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Frequency Distribution study of Sound: Special Reference to bird calls.

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ABSTRACT

There has been interest in identification and characterization of bird calls from different point of views including breading of birds. We studied sound produced by different birds like small green barbet, Jordon's chloropsis, necklaces laughing thrush etc. to characterize the bird calls using the prominent frequencies that are produced. The bird calls are qualitatively different for different birds and can clearly be identified in most of the cases. Comparison of sound produced by selected birds is implemented using the frequency distribution of sound. The frequency spectrum of sound is obtained using Fourier Transform technique implementing Fast Fourier Transform (FFT) employing standard mathematical software Mathcad. Findings and details are presented, the noise power levels are also presented for a typical case.

Keywords: Bird Call, Fast Fourier Transform, Amplitude frequency spectrum

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INTRODUCTION

Most of the birds species are social they live together and help one another. Doing things together requires language. Language is a means of communication [1]. Birds use a variety of sounds to communicate. Calls are used for interacting with family members, alerting one another to presence of predators, keeping in touch while flying or sharing information about foods. Many birds use contact calls to keep in touch while migrating, for example, gees use contact calls when they fly. Many birds use alarm calls in response to nearby predator when they see predator they utter alarm calls to alert other members of the species for example, Florida scrub jay use a thin high pitched call when they see hawk or falcon for alerting nearby jay to dive for cover. There is one more advantage of alarm calls, birds let the predator know that he has been sighted and the predator has lost the advantage of surprise. The predator may decide to give up the attack.

Some birds use calls to inform other birds of the same species when they have found food. For example cliff swallows forage for aerial insects in groups of 2 to more than 1000 birds. In bad weather, it is difficult for swallows to find food alone that is why they find food in group and use food alarming call. Chicks of the birds also produce sound/calls to let their parent know they are hungry. The calls produced by chicks for food are called begging calls for example in common Indian sparrow chicks produce begging calls when their parents come into the nest. In large bird colonies it is difficult for parent birds to recognize their own chicks, begging calls from their own chicks help them recognize. Bird calls are very interesting and important aspects of bird’s biology many scientists are using birds calls as a mode to understand various aspects of sexual selection and behavioral ecology of birds. Detailed study of bird calls will help to understand bird behavior and ecology. There is difference between calls and songs. In birds, songs are generally produced by males but calls are produced by both sexes. Calls are shorter and simpler than songs [2].

In birds, calls are mainly produce by syrinx, which is an organ unique to birds [3]. Syrinx is the sound producing organ of birds; situated at lower end of trachea where it splits into bronchi it has a complex structure with number of vibrating membranes [4]. Function of syrinx is quite similar to that of human vocal cords in many ways. But the structure of syrinx is much more complex. By using syrinx a bird can produce a large variety of different sounds. In human sounds are mainly produced by muscular control of vocal track mouth, lips, tongue and teeth but in birds, syrinx is the main organ to produce different sounds. Only few bird species like myna, parrots can use their tongue to produce different sound [5]. Several techniques have been recommended to categorize segments of bird call by species. These techniques work fine when input audio is made up of sequential single-species calls with minimal noise [6 - 10]. In previous study we found that different birds produce sounds at different frequencies. Some birds produce sound only at lower frequencies, some birds produce sounds at higher frequencies and some birds produce sound over a broad range of frequencies like parrot [11, 12].

METHODOLOGY

Data sample

Bombay Natural History Society (BNHS) [13] from Mumbai has released a comprehensive collection of bird calls collected from different part of India in the form of a set of two audio cassettes. Most of the samples of calls studied are taken from this standard collection; few samples are recorded from actual bird breeder sites. For the purpose these samples are converted to computer wave format at a sampling rate of 44.1 KHz using reliable sound system and related software. Prominent components of sound from calls were selected and saved for further analysis after suitably labeling.

Noise reduction

As most of the cases bird calls had been recorded in deciduous forest, rain forest, evergreen forest, around lakes, rivers, etc. unwanted sound such as wind noise, other bird calls noise etc. were also present in the recorded samples. All unwanted sounds limit the quality of recorded samples and it is also difficult to analyze these samples for useful information. In order to remove all unwanted and background sounds, sound processing software was used for noise reduction purpose.

Segmentation

After removing unwanted and background sounds, bird call samples were segmented into smaller pieces where each segments contains a single type call of the bird. Wave pad software was used for segmentation the segmentation was done by listening to filtered sample calls.

The frequency distribution of the call sound in these samples was obtained using Mathcad by implementing FFT. This technique is used for transformation of time domain data into frequency domain. The program developed in Mathcad reads in the call sound in wave format with '*.WAV*' file extension and performs FFT on the sound data to find sound amplitude at different frequencies. In frequency domain the results of FFT i.e. the amplitudes are complex quantities having both real and imaginary parts. The absolute value of this complex amplitude is used and the power can be estimated from this using its square. All the amplitudes discussed are in arbitrary units as the steps involved in the whole process do not allow for maintaining identical condition, however this does not come in the way of present study.

Wave formats contain information about the sampling frequency and other related technical details in addition to all recorded available (audio) data. In most of the cases wave files are recorded at sampling frequency of 44.1 kHz with single channel and 16 bit resolution 16 bit data allows for a resolution. 16 bit data allows for a resolution of 1 part in 65536, a reasonably high resolution for 8 bit data this resolution is 1 part in 256. For 8 bit data at each sampling point therefore requires one byte (8 bits of data) this result in a data rate of 88.2k bytes per second which is doubled for 16 bit or two byte data.

After reading the audio file in wave format the length of the audio file is determined, the time for each sample is estimated from the sampling rate and an array corresponding to the data points is generated and populated for further use.

Fourier transform requires that the number of data points used comply with Nyquist criterion, thus from the data read, a suitable interval is chosen. For FFT the number of data points should be equal to 2^N where N is an integer. In most of the studies we used 8192 data points which correspond to N=13 and the sample studied has duration of little less than 0.2 second of recorded sound. On implementation of the FFT this gives power spectrum in terms of audio power in terms of amplitude at different frequencies. The number of frequencies at which the power spectrum available is half of the number of data points used i.e. 8192/2=4096, thus FFT extracts power at 4096 frequencies. The resulting power in the power spectrum is a complex quantity due to reasons presented earlier. The magnitude of power can be estimated using the modulus of this complex amplitude from FFT.

Small Green Barbet Bird

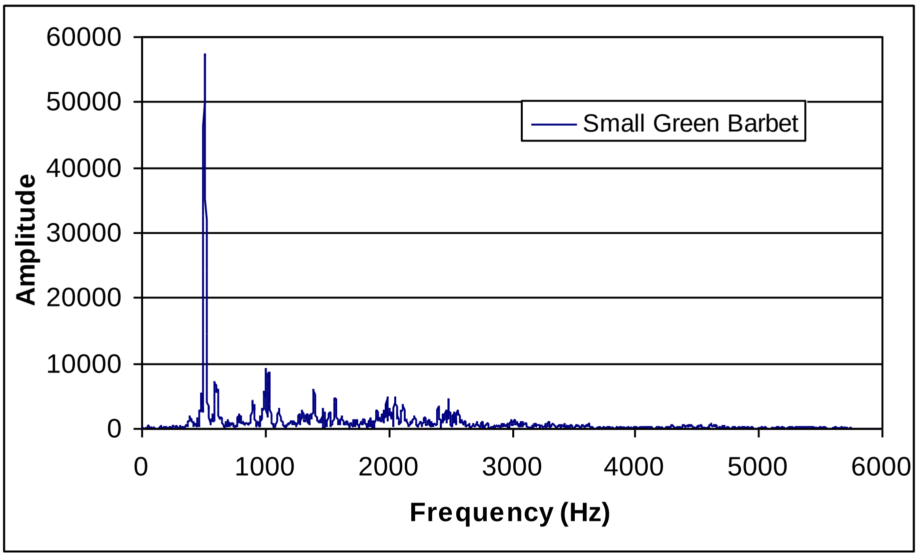

Figure 1: Sound amplitude from call of Small Green Barbet as a function of frequency

This bird is found in Western Ghats, Madhya Pradesh and south peninsular India and the call sound has a distinct note and the frequency spectrum i.e. the amplitude versus frequency plot for the call studied is presented in Fig. 1. The frequency distribution shows a distinct and very sharp peak at a frequency of 510 Hz and the full width at half maximum (FWHM) is about 10Hz. It is clearly seen from the frequency distribution plot that almost entire sound from the call is at this frequency alone and at the rest of the frequencies the levels are marginal.

Jordon's Chloropsis

This bird 'Jordon's chloropsis' is found in light forest scrub and groves, peninsular India. Frequency spectrum of the a typical call is shown in Fig. 2. This reveals that highest sound amplitude is at a frequency of 3962 Hz and the spectrum is like a broad peak with several humps, the FWHM around 1000 Hz. The peak is spread in the range of about 2800 to 4300 Hz with a slow rising part followed by few humps and spikes and the falling part is sharp with a faster decline.

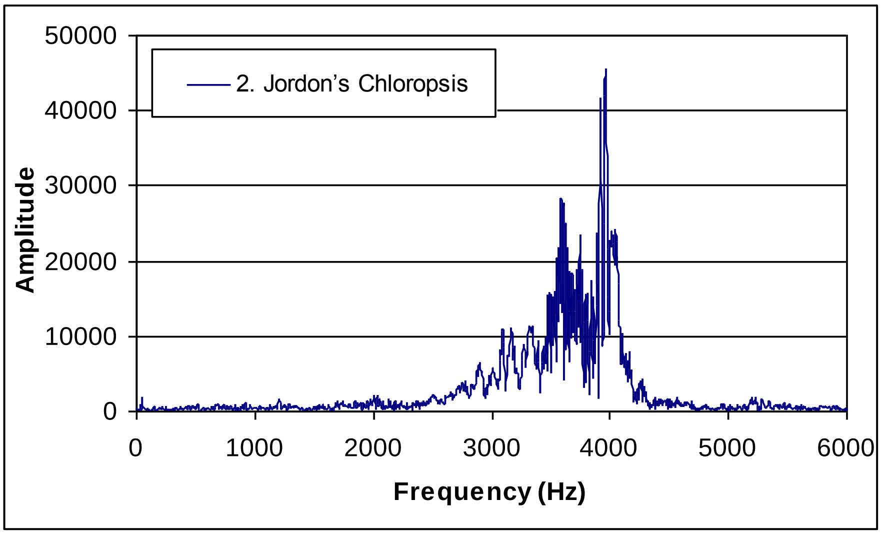

Figure 2: Sound amplitude from call of Jordon's chloropsis as a function of frequency showing broad peak in the range of 2800 to 4300 Hz with slow rise and sharp fall.

Necklaced Laughing thrush

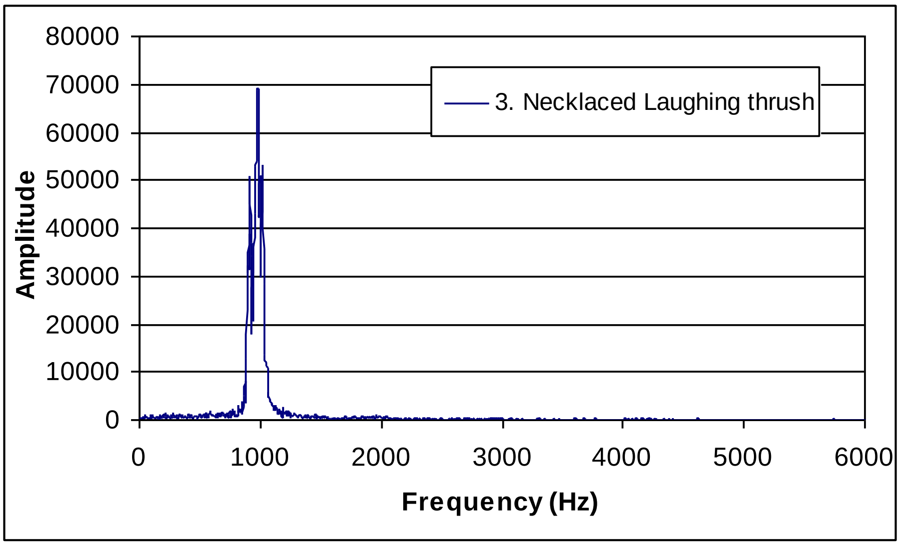

Figure 3: Amplitude versus frequency plot for call of Necklaced Laughing thrush showing narrow peak at 974 Hz, its characteristic frequency.

The bird Necklaced laughing thrush is found in thick evergreen moist, Deciduous and secondary forest Himalayas and produces sound of a unique Frequency and the amplitude of sound at other frequencies is almost negligible. The plot of amplitude versus frequency is shown in Fig. 3 which reveals the characteristic frequency of the call of 974 Hz (1 KHz approx) and peak is narrow with FWHM about 150 Hz.

Small Niltava

The bird small Niltava is found in bushes near streams and along roads in forests, Himalayas and north east. The amplitude versus frequency plot for this bird is different from the earlier plots, it has a broad peak of shape resembling that in Fig. 2. The prominent peak occurs around 1900 Hz with FWHM about 2.3k Hz and there is no appreciable sound at higher frequencies beyond 4KHz.

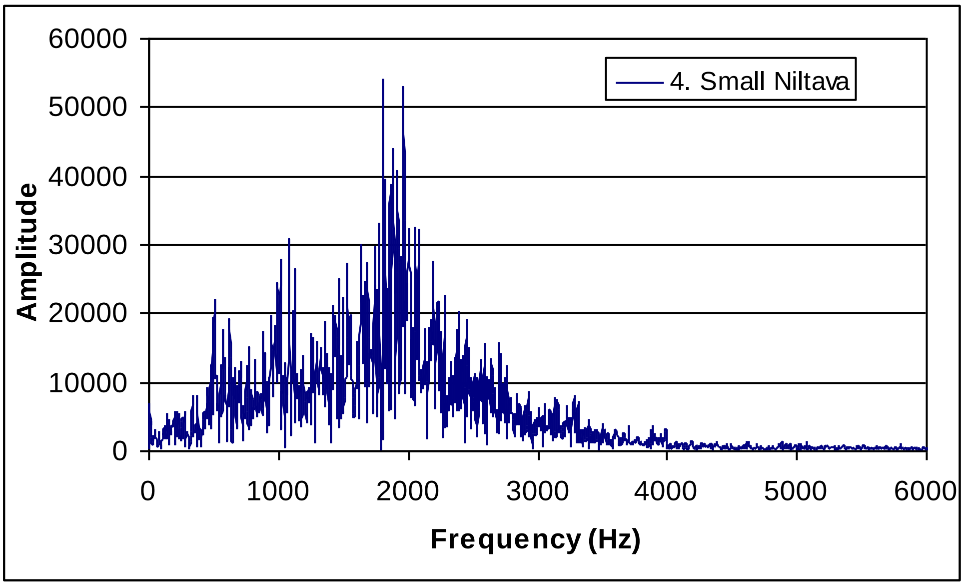

Figure 4: Amplitude versus frequency plot for call of Niltava showing a broad peak at 900 Hz, with FWHM of about 2.3 KHz

Blue Throated Flycatcher

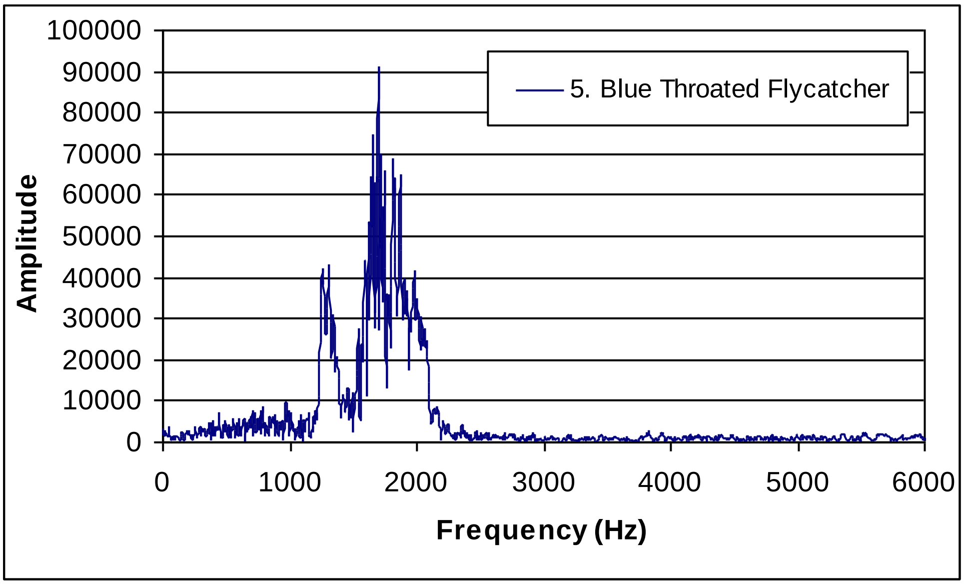

Figure 5: Amplitude versus frequency plot for call of Blue Throated Flycatcher a narrow peak followed by a broad peak at frequencies 1300 and 1700Hz.

The bird Blue throated flycatcher is found is gardens and secondary forest from Kashmir to northeast the frequency spectrum of its call is shown in fig 5, it shows two peaks. The first relatively narrow peak is found at 1300Hz followed by a prominent peak at 1700 Hz with FWHM of nearly 800 Hz and there is no appreciable sound beyond 2.2 KHz.

Stone Chat

The bird Stone Chat is found in grassy hillside in India, the frequency spectrum of the call is shown in Fig. 6. This shows that the sound begins well at lower frequencies and continues up to about 1200 Hz, thereafter there is a broad peak at 1720 Hz with FWHM of 345 Hz with several sharp spikes and there is no appreciable sound beyond 2.5 KHz.

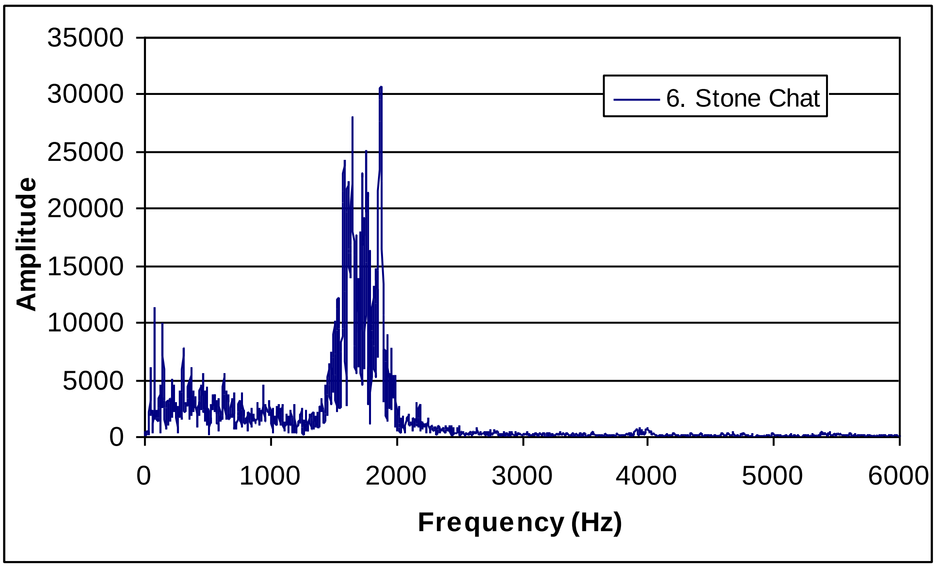

Figure 6: Amplitude versus frequency plot for call of Stone Chat a broad peak is present at frequency of d 1720 Hz.

Dark Grey Bush Chat

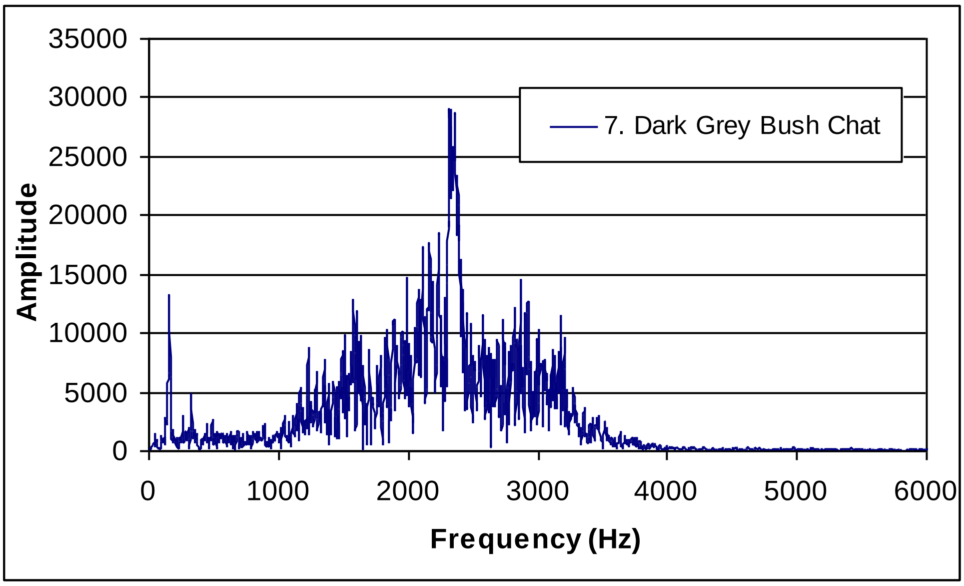

Figure 7: Amplitude versus frequency plot for call of Dark Grey Bush Chat a broad peak is present at frequency of 2350 Hz.

The bird Dark Grey Bush Chat is found in hillside forest glades, central Nepal, gangetic plains. The frequency spectrum for the call is shown in fig 7. It is seen that the sound is present over wide range of frequencies including relatively higher frequencies. The mean frequency of the call is 2350 Hz. The broad peak starts at around 1000 Hz and continues up to 3500 Hz. FWHM is about 1300 Hz.

Sultan Tit

The bird Sultan Tit is found in deciduous forest, evergreen forest, and large trees near cultivation in Northeast India. The frequency spectrum shown in Fig. 8 This shows that the sound is present over a wide range of frequencies right from the beginning and extends up to 6 KHz which is different from rest of the call samples presented above. This shows a fast rising broad peak at a frequency of 1600 Hz. Appreciable amplitude is present beyond 3 KHz up to 6 KHz.

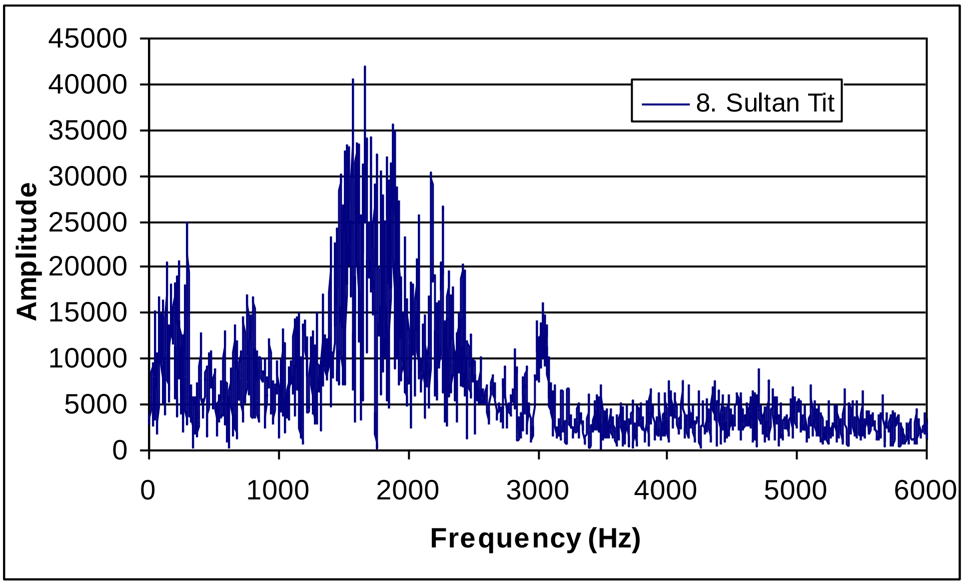

Figure 8: Amplitude versus frequency plot for call of Sultan Tit, a broad peak is present at frequency of 1600 Hz and appreciable sound is present over all frequencies up to 6 KHz.

Grey Tit

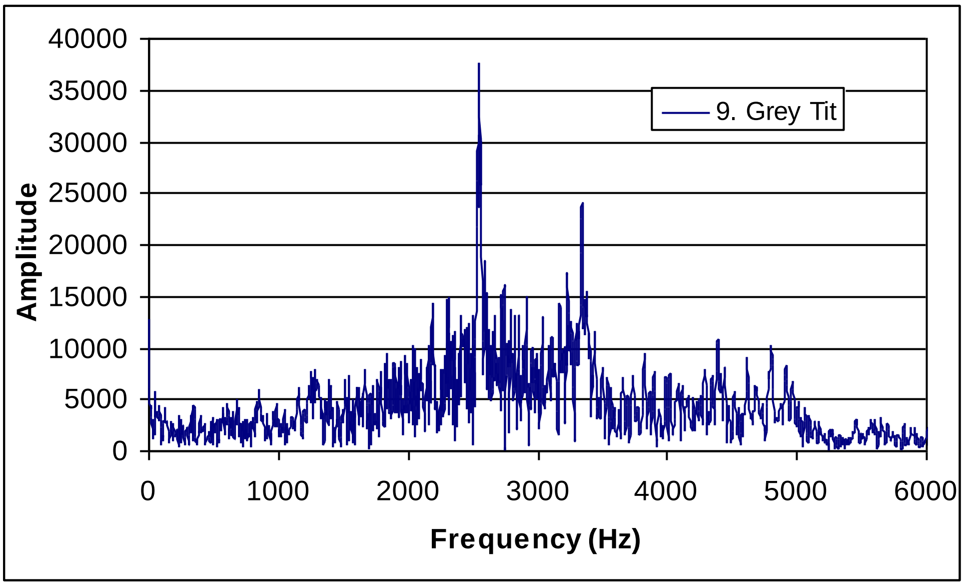

Figure 9: Amplitude versus frequency plot for call of Grey Tit, two mild peaks are seen in the range 2 - 4 KHz.

The bird Grey Tit is found in deciduous forest mixed plantation and orchards subcontinent. The frequency spectrum of its call is shown in Fig. 9 and 10. There is variation in characteristics of the call from sample to sample; two typical cases are presented in Fig. 9 and 10. The audio samples used for these two plots are also slightly different; amplitude frequency spectrum in Fig. 9 differs from that in Fig. 10 in that the two humps present in Fig. 9 are seen more distinctly in Fig. 10. The peak frequencies are also slightly shifted, in Fig. 10 the first peak is found at 2190 and the second one at 3700 Hz. The sound produced occupies wide range of frequencies extending up to 6 KHz.

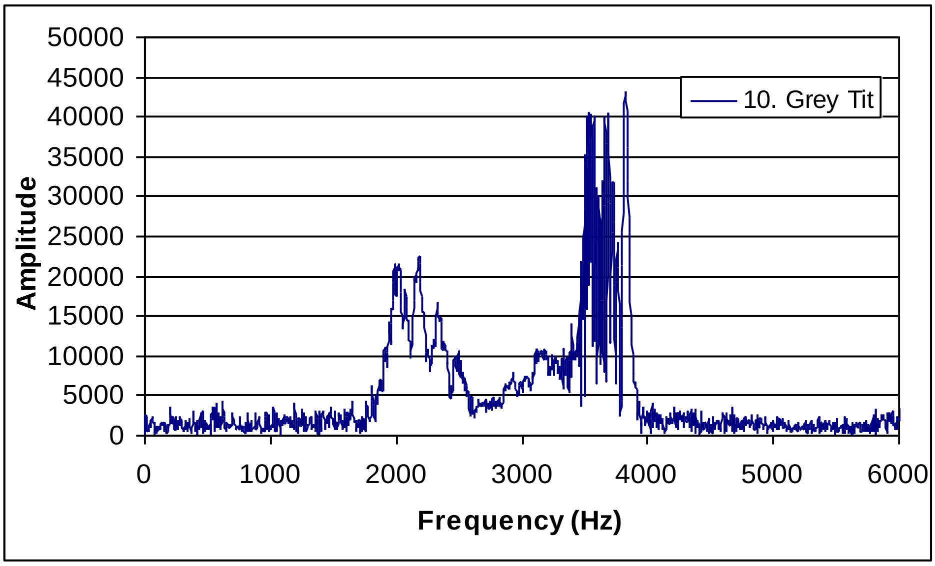

Figure 10: Amplitude versus frequency plot for call of Grey Tit, two prominent peaks are seen in the range 2- 4 KHz.

Chestnut Bellied Nuthatch

The bird Chestnut bellied nuthatch is found in light forest, mixed plantation and groves all over India except north. The frequency spectrum of call is shown in the Fig. 11, this shows a broad peak at frequency of 2700 it consists of many sharp spikes. The FWHM of the broad peak is about 840 Hz and no appreciable sound is present at higher frequencies beyond 4 KHz.

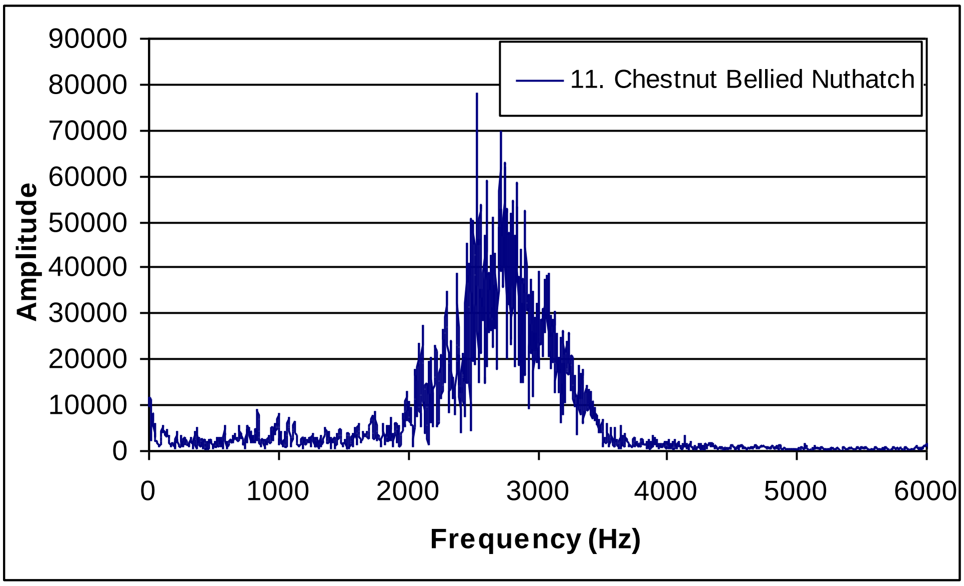

Figure 11: Amplitude versus frequency plot for call of Chestnut Bellied Nuthatch, broad peak has a frequency of 2700 Hz with FWHM of 800 Hz.

Peach Faced

The bird Peach Faced is found in different parts of southwestern Africa. Amplitude power spectrum of the call is shown in Fig. 12. The plot is interesting in the sense that it has two prominent peaks at two distinct frequencies i.e. 1640 Hz and 3300 Hz. The FWHM of the two peaks is 100 Hz and 200 Hz and the peaks occupy a narrow range of frequencies. The first peak is weaker as compare to the second one and almost all the sound is contributed by these two peaks and at frequencies other than those of these two peaks the sound amplitude is marginal.

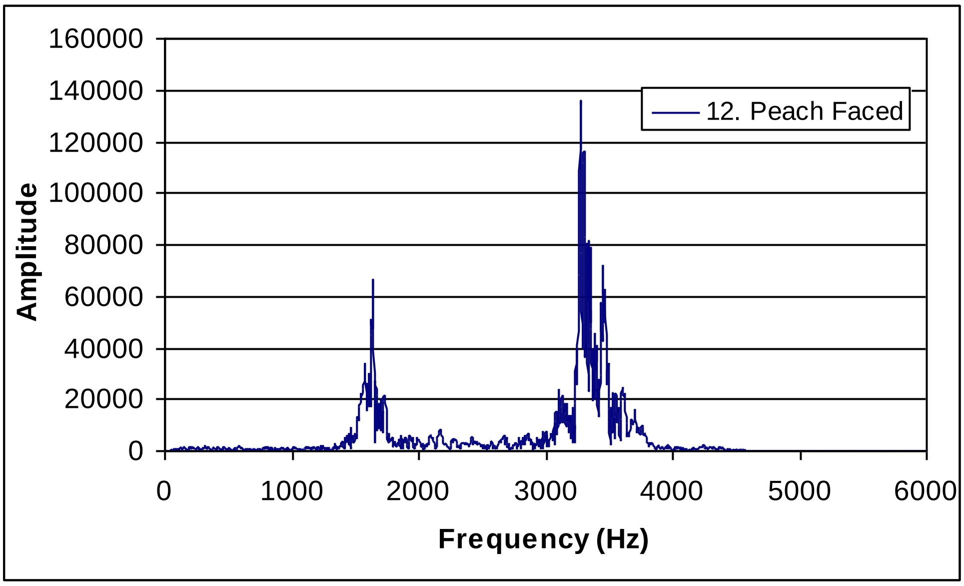

Figure 12: Amplitude versus frequency plot for call of Peach Faced Bird, frequencies of the two sharp peaks are 1640 Hz and 3300 Hz and the corresponding FWHM are 100 Hz and 200 Hz.

These birds produce sizable noise and contribute to ambient noise, se studied the noise produced by these birds quantitatively and present the details. The noise levels were measured using a standard calibrated sound level meter CENTER make, model 223. The noise produced by a single bird was recorded and it was found that the noise levels were varying in the range of 70 dB to 99 dB with an average of 85 dB. It is clearly seen that the noise levels produced by a single bird are high enough and exceed permissible limits [14].

Table 1: Bird call frequencies

S.No.	BIRD NAME	FREQUENCY (Peak) in Hz	FWHM of Peak in Hz
1	Small green barbet	506	10
2	Jordon's chloropsis	3962	1000
3	Necklaced laughing thrush	974	150
4	Small niltava	1900	2300
5	Blue throated flycatcher	1300, 1700	145, 452
6	Stone chat	1720	345
7	Dark grey bush chat	2350	1300
8	Sultan tit bird	1660	960
9	Grey tit	2550,3340 2190, 3700	517, 280 581, 398
10	Chestnut bellied nuthatch	2700	840
11	Peach Faced	1640, 3300	100, 200

RESULT AND DISCUSSION

Study of frequency distribution of calls produced by birds yielded interesting results, some of the birds produce sound of their own characteristic frequency that can easily be distinguished. The range of frequencies covered by different birds is different some of the calls are having sounds of a narrow frequency range such as Fig. 1, where more or less whole sound is produced at a frequency of 510Hz. Fig. 3, where the peaks cover a narrow range of frequencies and Fig. 12 shows two peaks but both peaks cover a narrow range of frequencies where as others produce sounds over a broader range like Fig. 2, where peaks occupy relatively broad range of frequencies, The cluster of peaks is spread in the range of about 2800 to 4300 Hz. Fig 4 shows a broad cluster of peaks and these peaks are present over a broad range of frequencies. Fig. 5 shows a broad cluster of peaks which is made up of two clusters of peaks, appreciable sound begins at around 1227 Hz and lasts up to about 2100 Hz covering a range of 870 Hz. Fig. 7 shows a broad cluster of peaks which starts at around 1000 Hz and continues up to 3500 Hz covering a range of 2500 Hz. Fig. 8 shows that the sound is present over a broad range of frequencies and appreciable sound is present up to 6 KHz. Fig 11 shows a broad bunch of peaks which is covering a range of 1500 Hz. It is interesting to note that in some cases the call is restricted to certain small range of frequencies and there is no sound at other frequencies as is seen in Fig. 1 there is no noticeable sound below 400 Hz and above 2600 Hz. In Fig. 3 appreciable sound is present between 800 Hz to 1200 Hz and there is no noticeable sound below 800 Hz and above 1200 Hz. In Fig. 5 there is no noticeable sound above 2200 Hz. In Fig.11appreciable sound is present up to 3800 Hz. In Fig.12 appreciable sound is present between 1500 Hz to 1800 and 3000 Hz to 3800 Hz, there is no noticeable sound at other frequencies which is different from other calls where sound persists at other frequencies than that of the main peak as is seen in Fig. 6, 8 and 9.

From Table-1 it is seen that each bird produce unique call having characteristic frequency and the frequency of different calls is different even one bird can produce more than one type of call and the frequencies of these calls will be different. In present study we analyzed 11 call samples from selected birds. Frequency of the peak of call produced by small green barbet is lowest which is 506 Hz and frequency of the peak of call produced by grey tit highest which is 3700Hz.

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