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Article

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ORNITHOPHONY IN THE SOUNDSCAPE OF ANAIKATTY HILLS, COIMBATORE, TAMIL NADU, INDIA

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Abstract: An attempt has been made to understand the extent of ornithophony (vocalization of birds) in the soundscape of Anaikatty Hills. The study was limited to 13 hours of daylight from dawn to dusk (06.00–19.00 h) between January 2015 and October 2016. Six replicates of 5-minute bird call recordings were collected from each hour window in 24 recording spots of the study area. Each 5-minute recording was divided into 150 '2-sec' observation units for the detailed analysis of the soundscape. A total of 78 recordings amounting to 390 minutes of acoustic data allowed a preliminary analysis of the ornithophony of the area. A total of 62 bird species were heard vocalizing during the study period and contributed 8,629 units. A total of 73.75% acoustic space was occupied by birds, among which the eight dominant species alone contributed to 63.65% of ornithophony. The remaining 26% of acoustic space was occupied by other biophonies (12.60%), geophony (5.57%), indistinct sounds (7.66%), and anthropogenic noise (0.41%). Passerines dominated the vocalizations with 7,269 (84.24%) and non-passerines with 1,360 (15.76%) units. Birds vocalized in all 13 observation windows, with a peak in the first three hours of the day (06.00–09.00 h). Vocalizations of non-passerines were prominent in the dusk hours (18.00–19.00 h).

Keywords: Acoustic community, bird acoustics, bird vocalization, diurnal singing, ornithophony, soundscape analysis.

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INTRODUCTION

The biological sound produced by vocalizing animals (e.g., birds and stridulating insects (biophony)), non-biological sounds such as wind, rain, running stream (geophony) in a forest or any natural habitat (Hildebrand 2009) constitutes the soundscape of that area (Pijanowski et al. 2011; Gage & Axel 2014). The man-made sounds produced from automobile, machinery (technophony or anthrophony) that dominate in urban settings are rarely detected in forest habitats (Krause 1987; Pijanowski et al. 2011; Gage & Axel 2014). Vocalization of birds (ornithophony) of a terrestrial habitat varies due to the variations in the dominant vocalizers, number of species involved in vocal activity and the time specificity of the birds. It is well known that many species of birds are more vocally active during dawn and dusk hours as they are active in search of food and / or attracting a female partner (Slabbekoorn 2004; Brumm, 2006; Catchpole & Slater 2008; Ey & Fischer 2009). Leaving aside the functionality, ornithophony is observed as one of the dominant aspects of the soundscape of any natural ecosystem, especially in forests.

The vocal communication of the birds was well studied, experimented and the results give insights about the characteristics of avian vocal signals (Aylor 1971; Morton 1975; Wiley & Richards 1978; Brenowitz 1982). The environmental factors such as humidity, temperature, atmospheric turbulence, or vegetation cover influence the signal transfer through masking, absorption, attenuation, reverberation or signal scattering effect (Wiley & Richards 1978). Birds prefer a suitable environmental condition for the effective long-distant signal transfer (Morton 1975; Kroodsma 1977; Brenowitz 1982). As the vocal communication consumes significant energy and time (Prestwich 1994; Oberweger & Goller 2001), animals adapt their vocal signals spectrally, by altering their syllable structure and usage; or temporally, by opting for a better daytime hour for signal transfer (Ficken et al. 1974; Nelson & Marler 1990; Boncoraglio & Saino 2007; Planque & Slabbekoorn 2008; Ey & Fischer 2009; Velásquez et al. 2018). Birds reduce the interference and masking effect of other animal signals such as insects (Stanley et al. 2016), and abiotic noise like wind and water (Klump 1996). Hence, birds have vocal partitioning or an 'acoustic niche' (Brumm 2006; Planque & Slabbekoorn 2008; Luther 2009; Hart et al. 2015). As dawn and dusk hours have a favourable environmental conditions (Morton 1975; Slagsvold 1996; Hutchinson 2002) and enhance long-distant signal transfer (Henwood & Fabrick 1979; Dabelsteen & Mathevon 2002; Brown & Handford 2003), birds probably prefer those hours for consistent signal transfer.

The interaction of biological and non-biological sounds provides the overall framework of the acoustic ecology of a landscape (Pijanowski et al. 2011). Spectral frequency (Hz) analysis is a valid method for interpreting the terrestrial soundscape (Irwin 1990; Nowicki & Nelson 1990; Cardoso 2010; Cardoso & Atwell 2011). Overlapping of sound frequencies of geophony (such as wind, rain) or technophony (automobiles) may mask the biophony signals (Qi et al. 2008; Mullet 2017). Most of the technophony and a few biophonic sounds (birds) occur in lower frequency range 1–2 kHz. Passerines species' frequency ranges between 3 and 6 kHz, whereas insects occupy a higher range, > 6kHz, and all the geophony are of low frequency ranging from 1–11 kHz (Napoletano 2004; Qi et al. 2008; Joo et al. 2011; Kasten et al. 2012; Gage & Axel 2014).

Biophony of the soundscape can be comprehended by examining the temporal framework across the daytime from dawn to dusk (Joo 2008; Joo et al. 2011). It also provides valuable insights on species diversity (Napoletano 2004; Sueur et al. 2008) and ecosystem (Qi et al. 2008). This study is a first step to understand the biophony in the soundscape of Anaikatty Hills through a community acoustics' approach on the ornithophony across daylight hours.

METHODS

Study area

The study area is Anaikatty Hills (11.090–11.097 ^{0}N & 76.778–76.792 ^{0}E; Fig. 1), in Coimbatore District, Tamil Nadu, India, is a part of the Nilgiri Biosphere Reserve (NBR), approximately 500 to 600 m, lies on the leeward side of the Western Ghats. It receives an annual rainfall of about 700mm, which is mainly contributed by the north-east monsoon. The temperature varies from 17˚ C to 36˚ C (Mukherjee & Bhupathy 2007). It is a secondary forest area surrounded by dry deciduous forests rich in biodiversity and forms a part of the Western Ghats, which is one among the 35 biodiversity hotspots of the world (Noss et al. 2015). The study site is dominated by trees such as Ceylon Tea *Cassine glauca*, Woolly-leaved Fire-brand Teak *Premna tomentosa*, Umbrella Thorn *Acacia planifrons*, Neem *Azadirachta indica*, Ceylon Boxwood *Psydrax dicoccos*, Krishna Siris *Albizia amara*, Bidi Leaf Tree *Bauhinia racemosa*, Algaroba *Prosopis juliflora*, and shrubs such as Orangeberry *Glycosmis*

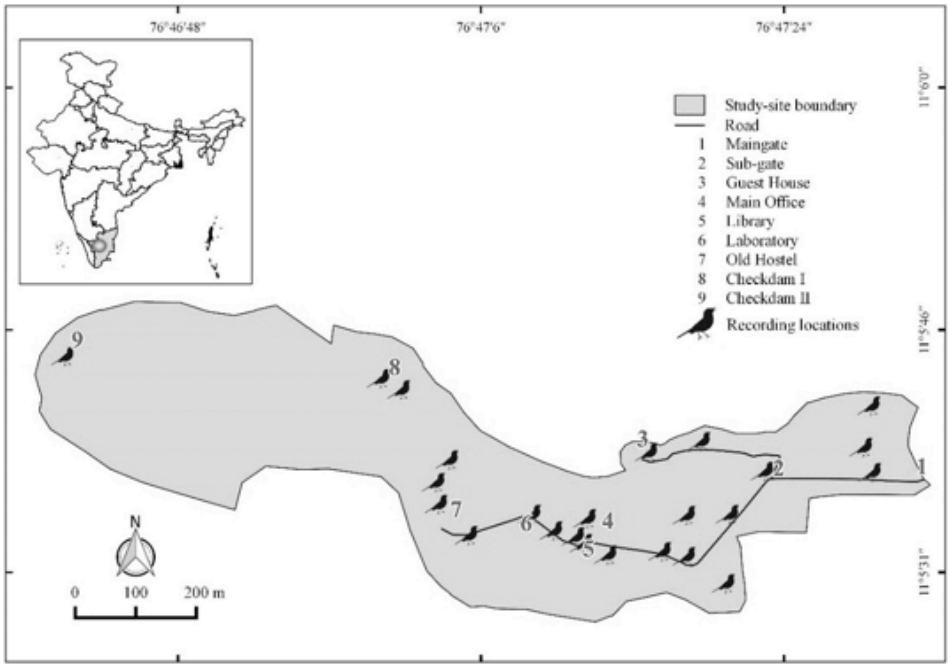

Figure 1. The study location of Anaikatty Hills in India (inset). Map showing the study area with Tamil Nadu State boundary.

mauritiana, *Clausena dentata*, Cat Thorn *Scutia myrtina*, Siam Weed *Chromolaena odorata*, and Lantana *Lantana camara* (Balasubramanian et al. 2017). A total of 145 bird species, from 48 families with 52% of passerine species has been reported from the study site (Ali et al. 2013).

Field methods

The acoustic signals were recorded from 24 different recording spots (Fig. 1) of the landscape to capture the soundscape from the maximum microhabitats from January 2015 to October 2016. The study area is a scrub jungle with dry deciduous forest patches (Ali et al. 2013). Acoustic data was recorded using Sony PCM-M10 portable linear PCM handheld audio recorder (2009), with an Audio-Technica ATR-6550 condenser shotgun microphone in .WAV format with 44.1kHz sampling frequency and 24-bit accuracy rate. The diel pattern of acoustic behavior of birds was observed and calls were recorded from 06.00h to 19.00h spanning 13 hours of a day. The daylight period is segmented into 13 one-hour slots (from henceforth mentioned as 'observation window'). Six replicates of 5-minute bird call recordings were collected from each window, of which each 5-minute call recording is considered as 'a sampling unit'. The first author held the microphone for one minute in each direction to capture the soundscape. The sampling effort is six replications of 13h, makes 78 recordings. The average sampling effort per location was 3.0. The sampling effort is presented in Table 1. The recording date, time and location were noted during the recording period. Recordings were not collected during rainy days. The sunrise and sunset time was 06.00–06.48 h and 17.57–18:51 h, respectively. The sunrise and sunset data were obtained from the official website of Indian Meteorological Department, Government of India.

Data analysis

Each 5-min recording was analysed by dividing it into 150 '2-sec' parts (henceforth mentioned as 'observation unit(s)'). The first author manually investigated each 2-sec unit for capturing the dominant vocalizing bird species. It was a challenging and time-consuming task, however, it helped to understand the soundscape in a much finer resolution. About 90% of the species were identified and the remaining were documented as unidentified species. One second would be too short, whereas 3-sec part would miss out the short vocal signals, hence, 2-sec unit analysis was preferred. The term 'vocal unit' is used to refer to any biophony (animal vocalizations) present in it. The calls/audio signals of (i) individual birds, (ii) unidentified birds, (iii) birds which were identified to their genus category, (iv) gap during the absence of any vocal signal of bird, (v) wind, (vi) vehicle noise, (vii) sound of other animals like Spotted Deer, Indian Palm Squirrel, goat, and (viii) other

Table 1. Sampling effort of the study in Anaikatty Hills.

13 hrs/ 24 loc	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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The sampling effort was distributed across 13 hours in 24 locations to capture the soundscape of the study area.

indistinct sounds were also noted in each observation unit. The loud and vocally dominant species in each observation unit was visually classified and considered for further analysis. The vocalizations identified to group level were also considered as separate taxa for broad level classifications, however, they are not included as separate species while accounting for the total number of species vocalized.

The 13 daytime hours were classified into morning (06.00–09.00 h), mid-day (09.00–12.00 h), afternoon (12.00–16.00 h), and evening (16.00–19.00 h) hours. To study the variation on the number of bird species and vocal units across 13 observation windows, ANOVA test (Fisher 1925) with random effect was performed. Kruskal-Wallis test (Kruskal & Wallis 1952) was performed to show statistical proof for significant variation between morning and evening hours against mid-day and afternoon hours. All the statistical tests were performed using SPSS v.16.0 (SPSS Inc. 2007). The sound recordings were analyzed for spectrogram views with the aid of sound analysis software Raven Pro 1.4 (Bioacoustics Research Program 2011) and audio signals were edited using Audacity 2.0.6. software. The spectrogram settings in Raven Pro 1.4 (2011) were as follows: Hann 512, 3dB filter Bandwidth 124Hz, 50% overlap, grid spacing 86.1Hz. The frequency values of bird vocalizations were measured by visual inspection method (Irwin 1990; Nowicki & Nelson 1990; Baker & Boylan 1995; Cardoso & Atwell 2011; Singh & Price 2015).

RESULTS

Soundscape analysis

The acoustic data collected from the field had 78 recordings with a total duration of 390 minutes sampled from multiple locations (24) of the same landscape evenly spread along the 13 different observation windows. This gives 900 observation units per window adding to 11,700 units in total. Visual classification of these observation units yielded a total of 62 bird species' calls (Tables 2, 3). The checklist of species was prepared following Praveen et al. (2019). Passerines dominated all through the 13 day-hours and non-passerines were more vocalizing during 18.00h to 19.00h. Especially, the first three hours had 19, 22, and 20 passerine species (Fig. 2). Thirty-nine passerine species (62.90%) and 23 (37.09%) non-passerine species (Tables 2, 3) were recorded as the vocalizers of the Anaikatty soundscape. Among the total 11,700 observation units, birds occupied 8,629 (74%); of these, passerines occupied 7,269 (84.24%), and non-passerines only 1,360 (15.76%) vocal units (Fig. 3). Of the remaining 26% of the sample, 12.60% was contributed by biophony of other creature such as insects and 5.57% by geophony (wind, indistinct noise). Undetectable or indistinct sounds were 7.66%, and the remaining negligible 0.41% by anthropogenic noise. ANOVA (Fisher 1925) showed that the bird species and vocal units significantly varied across the 13 observation windows, i.e., $F_{12,65} = 4.220$, $p < 0.01$ and $F_{12,65} = 2.251$, $p = 0.019$, respectively. ANOVA (Fisher 1925) showed that

the vocalization number of bird species were significantly varied across 13 hours (random effect in ANOVA).

Bird vocalizations across diurnal hours

The number of species recorded vocalizing was high in the initial three hours of the day (Fig. 2). In the first hour of observation, i.e., 06.00–07.00 h, 95% of the time was occupied by bird calls (858 out of 900 observation units), 10.00–11.00 h window received the next maxima with 763 bird vocal units, and in the evening just before the sunset, i.e., 17.00–18.00 h had the next peak with 647 vocal units. (Fig. 3, 4).

The Kruskal-Wallis test showed no significant difference across the bird species between mid-day–afternoon hours against morning–evening hours, $\chi 2$ = 3.47, df = 1, p = 0.063 (N = 13). There was no significant variation in vocal units among the tested groups $\chi 2$ = 0.73, df = 1, p = 0.39 (N = 13). In any one-hour observational window, a minimum of 16 species was recorded to be vocally active.

Non-passerines were higher at 06.00–07.00 h and declined as the day progressed. There was a peak in their vocalizations during 18.00–19.00 h (Fig. 2). It is to be noted that non-passerine vocal contribution increased from 15.00h onwards (Fig. 3). Among the 13 hours, Indian Pitta was more vocal during 18.00–19.00 h. The 15 species that contributed to dusk calls were either producers of low-frequency calls or harmonics. Totally, 10 species (Yellow-billed Babbler, Jungle Crow, Common Tailorbird, Indian Peafowl, Indian Robin, White-browed Bulbul, Spotted Dove, Red-vented Bulbul, Grey Jungle fowl, and Common Hawk Cuckoo) were observed to be vocalizing both in dawn and dusk time. The low and high frequency values of the 62 species are given in Tables 2 and 3.

Dominance in vocalization

Eight species dominated the ornithophony with 63.65% of vocal units' contribution (Fig. 5 and their statistical analysis is provided in Table 4). Of these, Common Tailorbird, Red-vented Bulbul, Yellow-billed Babbler, Indian Robin, and White-browed Bulbul had vocalized in all 13-hour observation windows (Fig. 5), whereas Purple-rumped Sunbird, Grey-breasted Prinia,

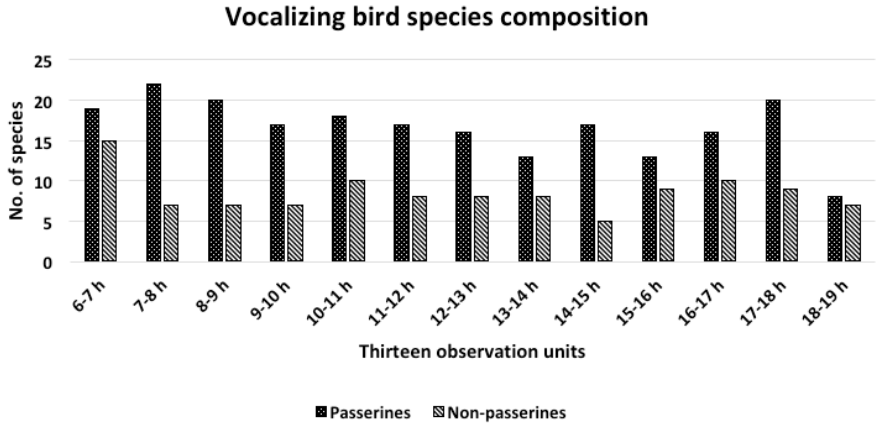

Figure 2. Bird species composition of vocalizing passerines and non-passerines in 13 observation windows.

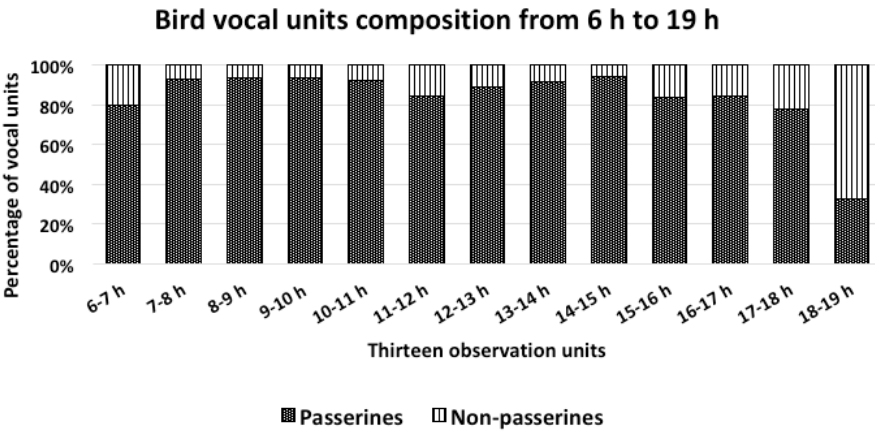

Figure 3. Vocal units of birds across 13 observation windows. Passerines are more in morning 07.00–08.00 h onwards. Non-passerines are more 18.00–19.00 h.

Table 2. List of passerine species of Anaikatty Hills recorded during the study. Birds with harmonics are marked with an asterisk (*). Sample size of the low and high frequencies are 10, except # - sample size 5; ^ - sample size 4.

	Bird species /Family	Scientific name	Low-frequency values (in Hz) (Mean ± S.D.)	High-frequency values (in Hz) (Mean ± S.D.)
	Pittidae			
1	Indian Pitta	*Pitta brachyura*	1662.5 ± 289.5	4662.9 ±3353.1
	Oriolidae			
2	Black-hooded Oriole	*Oriolus xanthornus*	1465.97 ± 798.58	2229.97 ± 564.44
3	Eurasian Golden Oriole	*Oriolus oriolus*	1099.7 ± 408.8	7825.8 ± 6266.1
	Aegithinidae			
4	Common Iora	*Aegithina tiphia*	1589.54 ± 301.49	3432.68 ± 682.08
	Dicruridae			
5	Ashy Drongo*	*Dicrurus leucophaeus*	1661.9 ± 329.3	10420.0 ± 3202.1
6	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	1673.6 ± 118.9	2741.6 ± 53.9
	Laniidae			
7	Brown Shrike*	*Lanius cristatus*	2166.9 ± 504.1	10701.9 ±1479.1
	Corvidae			
8	Rufous Treepie*	*Dendrocitta vagabunda*	815.2 ± 272.5	18059.0 ± 1996.3
9	House Crow*	*Corvus splendens*	1205.1 ± 955.5	3136.6 ± 1317.2
10	Large-billed Crow*	*Corvus macrorhynchos*	1193.6 ± 690.6	2298.2 ± 658.7
	Monarchidae			
11	Indian Paradise-flycatcher*	*Terpsiphone paradisi*	1231.56 ± 262.78	13764.35 ± 1550.62
	Dicaeidae			
12	Thick-billed Flowerpecker	*Dicaeum agile*	2562.6 ± 602.4	14147.4 ± 592.3
13	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	3721.5 ± 549.8	11403.5 ± 567.2
	Nectariniidae			
14	Purple-rumped Sunbird	*Leptocoma zeylonica*	3581.8 ± 461.5	6273.3 ± 1006.4
15	Purple Sunbird	*Cinnyris asiaticus*	4145.5 ± 1099.1	7016 ± 734.1
16	Loten's Sunbird	*Cinnyris lotenius*	4145.5 ± 662.3	6643.9 ±1530.6
	Chloropseidae			
17	Jerdon's Leafbird*	*Chloropsis jerdoni*	1844.6 ± 460.3	7736.8 ± 5421.0
	Fringillidae			
18	Common Rosefinch#	*Carpodacus erythrinus*	2060.1 ± 146.1	6003.3 ± 166.8
	Paridae			
19	Cinereous Tit	*Parus cinereus*	2835.5 ± 350.4	8553.6 ± 427.4
	Cisticolidae			
20	Grey-breasted Prinia	*Prinia hodgsonii*	3002.7 ± 329.6	7107.9 ± 325.6
21	Jungle Prinia	*Prinia sylvatica*	2705.6 ± 244.5	6545.5 ± 600.1
22	Ashy Prinia	*Prinia socialis*	2821.5 ± 530.2	6394.2 ± 611.4
23	Common Tailorbird	*Orthotomus sutorius*	2604.27 ± 1153.85	5840.91 ± 833.58
	Acrocephalidae			
24	Blyth's Reed Warbler	*Acrocephalus dumetorum*	2663.7 ± 505.34	7379.51 ± 335.14
	Hirundinidae			
25	Red-rumped Swallow*	*Cecropis daurica*	2719.4 ± 196.9	7807.4 ± 1334.1
26	Barn Swallow*	*Hirundo rustica*	2587.8 ± 597.3	8021.2 ± 2566.4
	Pycnonotidae			
27	Red-whiskered Bulbul	*Pycnonotus jocosus*	1703.8 ± 509.9	3667.3 ± 488.7

	Bird species /Family	Scientific name	Low-frequency values (in Hz) (Mean ± S.D.)	High-frequency values (in Hz) (Mean ± S.D.)
28	Red-vented Bulbul	*Pycnonotus cafer*	1562.8 ± 194.1	3062.5 ± 393.1
29	White-browed Bulbul	*Pycnonotus luteolus*	1256.8 ± 227.8	3707.7 ± 504.8
	Phylloscopidae			
30	Greenish Leaf Warbler	*Phylloscopus trochiloides*	3438.2 ± 716.6	7505.9 ± 1717.6
	Timaliidae			
31	Indian Scimitar Babbler*^	*Pomatorhinus horsfieldii*	622.7 ± 116.9	1300.2 ± 248.2
32	Tawny-bellied Babbler	*Dumetia hyperythra*	3475.0 ± 554.3	6443.7 ± 193.6
	Leiothrichidae			
33	Yellow-billed Babbler*	*Turdoides affinis*	3702.7 ± 518.8	9946.6 ± 2710.5
	Sturnidae			
34	Common Myna*	*Acridotheres tristis*	1399.8 ± 393.8	10244.5 ±3148.6
35	Jungle Myna*	*Acridotheres fuscus*	1368.7 ± 204.5	9803.4 ± 3469.0
	Muscicapidae			
36	Indian Robin	*Saxicoloides fulicatus*	5034.9 ± 1375.7	7261.5 ± 642.1
37	Oriental Magpie Robin*	*Copsychus saularis*	2399.4 ± 320.9	6770.0 ± 2349.3
38	Tickell's Blue flycatcher	*Cyornis tickelliae*	3095.0 ± 206.8	7318.3 ± 1788.8
39	Pied Bushchat	*Saxicola caprata*	2037.4 ± 349.7	5089.6 ± 849.5

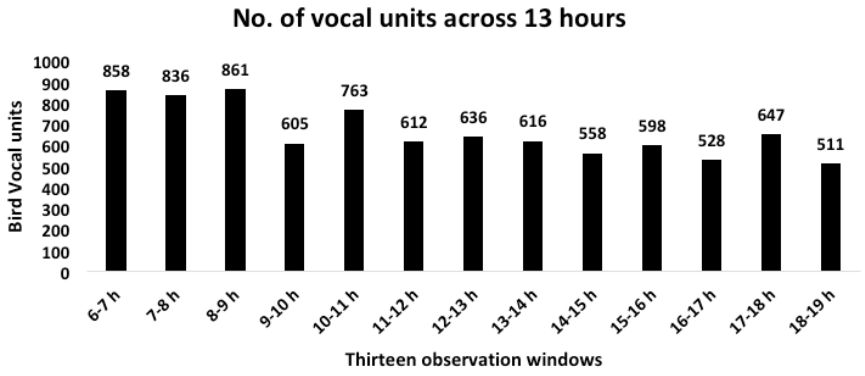

Figure 4. Distribution of bird vocal units in the study area shows that the early hours have more vocal units with second peak at 10.00–11.00 h and a third maxima at 17.00–18.00 h.

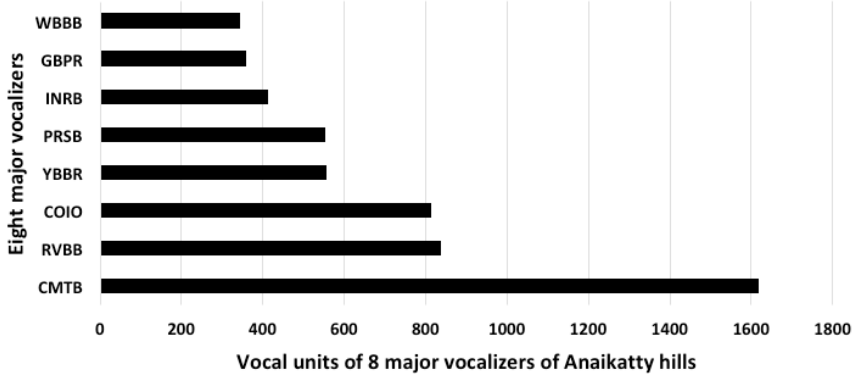

Figure 5. Vocal units of the eight most vocalizing resident passerines of Anaikatty Hills. CMTB—Common Tailorbird | RVBB—Red-vented Bulbul | COIO—Common Iora | YBBR—Yellow-billed Babbler | PRSB—Purple-rumped Sunbird | INRB—Indian Robin | GBPR—Grey-breasted Prinia | WBBB—White-browed Bulbul. These common vocalizers together occupied 63.65% of total birds' vocal participation of Anaikatty Hills.

and Common Iora were absent in the 18.00–19.00 h window. Common Tailorbird dominated the soundscape of the study area with 1,619 vocal units (Fig. 5), i.e., 18.76% vocal signal contribution and was present in 74 out of 78 recordings. White-browed Bulbul's vocal signals were present in 66 recordings, occupied just 3.97% of total ornithophony (Table 4). Indian Paradise-flycatcher was found only in a 5-min recording. They produce several quick high-pitched notes and hence, occupy several observation units (40) in a single utterance. The Common Rose-finch, Blue-bearded Bee-eater, Rose-ringed Parakeet, Indian Golden Oriole, Ashy Drongo, Plum-headed Parakeet, Tawny-bellied Babbler, Greater Racket-tailed Drongo, and Barn Swallow were observed in only one of the recordings.

Fifteen non-passerines were recorded vocalizing during the dawn hour (06.00–07.00 h), after that non-passerine composition declined in the subsequent hours (Fig. 2). It is to be noted that non-passerines vocal contribution slightly increased from 15.00h onwards (Fig. 3). Indian Peafowl, Grey Francolin, Grey Junglefowl, Red-wattled Lapwing, Jerdon's Nightjar, and Common Hawk Cuckoo were the dominant non-passerines during the 18.00–19.00 h window and were at low ebb or almost nil during other hours. Indian Peafowl was the only non-passerine to be vocally active in all 13 observation windows, the Grey Francolins were present in seven out of 13 observation windows, and the Grey Junglefowl calls were recorded in six observation windows. Indian Pitta being a winter visitor and lower song rate species had fewer vocal units in the present study. Figure 6 shows the number of bird species' spread in each observation window. The 06.00–08.00 h window had more bird species, whereas, 18.00–19.00 h had the least. Figure 7 depicts the vocal units' data spread. Vocal units at 09.00–10.00 h, 12.00–13.00 h, and 18.00–19.00 h were relatively more variable than other observation hours.

DISCUSSION

Soundscape analysis

The study area, a scrub jungle in a dry deciduous landscape, had more of sound than silence in day hours. The sounds of birds dominated 74% of the time in the study area, especially in the initial three hours. We have recorded other biophony and indistinct, undetectable sound sources from the study area. The indistinct sounds in the study area could be relatively short-bursts of wind or sound produced by any other vocalizing animal. Earlier studies say that the forest environment has lesser decibel (Aylor 1971; Marten & Marler 1977; Marten et al. 1977) as background sound than in urban areas (Brumm & Slabbekoorn 2005; Brumm 2006). The terrestrial habitats are prone to low-frequency noise caused by air turbulence, rain, running water (Brumm & Slabbekoorn 2005) and other biotic noises (Slabbekoorn 2004). The omnipresent cicadas and their concert produce a constant spectrum of background noise (Slabbekoorn 2004). Therein, the biophony generally ranges between 2kHz and 11kHz (Napoletano 2004; Qi et al. 2008; Joo et al. 2011; Kasten et al. 2012; Gage & Axel 2014). Mullet et al. (2016) clarify that the high-frequency vocalizing passerines can be effectively distinguished from low-frequency producers through a spectrogram analysis. To avoid the biological or non-biological sound frequency overlap, birds utilize different acoustic niches to broadcast the information (Krause 1987; Qi et al. 2008; Luther 2009).

This acoustic diversity study assessed the ornithophony distribution across day hours. Anaikatty soundscape has 86.60% of biophony. Gage & Axel's (2014) soundscape power analysis study of Cheboygan County soundscape showed that the biological sounds attributed to 80% of total eco-acoustics. The frequency-dependent acoustic analysis corroborates that ornithophony occupies the 2–8 kHz of spectral bandwidth (Napoletano 2004; Qi et al. 2008; Gage & Axel 2014). Thus, acoustic diversity study across the day hours will assess the ornithophony distribution and assess the soundscape framework of a habitat.

Bird vocalizations across diurnal hours

More number of species showed acoustic activity in dawn and dusk hours; however, the vocal units were not significantly different across 13 hours. The soundscape of the study area had higher bird vocalizations in the early three hours (0600–09.00 h). The temperature, wind, humidity is more advantageous with least atmospheric turbulence and less background noise during dawn, thus enhancing the signal transmission (Morton 1975; Kroodsma 1977; Krebs & Davies 1981; Slagsvold 1996; Hutchinson 2002; Luther 2009; Hart et al. 2015). Early hour bird vocalizations were observed in Arizona and in Kutai Nature Reserve, Borneo (Henwood & Fabrick 1979), deciduous forest in Denmark (Dabelsteen & Mathevon 2002), open grassland and closed forest habitat in Ontario (Brown & Handford 2003), and upland pasture at New York (Brenowitz 1982). Moreover, the dawn (and dusk) chorus gives the advantage to use the energy reserve unused since the previous night (McNamara et al. 1987; Hutchinson 2002). Dawn

Table 3. List of non-passerine species of Anaikatty Hills recorded during the study. Birds with harmonics are marked with an asterisk (*). The sample size for low and frequencies of the species are ten, except ^ - sample size is 8.

	Bird species /Family	Scientific name	Low-frequency values (in Hz) (Mean ± S.D.)	High-frequency values (in Hz) (Mean ± S.D.)
	Phasianidae			
1	Indian Peafowl*	*Pavo cristatus*	551.36 ± 84.9	10284.2 ± 891.5
2	Grey Francolin*	*Francolinus pondicerianus*	1908.2 ± 106.1	6700.1 ± 1873.2
3	Grey Junglefowl*	*Gallus sonneratii*	763.5 ± 647.6	8009.7 ± 4212.4
	Columbidae			
4	Spotted Dove	*Streptopelia chinensis*	569.0 ± 44.2	837.9 ± 39.6
5	Laughing Dove	*Streptopelia senegalensis*	640.8 ± 26.4	886.1 ± 22.9
	Caprimulgidae			
6	Jerdon's Nightjar	*Caprimulgus atripennis*	574.9 ± 41.2	1476.0 ± 30.8
	Cuculidae			
7	Greater Coucal	*Centropus sinensis*	398.0 ± 102.5	870.5 ± 233.4
8	Asian Koel*	*Eudynamys scolopaceus*	982.3 ± 75.49	10473.3 ± 4694.39
9	Common Hawk Cuckoo	*Hierococcyx varius*	1510.81 ± 357.50	2225.95 ± 280.65
	Charadriidae			
10	Red-wattled Lapwing*	*Vanellus indicus*	1490.9 ± 431.3	8282.1 ± 4678.9
	Accipitridae			
11	Crested Serpent Eagle*	*Spilornis cheela*	1806.7 ± 91.9	6317.6 + 1242.54
12	Shikra*	*Accipiter badius*	1472.9 ± 453.0	13709.4 ± 1980.1
	Upupidae			
13	Common Hoopoe	*Upupa epops*	795.0 ± 410.2	1621.1 ± 1052.1
	Megalaimidae			
14	White-cheeked Barbet	*Psilopogon viridis*	940.8 ± 61.7	1307.6 ± 40.2
15	Coppersmith Barbet	*Psilopogon haemacephalus*	633.8 ± 25.1	898.1 ± 25.4
	Meropidae			
16	Blue-bearded Bee-eater	*Nyctyornis athertoni*	586.17 ± 80.15	3740.23 ± 695.06
17	Green Bee-eater	*Merops orientalis*	2781.7 ± 219.5	4373.6 ± 241.5
18	Chestnut-headed Bee-eater	*Merops leschenaulti*	2538.88 ± 113.84	3590.01 ± 215.33
	Alcedinidae			
19	White-throated Kingfisher*	*Halcyon smyrnensis*	2436.2 ± 105.3	7272.7 ± 2739.7
	Psittaculidae			
20	Plum-headed Parakeet*^	*Psittacula cyanocephala*	1828.0 ± 468.1	6735.8 ± 1347.2
21	Malabar Parakeet*	*Psittacula columboides*	2571.6 ± 165.1	4199.9 ± 277.9
22	Rose-ringed Parakeet*	*Psittacula krameri*	2047.4 ± 798.9	8566.3 ± 1257.9
23	Vernal Hanging Parrot*	*Loriculus vernalis*	6261.7 ± 571.0	7948.1 ± 179.5

chorus also has reproductive benefits such as attracting a mate and deter other potent males to get access to the partner (Slagsvold 1996; Catchpole & Slater 2008), to defend territory and nest site from conspecific males (Slagsvold 1996).

Low frequency and/or harmonic producing birds' vocalizations dominated the dusk hour (18.00–19.00 h; Tables 2,3). Low frequency vocalizations of birds and amphibians dominated during the night at Cheboygan County, Michigan (Gage & Axel 2014). Harmonics increases the difficulty in locating the calling bird (Blindfolded birdwatching 2010), thus avoiding predatory attacks. As the visual cues are undependable during the sunset hour (Kacelnik 1979), low frequency gives an advantage for long-distance signal propagation (Aylor 1971; Morton 1975; Marten & Marler 1977;

Table 4. Descriptive statistics of the eight most vocalizing passerines of the study area.

Bird sp.	Mean	Std. Dev.	Co-efficient of Variation (CV)	Min	Max	No. of presence among 78 recordings	No. of vocal units
Common Tailorbird	20.76	15.43	74.32	1.00	61.00	74	1619
Red-vented Bulbul	10.73	10.36	96.53	1.00	45.00	69	837
Common Iora	10.42	16.47	158.06	1.00	63.00	52	813
Yellow-billed Babbler	7.13	10.47	146.83	1.00	58.00	54	556
Purple-rumped Sunbird	7.09	11.61	163.72	1.00	68.00	52	553
Indian Robin	5.31	7.99	150.55	1.00	36.00	55	414
Grey-breasted Prinia	4.59	9.60	209.14	1.00	41.00	29	358
White-browed Bulbul	4.40	4.19	95.38	1.00	18.00	66	343

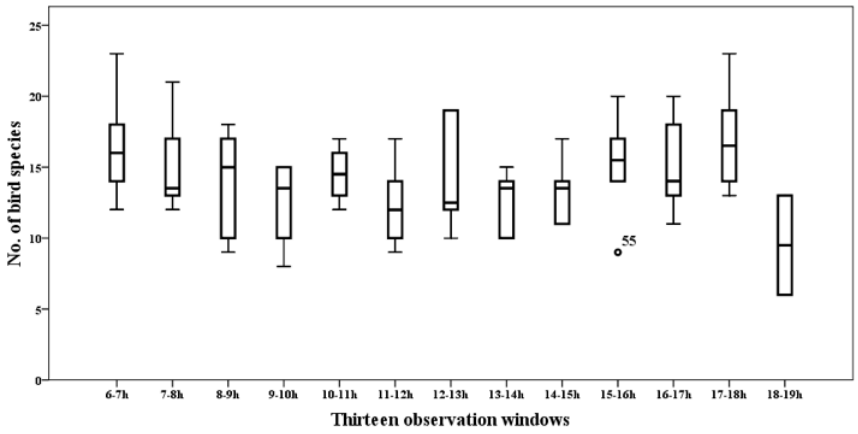

Figure 6. Vocalizing bird species per sampling unit of 13 observation windows.

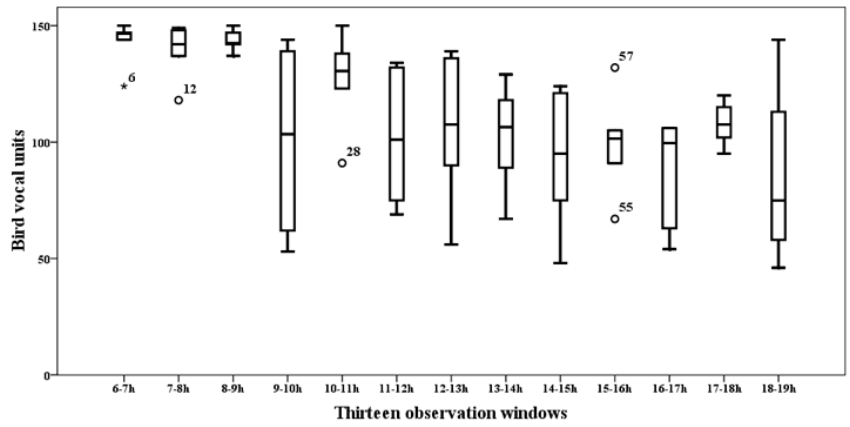

Figure 7. Bird vocal units per sampling units of 13 observation windows.

Martenet al. 1977; Wiley & Richards 1982; Wiley 1991). Song activity at dusk increases the pair-bonding behavior in American Robins (Slagsvold 1996), and in Blackbird (Cuthill & Macdonald 1990). A peak in dawn and dusk vocal activity suggest that these hours are important for a male to guard the mate and nest site (Sturkie 1976; Mace 1986, 1987; Cuthill & Macdonald 1990). Soundscape peaked at dawn chorus (06.00–07.00 h), then dropped shortly after sunrise, till evening and once again raised during dusk hours and reached second maxima at 20.00h in Cheboygan County, Michigan (Gage & Axel 2014).

Dominance in vocalization

The Common Tailorbird was the most dominant vocalizer of the landscape as their calls were louder and have a higher song rate, i.e., the number of call syllables produced in a minute. All the eight dominant species vocalize continuously. The passerines are louder and are continuous vocalizers (Garamszegi & Møller 2004; Catchpole & Slater 2008; Cardoso 2010). Seven of the dominant species are forage generalists and were vocally active all through the day yielding a higher vocal unit. The early hours had uniform vocal units' contribution per observation window. Increased variability of vocal units during 09.00–10.00 h, 12.00–13.00 h, 14.00–15.00 h, and 18.00–19.00 h could be attributed to relatively variable number of vocalizers (Fig. 7). This might also show the need of more sampling efforts.

The 16.00–17.00 h observation window had more non-passerines (11 species) yielding fewer vocal units, whereas, passerines were predominant in the study area with more vocal units. More vocal units and complexity exhibits the versatility of passerine birds (Garamszegi & Møller 2004; Boncaraglio & Saino 2007; Catchpole & Slater 2008; Cardoso 2010), as they are louder (Calder 1990; Cardoso & Mota 2009; Cardoso 2010) and are continuous vocalizers (Hartley & Suthers 1989; Irwin 1990; Podos 1997; Forstmeier et al. 2002). This makes passerines to occupy a larger portion of the soundscape of Anaikatty Hills in general.

Song rate analysis is beyond the scope of this present study, however, any trained ears could relatively understand the song rate of bird calls. The study which aimed at understanding the vocal activity pattern of diurnal birds illustrates that the soundscape of Anaikatty is largely occupied by birds in those hours.

CONCLUSIONS

Birds occupy 73.75% of acoustic space in the soundscape of Anaikatty Hills and the remaining 26.25% includes the vocal activity of insects, other indistinct sounds or complete silence. Thirty-nine passerine species (62.90%) and 23 non-passerine species (37.09%) vocalized in the sampled soundscape of the study area. The eight dominant species constitutes 63.65% of ornithophony of the study area. Out of the total sampled ornithophony, passerines occupied 84.35% and non-passerines 14.74% of the vocal units. Birds vocalized in all 13 daylight hours, with a peak in the first three hours of the day (06.00–09.00 h). Passerines dominated the soundscape in all hours except the dusk 18.00–19.00 h.

Limitation of the study

The sampling effort was done to answer the preliminary account of ornithophony of the soundscape of the region. Though the researcher intentionally did not direct the microphone towards the vocalizing bird, the usage of shotgun microphone might have had an effect on the calling bird. Though the researcher had sampled the 5-min by directing the microphone in all directions, the shotgun microphone was a limitation for the soundscape study compared to the omnidirectional microphone.

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