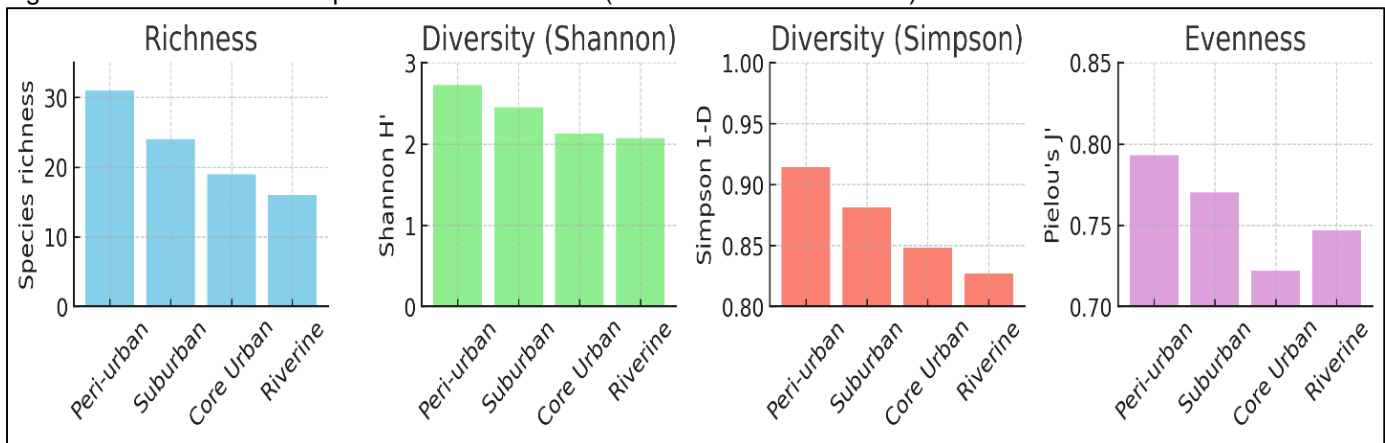


Figure 7. Habitat-wise species richness and diversity indices.

Table 1. Seasonal summary of species richness and abundance (Winter peak, Spring dip, Summer/post-breeding surge).

Season	Species richness	Total individuals
Winter (Dec–Jan)	~28 (highest richness)	~1,200–1,300 (high)
Spring (May–Jul)	19–20 (lowest)	~1,200 (moderate)
Late Summer (Aug)	~26 (second peak)	1,477 (peak)

and less vocal species, and acoustic recordings detecting a broader suite of vocally active, often canopy-dwelling or cryptic taxa. Acoustic surveys using BirdNET were effective at detecting vocal species, including nocturnal or cryptic taxa that often call from cover and are easily missed by observers, whereas point counts excelled at recording large flocks and visually conspicuous birds moving through open airspace. Although overall species richness was similar between methods, point counts provided more reliable estimates of local abundance and flock size because observers could track numbers of individuals in real time, while automated classifiers are currently less suited to precise counting of individuals. For example, during early mornings, BirdNET detected white-eyes and titmice vocalizing, while point counts were dominated by House Sparrows. This highlights a complementary bias: PAM is better for frequent singers, while human observers are more effective at detecting silent or flocking species. Combining the two approaches, therefore, provides a more complete picture of bird communities, as also advocated in recent bioacoustics studies (Sugai et al., 2019).

Sampling and detection

The high number of singletons in the acoustic dataset suggests a rich but under sampled soundscape. Similar studies show that urban PAM often under-represents rare species unless recording intensity is very high (Towsey et al., 2014). Longer deployment times and greater coverage would likely detect additional species, including nocturnal migrants

and warblers. Limitations also include BirdNET’s difficulty in classifying quiet or overlapping calls; species recorded during point counts were often missed acoustically. Nevertheless, BirdNET provided a reliable baseline inventory consistent with traditional surveys, confirming its applicability in remote settings. Figure 8 and Table 2 give the data about both methods clearly. Moreover, open-source software (e.g., Audacity) for preprocessing (Mellinger & Clark, 2000) helps reduce observer bias and effort in such monitoring.

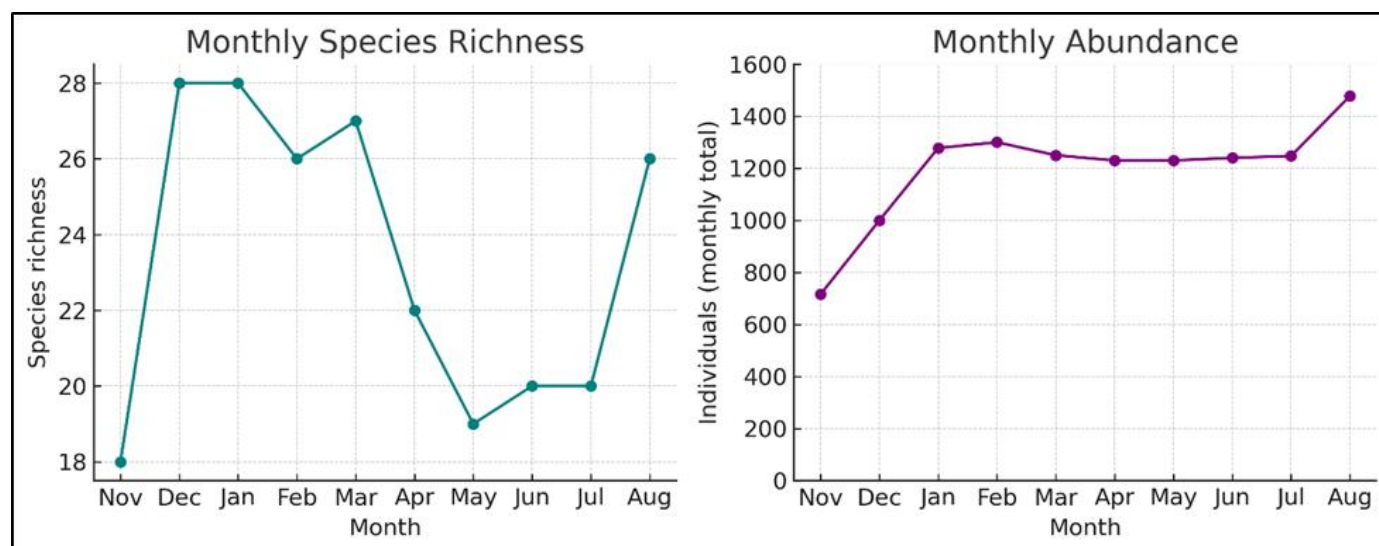


Figure 8. Seasonal dynamics of urban bird communities in Gilgit city. Species richness peaked in winter, while abundance surged in late summer.

Table 2. Comparison of the five most frequently detected bird species in Gilgit City using BirdNET acoustic detections and point counts, showing differences in detection bias between methods.

Rank	BirdNET acoustic (detections)	Count	Point counts (individuals)	Count
1	Indian White-eye (<i>Zosterops palpebrosus</i>)	10	House Sparrow (<i>Passer domesticus</i>)	2,060
2	Streaked Laughingthrush (<i>Trochalopteron lineatum</i>)	8	Streaked Laughingthrush (<i>Trochalopteron lineatum</i>)	1,510
3	Cinereous Tit (<i>Parus cinereus</i>)	6	Great Tit (<i>Parus major</i>)	1,387
4	Himalayan Bulbul (<i>Pycnonotus leucogenys</i>)	6	Himalayan Bulbul (<i>Pycnonotus leucogenys</i>)	1,318
5	Eurasian Tree Sparrow (<i>Passer montanus</i>)	5	Rose-ringed Parakeet (<i>Psittacula krameri</i>)	984

Urbanization effects

The results reflect typical patterns of avifaunal responses to urbanization. Urban cores were dominated by resilient generalists (granivores/omnivores) exploiting anthropogenic food and nesting resources (McKinney, 2006, 2008). It was noted that a greater range of guilds was present in peri-urban and suburban areas, including insectivore, frugivore, and riparian specialists. These findings support our initial hypothesis and reflect findings in other Pakistani city settings (Umar et al., 2018).

Seasonal variant is one more aspect that makes Gilgit strong as an important part of major migratory flyways since the Eurasian migrants use riparian trees and gardens as their stopover and wintering areas. Based on this, conservation efforts should focus on peri-urban green spaces and riparian corridors as important biodiversity reserves in the framework of the growing urban development.

Conservation and planning implications

Considering that the urban core is represented by a few species, city planners may improve heterogeneity of habitats (e.g. adding more trees, shrubs, and green areas) in order to allow more specialist species to thrive. We have also shown that a BirdNET workflow can be used to create strong inventories of species through minimum field work, so the workflow is useful in data-poor areas to undertake ornithological surveys. Such an approach might be improved in

future studies through calibration of BirdNET confidence scores and combining acoustic indices and species-specific surveys.

CONCLUSION

In conclusion, our results correspond to the general tendencies of urban biotic homogenization, as even small green spaces may have a significant effect on the avian diversity of urban regions. To sum up, when passive acoustic monitoring (BirdNET) is used together with classical point counts, it is possible to state that the bird community within Gilgit City is diverse and still urban-structured. Our two techniques revealed almost similar counts of species (~45-47) with generalist omnivores prevailing in the high-density urban core, and the more species-rich in the greener outskirts. Seasonal migrants enhanced the richness of winter, which is expected by the global urban ecology theory: cities are home to cosmopolitan generalists, and the remaining natural habitats contain specialists.

On the methodological level, our experiment proves that BirdNET is able to provide quality and large-scale acoustic data in mountainous urban settings and significantly decreases the amount of work needed to conduct the survey manually. The method is scalable and can be used to monitor the environment in the long term.

To enhance long-term monitoring, we suggest extending passive acoustic surveys over seasons and habitats and combining them with the traditional ways to confirm the detection and improve the abundance estimates. The urban planning should focus on the protection and creation of green space and riparian buffers, preserve native vegetation corridors, and incorporate into the master plan of Gilgit, the concept of bird-friendly design (e.g. green roofs, bird-safe buildings). Citizen science and other community activities as well as the reduction of pollution, poaching, and habitat destruction, are necessary to make sure that urban development in Gilgit can be sustainable alongside the need to preserve a diverse avifauna.

AUTHOR'S CONTRIBUTION

Performed the experiment/ Survey: Mufeed Hussain, Nasir Mehdi and Atif Hussain, analyzed the data: Saeed Abbas and Mufeed Hussain, contributed in material: Rahila Tabassum, Saeed Abass and Mufeed Hussain, designed the experiment & wrote the paper: Mufeed Hussain and Saeed Abbas.

FUNDING

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AVAILABILITY OF DATA AND MATERIAL

The collected and analyzed data is presented in the form of figures.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable as the data was collected using non-invasive techniques.

CONSENT FOR PUBLICATION

All authors have reviewed the manuscript and approved it for publication.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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