# Sonic signatures of different orders of birds: A comparative analysis

A Dissertation Report for

Credits: 08

Submitted in partial fulfilment of M.Sc. Zoology

by

POOJA CHANDRAKANT GAUDE

21P044012

Under the Guidance Of

**DR. MINAL DESAI SHIRODKAR**

School of Biological Science and Biotechnology
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## DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Sonic signatures of different orders of birds: A comparative analysis" is based on the results of investigations carried out by me in Zoology at the School of Biological Sciences and Biotechnology, Goa University under the Supervision Dr. Minal Desai Shirodkar and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given in the dissertation. I hereby authorize the University authorities to upload this dissertation on the dissertation repository or anywhere else as the UGC regulations demand and make it available to any one as needed.

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## COMPLETION CERTIFICATE

This is to certify that the dissertation report "Sonic signatures of different orders of birds: A comparative analysis" is a bonafide work carried out by **Ms. Pooja Chandrakant Gaude** under my supervision in partial fulfilment of the requirements for the award of the degree of M.Sc. in the Discipline Zoology at the School of Biological Sciences and Biotechnology, Goa University.

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# INTRODUCTION

Birds are the most beautiful creatures on the planet, enticing everyone with their vibrant colours. Their ability to fly distinguishes them and makes them fascinating to observe in nature. Their voice creates beautiful melodies and soothing music that works in harmony with nature and brings peace. They were the inspiration for some of our greatest poets and composers. (C. K. Catchpole and P. J. B. Slater, 1995)

Communication is a fundamental aspect of animal behaviour, essential for survival and reproduction. Birds' vocalizations play a crucial role in their communication, allowing them to convey information about mating, territorial boundaries, and alarm signals to other birds in their species (Searcy & Nowicki, 2005). Sound is the primary mode of long-distance communication, allowing birds to transmit large amounts of information efficiently. Vocal signals are critical for pair maintenance, parent-offspring interactions, flock or family member cohesiveness, and response to threats. Birds produce sounds using a specialized structure called the syrinx, which is located at the base of their trachea (windpipe). Syrinx's has a bipartite nature, the bird can simultaneously produce two notes (S. A. Zollinger et al. 2003).The vocal tracts of different avian families differ. The opening of the beak (gape) can change the pitch by shortening the vocal tract as the oral cavity flares. It may also change the impedance of the vocal tract by closing the tube as the beak closes. (Kahrs Mark,2001). Birds are classified into songbirds and non-songbirds based on the structure of their syrinx, which is responsible for phonation. Songbirds have a specific pathway in their brain that plays a vital role in song production, whereas non-songbirds produce simple and repetitive vocalizations. Non-songbird vocalizations are frequently referred to as songs, such as the songs of doves, barbets, nightjars, and cuckoos. (Kumar A. 2003)

One well-established method for analysing and characterizing these vocal signals is the sound spectrogram, which captures the frequency, duration, and amplitude of a sound. In a sound waveform, frequency indicates pitch and amplitude indicates loudness. Spectrograms and oscillograms are commonly used graphical representations of sound in bird vocalization analysis. Biologists use a variety of techniques to study bird vocalisations, including field observations, acoustic analysis, and experiments involving the playback of recorded sounds, which provide detailed quantitative measurements for analysis. High-quality playbacks can be used to lure conspecifics and study their response. (Sylvia L. Halkin). In the case of birds, the features of their acoustic signals have been used to infer evolutionary relationships and estimate population sizes. This approach has shown that closely related bird species tend to have similar vocalization patterns, while distantly related species show greater variation. The study of songs and calls adds to our understanding of the communication value of these signals in birds, putting this research at the crossroads of neurobiology (James S. McCasland 1987), animal behaviour, and ecology. Vocalizations are also useful in classification, such as naming new species, determining taxonomic rank, and performing phylogenetic analyses. (Anil Kumar, 2003; Donald E. et.al, *1991*). There are methods for recording the discharge of neurons in singing birds that were developed in order to investigate the functions of nuclei in the previously implicated anatomical song control pathway. (James S. *et al.*, 1987). Bird songs and calls were also discovered to be the most commonly associated natural sound with perceived stress recovery and attention restoration, but not all bird thought to be beneficial for such processes. (Ratcliffe *et.al* 2013)

All sounds have some sort of meaning because they are only made when necessary (C. K. Catchpole 2006; Selin A. *et al*. 2006). Both songs and calls can be found in bird vocalisation. Songs are longer and more complex than calls, which are produced year-round by both sexes. The majority of birds appear to have between 5 and 15 different calls. Anil Kumar has found six different types of calls in *Copsychus saularis*. (Anil Kumar, *et.al*. 2000). Some birds have multiple calls for the same function, whereas others use very similar calls in different situations to mean different things. Furthermore, many species have a high level of individual and regional variability in their phrase and song patterns. As a result, two types of bird sound variability must be considered in the classification i.e. variation among different sound types and variation across geographic regions and among individuals. The traditional methods of classification in bird sound research have been listening and visual evaluation of spectrograms. Automating this classification process would be a significant new tool for bioacoustics research. Automatic classification opens up new avenues for identifying vocal groups in birds, and it may also provide new tools for categorizing the sounds of other animals. (Selin A. *et.al.* 2006).

Bird vocalizations vary greatly in form and function across different bird orders and species. Non-passerine birds such as waterbirds, raptors, and owls exhibit similar levels of variation in their calls. The review by Catchpole and Slater (2008) emphasizes the complexity of song structures in passerine birds, with variation seen within and between individuals and populations. The authors point out that each bird species' calls and songs are distinct and reflect the selective pressures and social contexts that have influenced their evolution. This variation in bird vocalisations reveals information about various aspects of avian behaviour and communication, such as sexual selection, territorial behaviour, and sound cognitive processing.

The present study aims to investigate the variation in vocalizations of five different orders of birds, namely Bucerotiformes, Charadriiformes, Columbiformes, Passeriformes and Piciformes. In particular, the study will focus on the comparison of the frequency, pitch, and amplitude of bird vocalizations across different orders.

This study will contribute to a better understanding of the vocal communication system of birds and how it relates to their behaviour and ecology, in particular; and animal communication in general. The findings from this study will indirectly have implications for the conservation and management of bird populations.

# LITERATURE REVIEW

Bird Songs and calls are diverse and complex vocalization that vary widely across species, individuals, and populations. Understanding the patterns and mechanisms underlying this variation is a major goal of animal communication research. In this literature review the current state of knowledge on the variation in bird song and calls including ecological and evolutionary factors that shape this diversity.

Bird vocalizations have long been of interest to scientists studying animal behaviour, and recent studies have shed light on the remarkable complexity and diversity of these sounds. Naguib et al. (2001) investigated the tonal contact calls of Chiffchaffs, recording 26 individuals on two Canary Islands. The researchers employed multiparametric and discriminant function analyses to identify individual differences and site-specific variations in call structure. Their findings revealed that the calls contained clear individual signature cues, as well as micro-geographic variation, indicating that birds may use these calls to communicate with specific individuals in their vicinity.

In a similar study, Rajashekhar and Vijaykumar (2015) analysed the recordings of Indian Robins in the Kalaburagi district of Karnataka state, India. Through spectral analysis, the researchers identified three distinct types of sounds produced by the birds, each with significant variations in their structural hierarchy and high and low frequencies. This study highlighted the diversity of vocalizations even within a single species and emphasized the importance of studying individual variation in animal communication.

Scott F. Lovell (2004) investigated the ability of the Alder Flycatcher, *Empidonax alnorum*, to distinguish between the songs of neighbour's and strangers. The playback method was used to test the subjects' reactions to the songs performed by strangers and neighbours. The results showed that the birds reacted more aggressively to songs performed by strangers than to songs performed by neighbours, suggesting that birds may use songs to recognize and defend their territory from outsiders.

The Tawny Lark, an endemic bird species in central and western India, was the subject of a study by Taylor Crisologo et al. (2017), which used acoustic and peer-based analyses to explore the variety of mimetic sounds produced by the species. The researchers found that the Tawny Lark had a diverse range of vocal mimicry, and that their mimetic vocalizations corresponded to the biodiversity of their acoustic environment. This study highlighted the role of mimicry in bird communication and emphasized the importance of studying the relationship between vocalizations and the surrounding environment. Selin et al. (2006) suggested a brand-new technique for identifying erratic and passing bird sounds. The researchers used wavelet analysis, which can analyse signals with discontinuities and sharp spikes and preserves both frequency and temporal information. Two neural networks—the supervised multilayer perceptron (SMP) and the unsupervised self-organizing map (SOM)—were fed with the shift-invariant feature vectors derived from the wavelet coefficients (MLP). The SOM network correctly identified 78% of the test sounds, while the MLP network correctly identified 96%, according to the results. The ability of machine learning algorithms to analyse intricate bird vocalisations was demonstrated in this study.
Wood and Yezerinac (2005) focused on Song Sparrows in Portland, Oregon. They found that birds singing in noisier environments had modified their songs to have higher-frequency low notes and less energy in the low-frequency range, where most anthropogenic noise occurs. This suggests that birds have the ability to adjust their behaviour in response to their environment, but the mechanisms for this are still unclear. The authors discuss potential explanations for this pattern and suggest future research to test these ideas.

Hunter and Krebs (1979) compared the songs of great tits from different habitats and found that forest birds had lower maximum frequency, narrower frequency range, and fewer notes per phrase than woodland birds. The authors suggested that differences in acoustic attenuation and territory size may be related to these differences, but other factors such as climate, body size, and perch height were found to be unimportant. The reason why woodland birds use less well-designed songs is still unclear. Kumar (2011) described the physical characteristics and biological significance of Indian Robin songs. The songs are made up of strophes that range in frequency from 1.03 to 8.00 kHz and are used in both inter- and intra-sexual situations. Songs were divided into two categories based on their acoustic characteristics and production context. Male-male competition for territory and mates drives type-A songs, whereas type-B songs are rare, female-oriented, and more complex. Males adjust their song rate in the presence of females, indicating that it is an indicator of male quality.

In their 2015 study, Zollinger and Brumm examined the function of vocal amplitude in bird song. They discovered that vocal amplitude affects mate preference and territorial behaviour in birds, with low-amplitude songs typically used in aggressive interactions between males and high-amplitude songs possibly acting as an honest signal of a male's current condition that may be preferred by females. Loud singing was found to have negligibly low energy costs, but social aggression may be able to constrain the maximum amplitude of vocal signals. The authors make recommendations for additional lines of inquiry to further our knowledge of the part that amplitude plays in animal acoustic communication.

Scordato (2018) looked into the role that sexual selection plays in the greenish warbler ring species' song divergence. When females were fertile, males sang longer songs, and when a territory had been established, they sang shorter songs. Females preferred males with longer songs and larger repertoires, whereas males used short songs to defend their territory. Maximum song length is likely constrained by stronger male competition at higher population densities, whereas weaker male competition at lower densities allows females to express their preference for long songs. This study emphasises how important it is to consider how male competition and ecology interact when phenotypic divergence and speciation occur. Whereas Robin et al. (2017) studied two songbird lineages in the Western Ghats biodiversity hotspot in India. They found that these lineages have diversified into multiple distinct species and are highly divergent from the taxa they were previously classified in. The authors designated two new genera and revised six previously named taxa. They also found that these lineages split from their Himalayan relatives during the Miocene due to climatic changes. This study highlights the need for more research in the biogeography of the Asian tropics and conservation efforts. This study looks at the evolution of geographic patterns of song variation in a wild passerine population, specifically the New Zealand hihi.Males shared more song elements with their neighbours than with distant males or males from the same natal area, according to Louis Ranjard et al2017 .'s research, demonstrating that repertoire is acquired post-dispersal. According to the study, this species' post-dispersal vocal learning behaviour was driven by intense male competition. The removal of perceptual bias in song classification is facilitated by the use of machine learning methods for song analysis. (2017) Louis Ranjard et al. Gisela Kaplan (1999) investigates the differences between two Australian songbirds, the Lyrebird and the Magpie. The study found that magpies have developed the ability to mimic human language and other species in their own territory. The study also compares the use of mimicry in magpies and lyrebirds, arguing that the different functions and complexity of communication may be related to the niche each species occupies. The study highlights the need for more research to understand the conditions that promote the development of complex communication patterns in avian species.

The second study by Chentao Wei et al. (2014) examines the geographic variation in the calls of the Common Cuckoo, a widely distributed bird in Eurasia. The study found significant differences in the calls of different subspecies of the Common Cuckoo, and that these differences were correlated with geographic distance but not with environmental differences. The study suggests that the differences in the calls of different subspecies may be a hint of cryptic species, meaning that they may be genetically and morphologically distinct but appear the same to the naked eye. Overall, the study highlights the importance of understanding the relationship between environment, genetic differentiation, and vocal differentiation in bird species.

The third study by Erik Bitterbaum et al. (1979) examines the songs of male and female House Finches in southern California. The study found that males had a larger repertoire of songs, and neighbouring males shared similar songs. California House Finches had more syllable diversity and themes than eastern populations, but no distinct song dialects were found. The study provides insights into the role of song in courtship and competition for mates, and the ways in which bird songs can differ between populations.

The fourth study by Vinaya Kumar Sethi and Dinesh Bhatt (2008) investigates the physical characteristics and functions of various types of calls used by the Indian chat bird. The study discovered eight different types of calls, including territorial, feeding, and distress calls. The functions of the calls were deduced by the researchers from the contexts in which they were produced, such as territorial calls for territorial establishment and begging calls for food solicitation. The study provides insights into the diversity of bird calls and the ways in which they are used to communicate.

The fifth and final study by Sonam Chorol and Manjari Jain (2021) examines different measures of bird song complexity in the Purple Sunbird, an old-world passerine. The study identified and characterized the repertoire size of notes and phrases, and assessed the positional fidelity and ordering of notes within phrases. The study found that the notes exhibited positional fidelity and combined in a specific order to form a phrase, indicating an underlying phonological syntax that limits the ways in which notes combine to form a phrase. Finally, the study found that suffix syllables exhibited the presence of mini-breaths, which are produced by complex vocal mechanisms (CVM). The study provides insights into the complexity of bird songs and the different measures used to assess it. Dietmar Todt and Marc Naguib (2019) reviewed about vocal interactions in territorial song birds highlights the complexity and importance of communication in these birds. Birds use a variety of vocal strategies to interact with each other, including the timing of signals and the use of specific song patterns. These strategies convey important information about the bird's intentions, emotions, and identity, and can affect the outcome of the interaction. Furthermore, vocal duetting behaviour and triadic interactions demonstrate the social and communicative behaviours of birds beyond simple dyadic interactions. By studying these interactions, researchers can gain insights into the evolution of bird communication and the role it plays in maintaining pair bonds and defending territories.

In an experiment with wild Savannah Sparrows, Claire M. Curry et al. (2018) investigated the effects of anthropogenic noise on the birds' ability to communicate and the efficacy of vocal adaptations for noise disruption. They discovered that in some altered acoustic environments, noise-adjusted songs were successful in restoring appropriate conspecific territorial aggression behaviours. However, they also discovered that the adrenocortical responsiveness of the individual and the noise source had an impact on how well the adjustments worked. The findings imply that acoustic and physiological effects on wildlife must be taken into account in mitigation strategies to reduce anthropogenic noise.

The development of dialects in territorial oscine songs is discussed by Robert E. Lemon (1975), with a focus on the family Fringillidae, which demonstrates a wide variety of dialect expressions. The study found that while time-limited copying and dispersal interact to produce differences, active generation of new syllables and sequential combinations also contributes to similarities in sound patterns and their sequences in the songs of birds on neighbouring territories. The paper suggests a general model of song development for oscines based on observations in fringillids and other species. The Cardinal (Cardinalis cardinalis) is used as an example because it has been extensively studied in both field and laboratory settings, and its singing is easily discernible in sound spectrogram visual displays.
G. D. Alexander & D. C. Houston (1993) wanted to see if hornbill casques could be used as resonating chambers to amplify or modify their calls. The casque cavities of 15 hornbills from eight different species were replicated in fibreglass, and the resonance characteristics were analysed and compared to the calls of each species. The findings indicate that the casque closely corresponds to the fundamental frequencies of the calls but not the dominant frequencies, and that it may operate via a feedback mechanism. This research sheds light on the evolution and function of hornbill casques.
Hugo J. Rainey and Klaus Zuberbu Hler (2007) used audio recordings to study three types of hornbills in a national park in Ivory Coast over 10 years. They found that the number of calls made by two types of hornbills decreased during March to June, suggesting that many of those birds had left the park during that time. This information is important for understanding how the forests are being affected by human activities and how they can be protected in the future.( Hugo J. Rainey And Klaus Zuberbu Hler2007). Similarly, the calls of six subspecies of Black Redstart birds were studied to better understand their relationships. They discovered three geographical variants of the calls, with distinct calls found in the eastern subspecies rufiventris. This study delves into the vocalisations of various subspecies of Black Redstart birds.( Nicolas

Martinez & Vincent van der Spek 2022). Whereas Ayesha Mohammad Maslehuddin et.al (2020) conducted a study in Purna Wildlife Sanctuary to identify the various species of warblers that winter in the area. Because morphological identification is difficult, they used bioacoustics as a tool for identification. They discovered seven new species of warblers from the genera Acrocephalus and Phylloscopus. The study adds to the body of knowledge about the warbler species that visit the sanctuary during the winter and emphasises the value of bioacoustics in identifying these birds.( Ayesha Mohammad Maslehuddin et.al 2020). D. E. Irwin et.al (2008) looked at two types of vocalisations, calls and songs, in a geographically diverse species complex called greenish warblers. The authors discovered that signal divergence is related to both geographic distance and genetic divergence, and that sexual selection is likely to play a larger role in song divergence than in call divergence. Instead of acoustic adaptation or morphology being major drivers of vocalisation divergence, the study supports the importance of stochastic evolution of communication systems in the evolution of new species.( D. E. IRWIN et.al 2008). Tshifhiwa G. Mandiwana-Neudan et.al (2014) studied the vocalizations of two groups of game birds to understand their relationships and evolution. They found that some species' calls evolved from longer to shorter strophes, and that Francolin calls are generally longer and tonal, while Spurfowl calls are generally shorter and atonal. They also discovered that one species, Ortygornis sephaena, is closely related to Francolins and two other Francolin species from Asia. Overall, this research shows how vocalizations can be used to study the evolutionary history of bird species. (Tshifhiwa G. Mandiwana-Neudan et.al 2014 ).

## STUDY AREA

The present work was carried out in Surla village located in the Bicholim Taluka, Goa.( Fig No. 1) It is located at latitude 15°29'41.53" N and longitude 74° 2'20.48"E. The area is defined by a patch of a plateau, small forested habitats, and extensive areas covered by bushes and cashew plantations. The area becomes lush green during the monsoon season. The region is rich in biodiversity, with over 50 bird species known to live there, commonly sighted and heard were Red-whiskered Bulbul, Jungle Babbler and Malabar Grey Hornbill. The region is also known for its rich biodiversity, including a variety of mammals, reptiles, and insects.

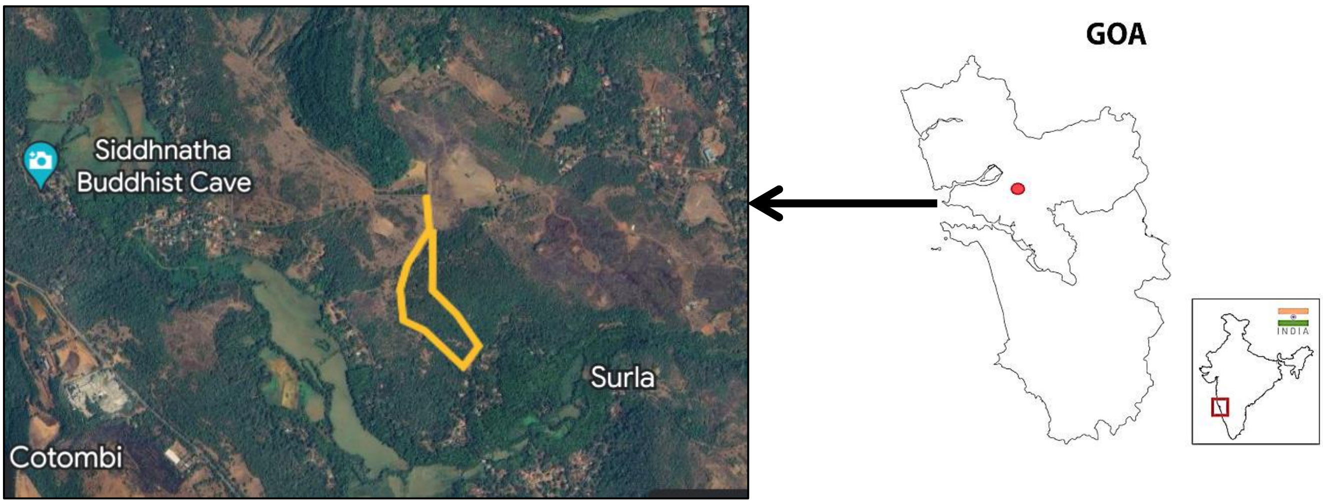



**Figure No.1: Study Area**

## MATERIALS AND METHOD

Spectrogram analysis was used to identify and compare the spectral profiles of the vocalizations. Spectrograms are graphical representations of sound that provide a detailed analysis of its frequency and intensity characteristics over time. By comparing the spectrograms of the different bird orders, we can gain insights into the similarities and differences in their vocalizations.

*Data Collection*

The bird calls were recorded from June 2022 to February 2023 in the field Once in a week. The data was collected in the study area once in a week on the field from 6.30 am to 10.00am. Initially, the bird calls were recorded of whichever bird was available, using a smartphone app RecForge II. WAV (.wav) file type, an uncompressed format that produces better quality than compressed formats like MP3s and M4As was used to save the calls. The recording quality was set to the highest possible setting. The sample rate was set to 48 kHz and a bit depth of 24 bits. Multiple recordings of bird species were made. Most smartphones record audio in mono, so it is best to choose mono option instead of "stereo," which records in two identical channels and unnecessarily doubles the size of the sound file. Then automatic gain control (AGC) is turn off. The peak is set between -6 and -12 dB in the level setting. By following these settings, I recorded high-quality audio with smartphone (Real me 7). For this project, I successfully recorded soft sounds from a distance using my smartphone. To minimize any noise that I might create while recording, I got as close to the source of the sound as possible without disturbing it, kept my hands and other obstructions away from the microphone, and pointed it at the target. Additionally, I rested the phone against a stable surface to help reduce fatigue and avoided any movement or noise that could create unwanted sounds. By following these tips, I was able to capture clear and detailed recordings of soft sounds from a distance using my smartphone. ("All About Birds," 2016).

The Five species belonging to five orders were chosen for the present study. Comparative analysis of bird calls of Red-whiskered Bulbul belonging to Order Passeriformes, Malabar Grey Hornbill belonging to Order Bucerotiformes, Red-wattled Lapwing belonging to Order Charadriiformes, Spotted Dove belonging to Order Columbiformes, White-cheeked Barbet belonging to Order Piciformes was done. Bird calls were recorded using BY-BM6060L direction Shotgun Microphone covered with Foam windscreen and Fur Windshield to reduce unwanted noise. This Microphone has highly sensitive i.e. -36 ±3dB(0dB=V/Pa@1KHz) and minimal noise, it also has high pass filter i.e. 150Hz. (Fig. No. 2)

In the field, binocular was used for visual identification of bird and some birds can be identified based on their sounds, which can be recorded and used for identification purposes. To familiarize myself with bird sounds, Xeno Canto websites was used. Additionally, apps like BirdNet and Merlin also was used for voice identification.

*Data Analysis*

The audio recordings were carefully listened to in order to extract the audio of specific bird sounds, which were then removed from the recording to obtain the bird calls for this study. BirdNet and Merlin Bird ID by Cornell Lab were used to later identify those calls that were initially unidentifiable. When the calls were located, they were divided into various orders and saved in folders with the Order name. MATLAB R2021b and Raven Pro 1.6 were both used to analyse the recordings in this study. The Cornell Lab of Ornithology created Raven Pro 1.6, a potent sound analysis programme, which can be used for research and instruction in acoustics, bioacoustics, animal behaviour, and other areas (Cornell Lab Of Ornithology). According to Sanchez-Hernández et al. (2019), the Max Planck Institute for Ornithology created Metalab, an open-source platform for analysing animal vocalisations that includes features for automatic detection, classification, and clustering as well as an interactive visualisation of spectrograms, annotations, and metadata. For this study, spectral analysis and data visualisation were carried out using MATLAB R2021b. Both Raven Pro and MATLAB, which each offered different features and capabilities, were frequently used software tools for analysing animal vocalisations.

Five birds, each belonging to a different order, were chosen from a sizable dataset. To hear the differences in each bird's sound, the five best recordings were selected. The audio file was converted into a vector for all analyses in MATLAB R2021b, and then it was read using the audio read function, which, because it was a stereo file, returned two data vectors. An audio file that has two channels, typically left and right, and produces a stereophonic representation of the sound is referred to as a stereo file. Since there is hardly any difference between the two vectors, only one vector is taken into consideration. The following analyses were carried out for this work:

1. Time Domain Representation: The signal behaviour over a specific time period is shown by time domain representation. As you can see in the time versus amplitude plot, the amplitude represents how loud the chirp signal is (Fig No.3.a). We can only learn about the chirps' duration and intensity/loudness from the time domain signal. The pulse width of the signal envelope is used to determine the length of the bird's chirp.

2. Frequency domain analysis: The time domain representations don't give us much information because the only thing we can tell about the audio recording's volume is how loud it is, as in (Fig No. 3.b). Utilizing the Fast Fourier transform, the audio signal is converted into the

frequency domain for improved comprehension (FFT). The FFT breaks down a signal into its individual frequencies and reports each frequency's magnitude, so the frequency domain representation essentially informs us of the various frequencies that are present in the audio. Although the original signal may have a specific frequency, the noise from unidentified signals that taints the signal can be seen in the frequency domain representation.Frequency domain representations helps in creating desired wave patterns and is also useful for signal processing such as filtering, amplification, etc. As can be seen in (Fig No.3.c) useful information is contained in the range of 0.750-10 KHz which is used while performing bandpass filtering.

3. Spectrogram: The frequency plot only displays the frequency of chirps, not their timing. The spectrogram provides a visual representation of frequencies as well as the time at which the chirps were observed. It also shows amplitude as a third dimension with variable brightness. The x-axis on a graph represents time, and the y-axis in a graph represents frequency in Hertz. As seen in figure c, a signal with a higher amplitude is represented by a brighter yellow colour, while a signal with a lower magnitude is represented by a red colour. The three calls include noise and a range of frequencies. To remove the noise, various filtering techniques were employed.

4. Filtering methods: By combining a moving average filter, a bandpass filter, and wavelet denoising, we were able to achieve the desired results as depicted in figure. By removing overshoots or noisy fluctuations, a moving average filter is a smoothing filter that aids in maintaining the true signal representation. By moving a sliding window of length k over an A-element signal, it produces an average-valued signal. For the components contained in the

sliding window, the average is determined. The signal was averaged, and then a bandpass filter was used. Only frequencies that fall within the designated range are permitted to pass through this filter. Wavelet denoising or wavelet thresholding is used to remove a significant amount of noise while preserving the signal's sharp features. The fundamental idea behind wavelet denoising is that the wavelet transforms concentrate signal features in a small number of large-magnitude wavelet coefficients. Small wavelet coefficients are typically noise, and their removal won't have any negative effects on the signal. The spectrogram of a filtered signal is shown in Figure D. The black colour denotes the absence of audio.

Raven Pro 1.6 was used to produce spectrograms of different types of calls and to analyse behavioral calls. The settings used in Raven Pro 1.6 were a Hann window with window size 800, a dB filter bandwidth of 86.3 Hz, 50% overlap, and a grid spacing of 46.9 Hz. The audio files were loaded in raven pro where different phrases were selected and to investigate the variation in bird vocalizations across different orders of birds, the Raven Pro software was used. Each audio file was imported into Raven Pro to generate a spectrogram. Next, individual phrases from each audio file were selected for analysis of low and high frequencies. Subsequently, each spectrogram was carefully scrutinized to classify bird calls into distinct types, such as whistle, chirrup, or harmonics. By scrutinizing spectrograms and listening to the audio, we noted any differences in the calls and categorized them based on the distinct characteristics observed. This approach allowed us to compare calls both within and between orders of birds.The Raven Pro's Batch Correlator function continued to analyse the sound. On an arbitrary large number of files, it automatically ran the Correlation operation, saving the results. Raven determines a normalised or non-normalized correlation value Ct between two spectrograms for each lag t. The normalised correlation used in this analysis is computed using the formula below::

$$C_{\Delta t} = \frac{\sum_{t=1}^{n} \sum_{f=1}^{FFT} (X_{t,f} \cdot Y_{t+\Delta t, f})}{\sqrt{\cdots}}$$

**Fig No.2:** BY-BM6060L direction Shotgun Microphone covered with Foam windscreen and Fur Windshield

## OBSERVATION

A total of 435 Bird calls were recorded were recorded. A total 10 orders and 29 birds were recorded. For analyzation only those orders are selected which were having a more and best recording. From each bird recording 0.3S call was use for Spectral analysis.  From the analyzation the vocal sounds of five birds belonging to five different orders using the MATLAB R2021b software following the results are obtain

**1. Order Bucerotiformes** (Malabar Grey Hornbill- *Ocyceros griseus*)

It produces a distinct vocal repertoire, including a loud "caaaaa-caaaaa" call and a short "cackk" contact call. The birds also engage in group choruses and produce a unique vocalization during flight.  From the spectrogram Time domain representation of bird cackles for 3 seconds duration, the time domain signal is symmetric which means that the signal has no DC component, that is, the spectrum at 0 Hz is essentially zero. Second is the frequency Domain which represents the useful information in the range of 0.750KHz - 10 KHz this was use for Bandpass filtering. The bright yellow colour indicates signal with higher amplitude while the red with lower magnitude. The three calls contain multiple frequencies called harmonics in the range of 1-10Hz mixed with noise. This noise is removed for getting noiseless graph. (Fig No.8)

**Order: Charadrriformes**(Red-wattled Lapwing - *Vanellus indicus*)

This species has a loud call. When they find any disturbance, they call out "did-he-do-it," and this is usually done while they are in flight. They make a short "tip-tip" call as a contact call. This type of call is made when they are on the ground feeding. A pattern was seen three times in the spectrogram, mixed with minor noise of lower magnitude. The frequency range visible here is up to about 15kHz. It indicates that there are strong magnitudes of bird chirps at lower frequencies, and that bird chirps exist after 10KHz but are of lower magnitude. Making a nasal sound. Begin with the fundamental frequency and work your way down. (Fig No. 9.)

**Order: Columbiformes (Spotted Dove -** *Spilopelia chinensis)*

Birds communicate with each other by making a continuous "Coo-a-roooo" call, sometimes with overlapping calls. Lower frequencies are present up to 1 kHz in bird calls, but strong frequencies are present up to 1 kHz. It has a lower amplitude/loudness up to about 0.05db. The bandpass filter has a frequency range of 750-10kHz and a pitch of 3 Hz. The spectrogram shows that during a bird chirp, lower frequencies of up to 1 kHz, frequencies of 3-5kHz, and frequencies of 7-9kHz exist, but the higher frequencies have low strength. (Fig. No. 10)

**Order: Passeriformes (Red whiskered Bulbul-** *Pycnonotus jocosus)*

These birds were making a lovely continuous "pik-pik-a-wew" sound. While feeding, gives a short and slow voice call, i.e. "pik-pik" loud contact call; sometimes simply sitting on a branch and singing "pik-pik-a-wew" for a long time. A spectral analysis of a single bird call reveals multiple frequencies in the 1-7kHz range with magnitudes ranging from 0.6-1dB. Among all the orders studied, it has the longest call duration of approximately 0.5s. A bandpass filter was used from 750 to 10kHz. The spectrogram after filtering, and the pitch is 3 Hz (Fig No.11)

**Order: Piciformes (White-cheeked Barbet-** *Psilopogon viridis)*

While feeding and making contact, they make a continuous loud "Kutrook-Kutrook-Kutrook" call. This bird call has low frequencies in the 1-2kHz range with a magnitude of about 0.3dB. Among the other orders studied, the bird call has the shortest duration of approximately 0.1s. A bandpass filter was used from 750 to 10kHz. The pitch is 3 hertz. It produces a buzzing sound. (Fig No. 12)

## Types of birds sound and their Behaviour

### 1. Malabar Grey Hornbill

**Type 1**: Single long loud call, Its start with single note “kuk – kuk” with a low Frequency 217.2Hz and higher at a centre 16724.0 Hz and again it come down. (Fig. No. 13.a)

**Type 2**: Laughing type sound: having multiple frequencies with different structural harmonics as in 0-1 s, 1-2, 2-3, and 4-5.(Fig.No. 13.b)

## 2.Red Whiskered Bulbul

**Type 1,2**: Three calls are added in a one spectrogram. In first phrase there are 5 elements, in second phrase there are 6 element in third 5 elements are present. The last call is incomplete may be the bird got any disturbance.(Fig.No.14.a)

**Type 3**: a complex short call of higher Frequency 4610.Hz and 2033.9 Hz.(Fig. No. 14.b)

## 3.Red Wattled Lapwing

**Type 1:** Loud Alarm Call with Lower frequency 610.2Hz and higher Frequency 16701.8Hz(Fig. No. 15. a)

**Type 2**: Short note call. Alarm call of Lapwing. Nasal type of sound with lower Frequency 1063.8 Hz and Higher Frequency 7399.1Hz. Continuation of type 1 call repetition of one element for a few seconds. (Fig.No. 15.b)

## 4.Spotted Dove

Hooting type of sound with low-pitched whistle that is appearing at very bottom of the spectrogram. it starts with low call co then it starting louder “coo-a-roo”. (Fig.No. 16)

## 5. White Cheekedd Barbet

It begins with a short call with a low tone, followed by a loud call. In a spectrogram, it appears to be a buzzy sound with a squiggly line, similar to an electric buzzer. This sound is so fast that when you u zoom in, it looks like a wave. Above the bright phrase, another phrase appears as a light-colour like shadow. (Fig. No. 17)

In this study, we Correlate the Spectrogram using the batch correlator in Raven Pro 1.6. We compared the correlation between the same order of birds, such as Piciformes and Piciformes, and found a high correlation coefficient close to 1, indicating a high degree of similarity. Similar results were observed for all comparisons within the same order. However, when comparing different orders, the correlation coefficients were near 0 or almost 0, indicating no significant correlation between them.

## Tables

**Table No. 1**: Names of selected five orders and the birds selected from this five orders

| ORDER | FAMILY | COMMON NAME | SCIENTIFIC NAME |
|---|---|---|---|
| Bucerotiformes | Bucerotidae | Malabar Grey Hornbill | *Ocyceros griseus* |
| Charadriformes | Charadridae | Red-wattled Lapwing | *Vanellus indicus* |
| Columbiformes | Columbidae | Spotted Dove | *Spilopelia chinensis* |
| Passeriformes | Pyconotidae | Red-whiskered Bulbul | *Pycnonotus jocosus* |
| Piciformes | Megalaimidae | White-cheeked Barbet | *Psilopogon viridis* |

| COMMON NAME | TOTAL NO. OF RECORDING |
|---|---|
| Malabar Grey Hornbill | 18 |
| Red-wattled Lapwing | 5 |
| Spotted Dove | 15 |
| Red-whiskered Bulbul | 30 |

| | |
|---|---|
| White-cheeked Barbet | 5 |
| | Total=73 |

**Table No. 2:** Total number of Recording for different bird Species

| File | Piciformes (U) | Passeriformes (U) | Columbiformes [1] (U) | Bucerotiformes[1] (U) | Charadriiformes [1] (U) |
|---|---|---|---|---|---|
| **Piciformes (U)** | 0.987 | 0.002 | 0 | 0.014 | 0.002 |
| **Passeriformes (U)** | 0.002 | 1 | 0 | 0.023 | 0.072 |
| **Columbiformes [1] (U)** | 0 | 0 | 1 | 0.014 | 0.048 |
| **Bucerotiformes[1] (U)** | 0.014 | 0.023 | 0.014 | 1 | 0.046 |
| **Charadriiformes[1] (U)** | 0.002 | 0.072 | 0.048 | 0.046 | 1 |

**Table no. 3**: Batch Correlation Peaks (U). The value 0 or near to 0 indicates there are no

correlation between the two group and 1 or near to 1 indicates the two groups are correlated.

| File | Piciformes | Passeriformes | Columbiformes (1) | Bucerotiformes(1) | Charadriiformes(1) |
|---|---|---|---|---|---|
| **Piciformes** | 0 | 1.9093 | -0.1093 | -0.152 | -2.7173 |
| **Passeriformes** | -1.9093 | 0 | -0.4053 | -0.5733 | -4.1227 |
| **Columbiformes(1)** | 0.1093 | 0.4053 | 0 | -0.4267 | -4.7787 |
| **Bucerotiformes(1)** | 0.152 | 0.5733 | 0.4267 | 0 | -4.032 |
| **Charadriiformes(1)** | 2.7173 | 4.1227 | 4.7787 | 4.032 | 0 |

**Table no. 4** : Batch Correlation Lags (s)

| Bird orders | Lowest Frequency | Highest Frequency | Range of frequencies | Prominent Frequencies/duration |
|---|---|---|---|---|
| **Bucerotiformes** | 1kHz | 10kHz | 9kHz | 1-8kHz/~0.2s |
| **Charadriformes** | 1kHz | 9kHz | 8kHz | 1-7kHz/~0.2s |
| **Columbiformes** | 1kHz | 5kHz | 4kHz | 1kHz/~0.25s |

| | | | | |
|---|---|---|---|---|
| **Passeriformes** | 1kHz | 7kHz | 6kHz | 2-4kHz/~0.5s |
| **Piciformes** | 1kHz | 3kHz | 2kHz | 1kHz/~0.1s |

**Table no. 5**: Table gives a comparison between the bird orders

**Fig No.3**:Malabar Grey Hornbill (*Ocyceros griseus)*

**Order :-** Bucerotiformes

**Fig No.4**: Red-wattled Lapwing (*Vanellus indicus)*

**Order:-** Charadriiformes

**Fig No.5**: **White-cheeked Barbet (***Psilopogon viridis)* **Order :-** Piciformes

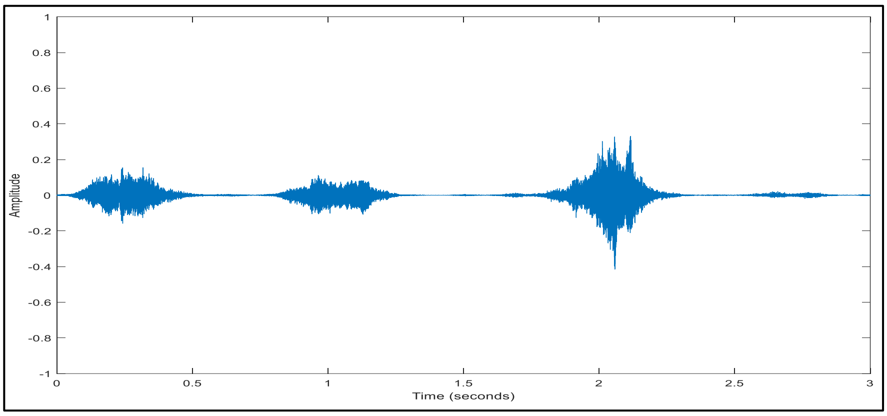
**Fig No.6**: Red whiskered Bulbul (*Pycnonotus jocosus)*

**Order :** Passeriformes

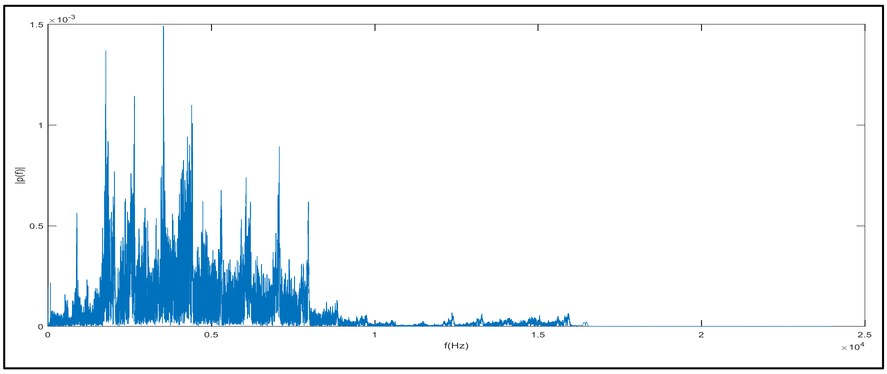
**Fig No.7**: Spotted Dove (*Spilopelia chinensis)*

**Order: Columbiformes**

(a)




(b)




(c)

(d)

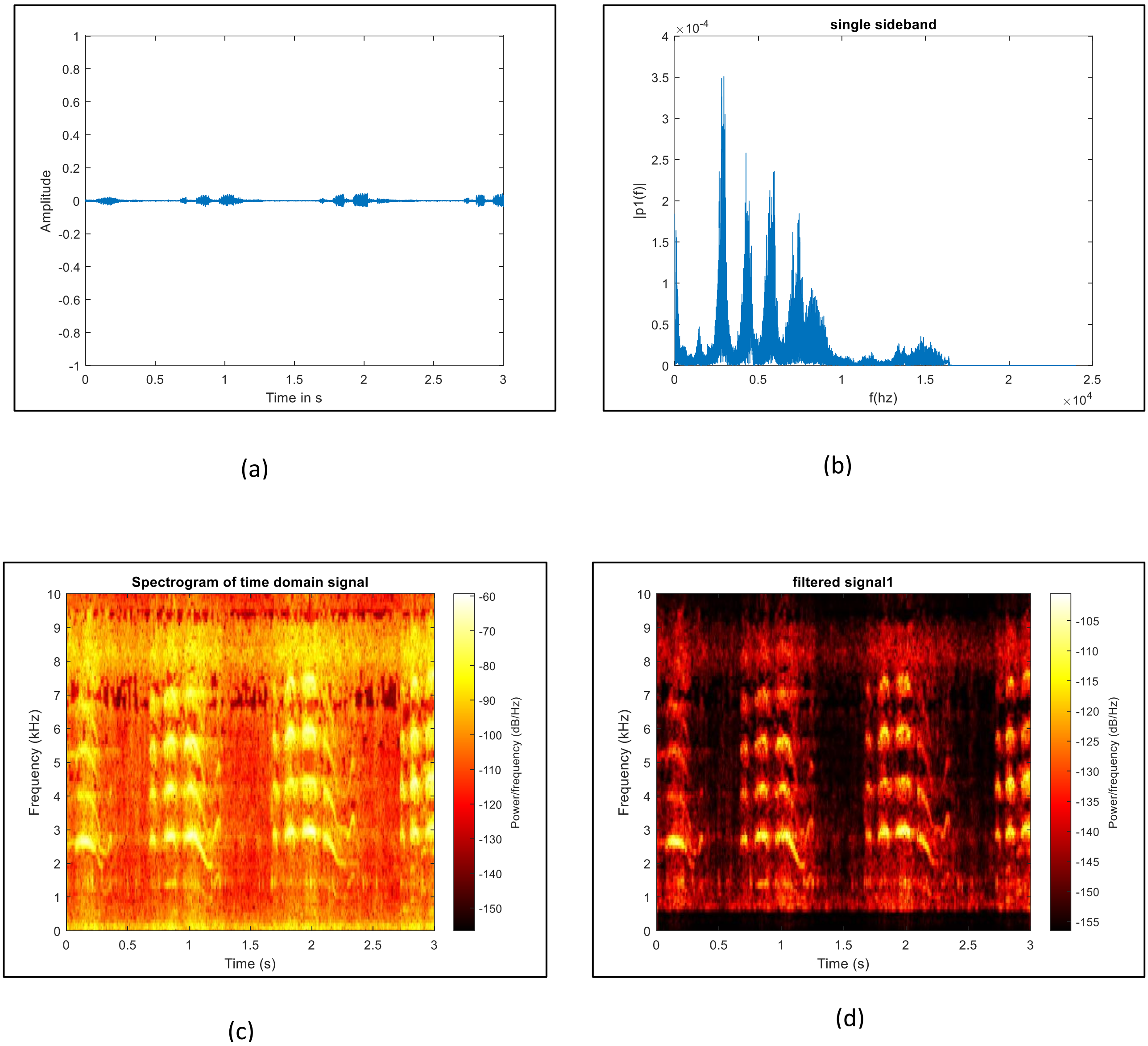



**Fig. No.9:** Spectogram of Charadriiformes (a) Time domain representation; (b) Frequency domain representation; (c) Spectrogram of the signal; (d) Spectrogram after filtering

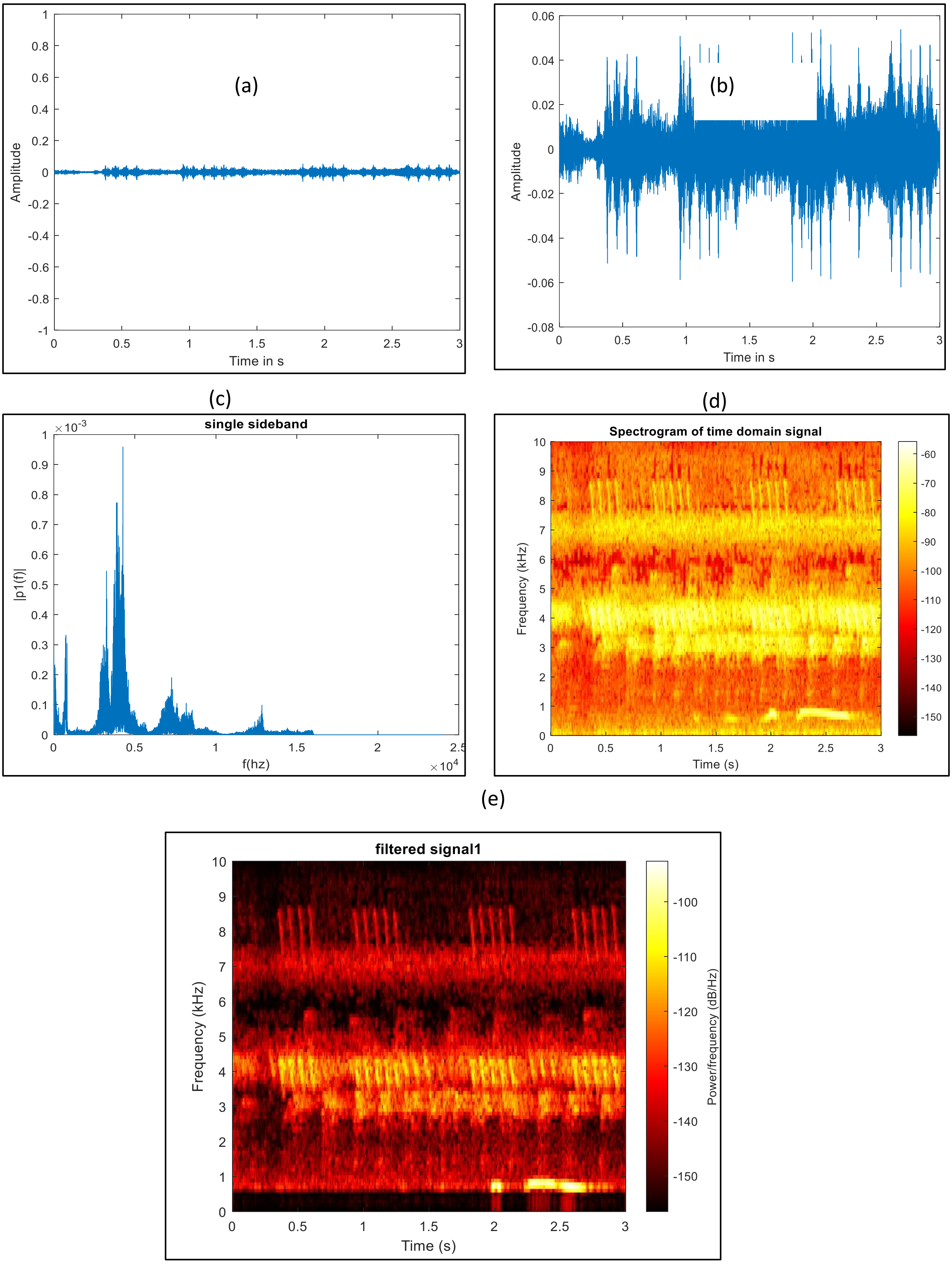



**Fig No. 10 :-** Spectogram of Columbiformes (*Spilopelia chinesis)* (a) Time domain representation (b)Reduced y scale time domain representation (c) Frequency domain representation (d) Spectrogram of the signal (e) Spectrogram after filtering

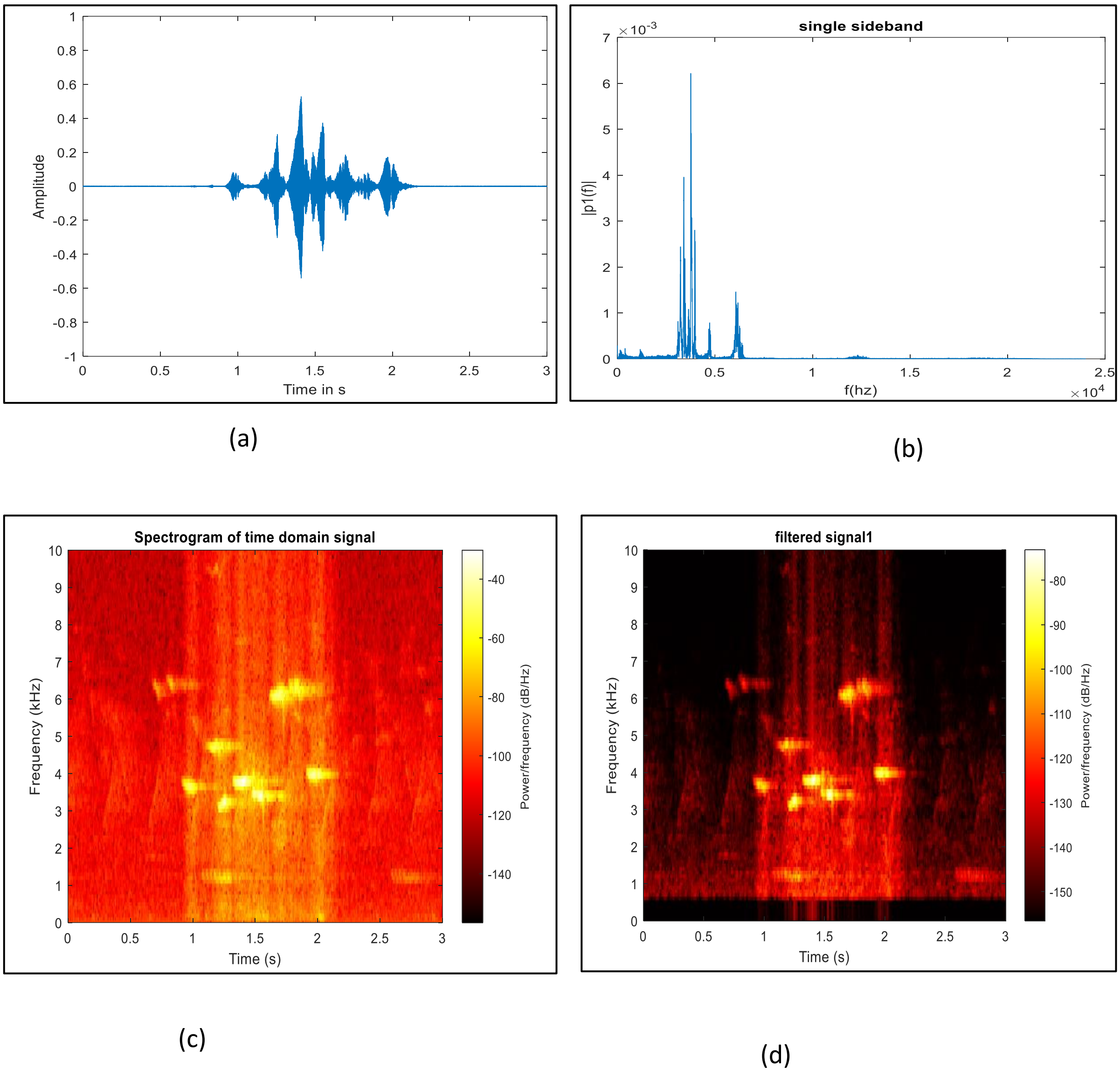



**Fig. No. 11-** Spectrogram of Passeriformes ( Pycnonotus jocosus) (a) Time domain representation(b) Frequency domain representation(c) Spectrogram of the signal (d) Spectrogram after filtering

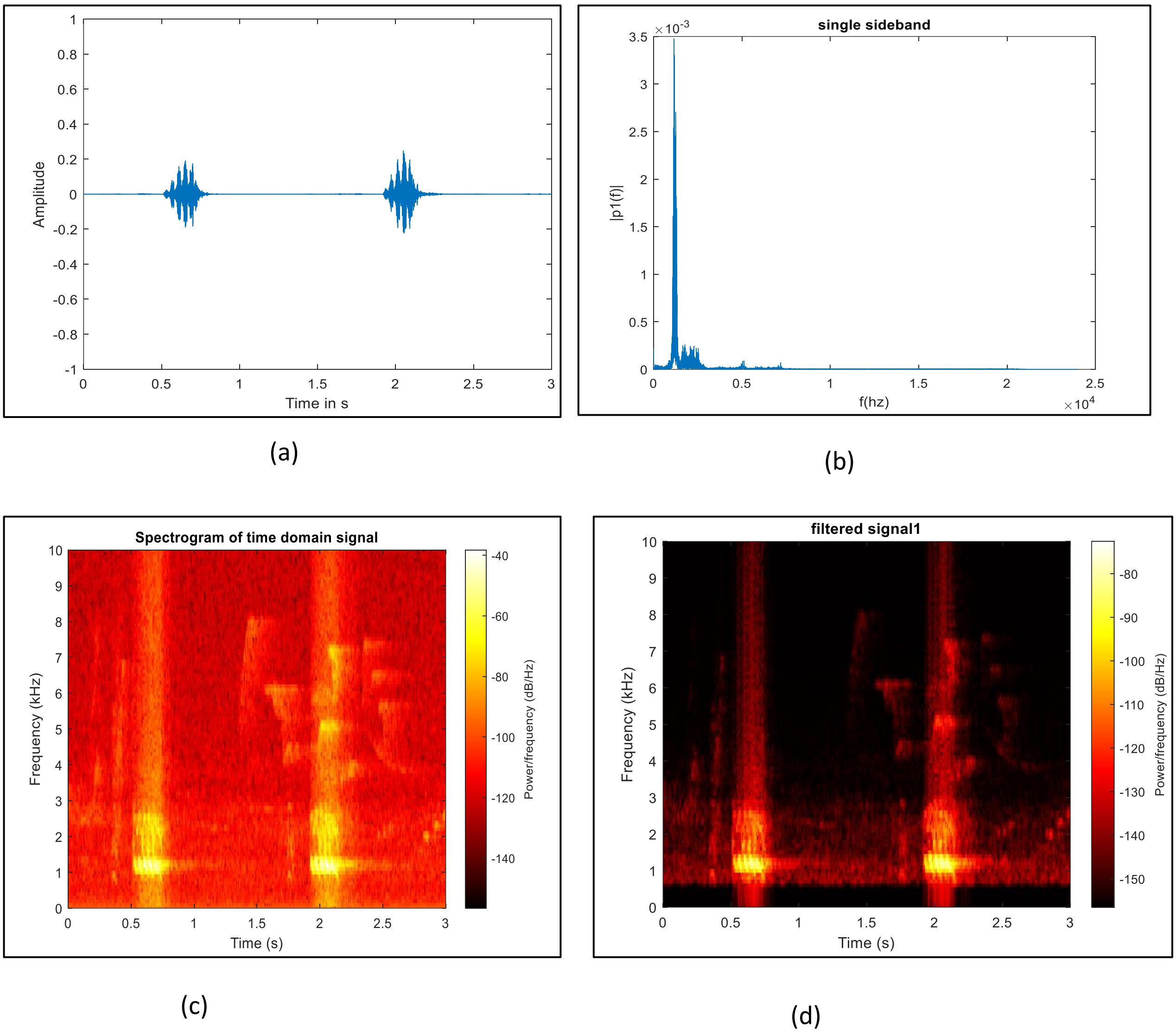
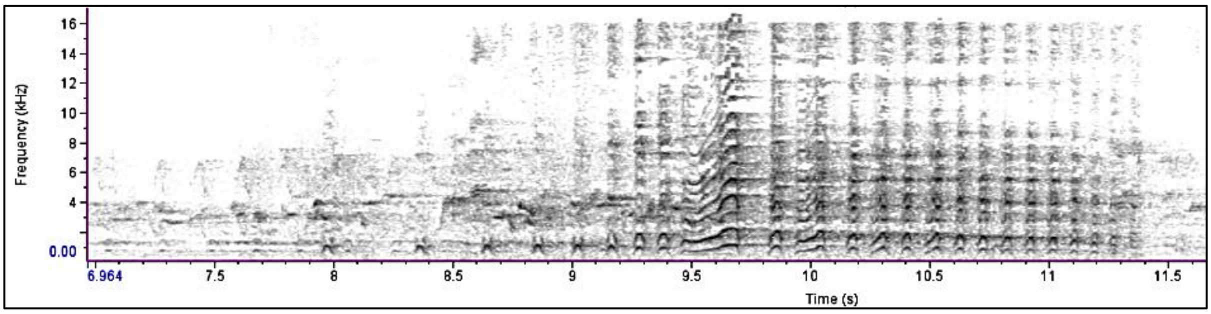


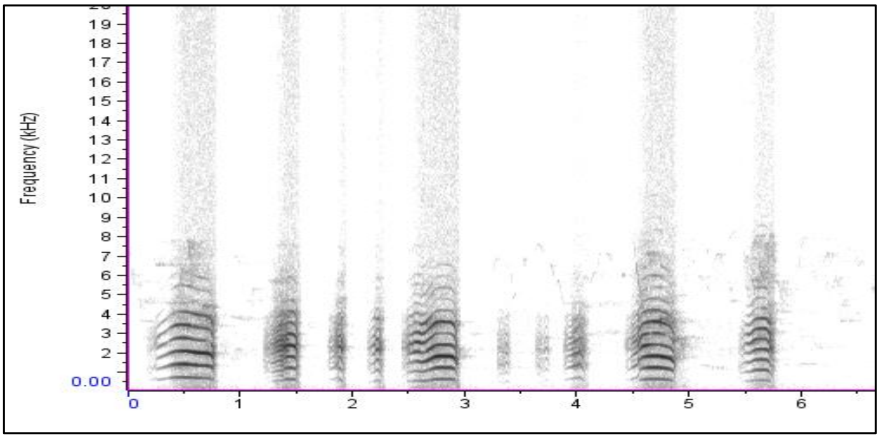

**Fig No. 12** :- Spectogram of Order Piciformes (*Psilopogon viridis*) (a) Time domain representation(b) Frequency domain representation(c) Spectrogram of the signal(d) ) Spectrogram after filtering

## Types of birds sound and their Behaviour

**Malabar Grey Hornbill *(Ocyceros griseus)***




(a)




(b)

**Fig No. 13:** Spectrogram of a Malabar Grey Hornbill (a) Long Call (b) Laughing type of call

## Red-whiskered Bulbul *(Pycnonotus jocosus)*

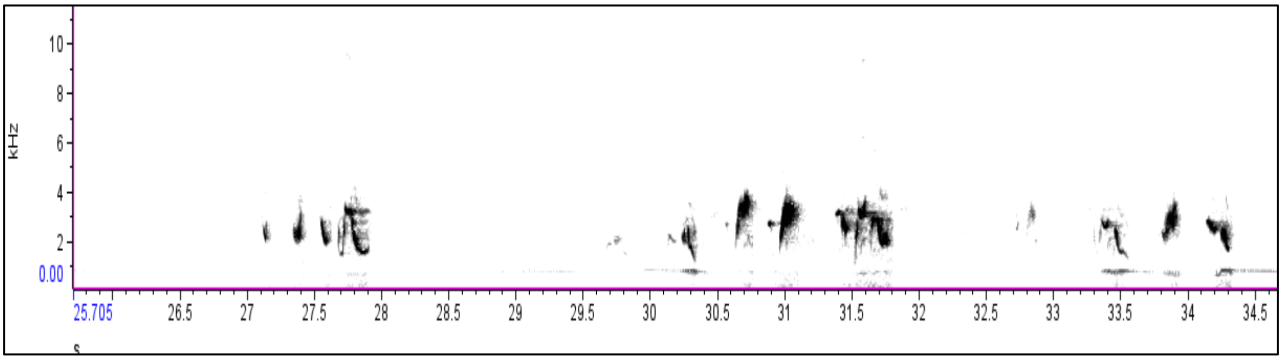



**Fig No. 14.1 :-** Three phrases of a Bulbul call are shown in a one spectrogram

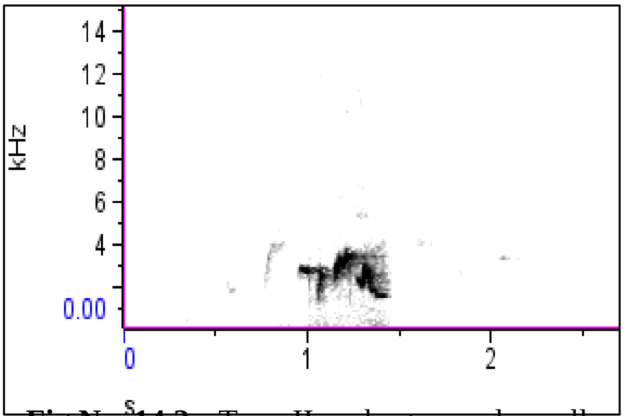
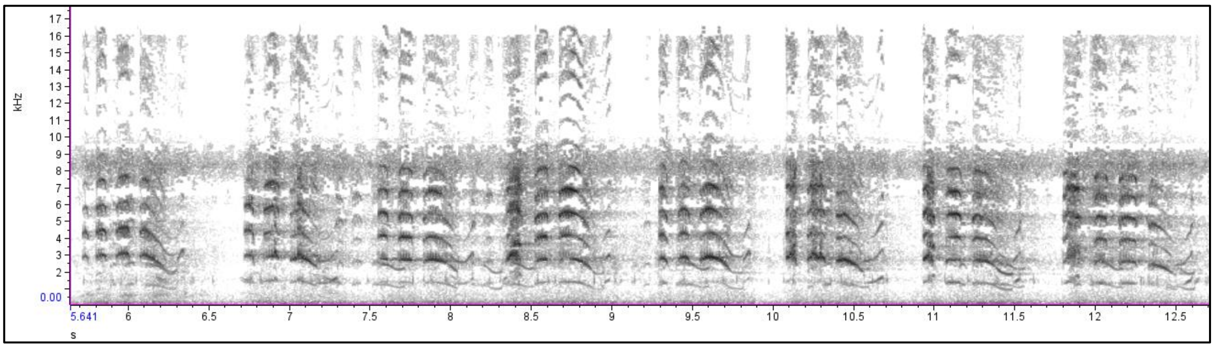
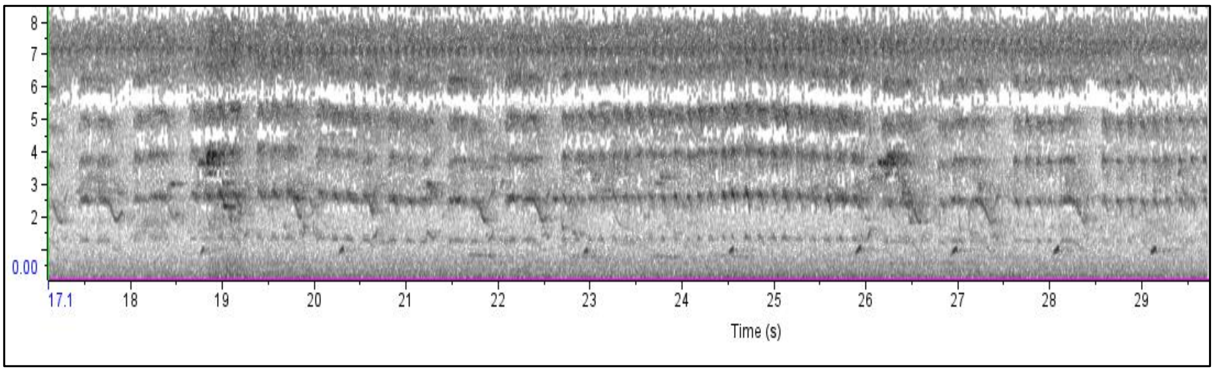



**Fig No. 14.2:-** Type II, a short complex call

## <u>Red Wattled Lapwing (*Vanellus indicus*)</u>



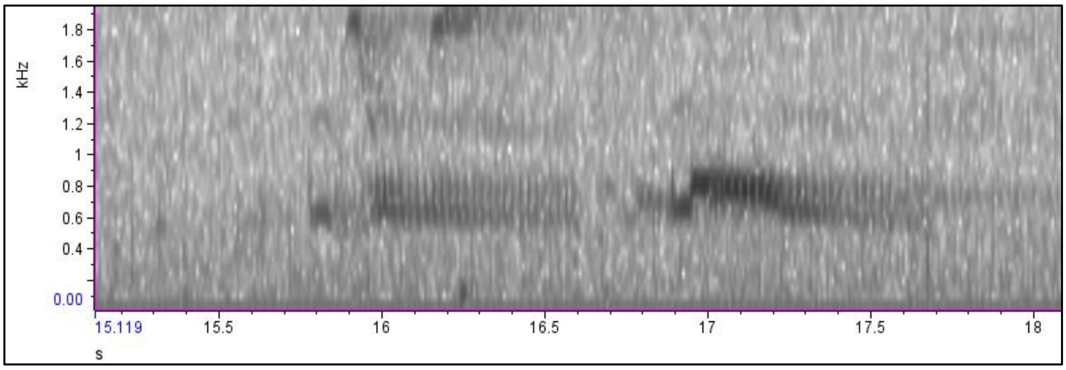

(a)



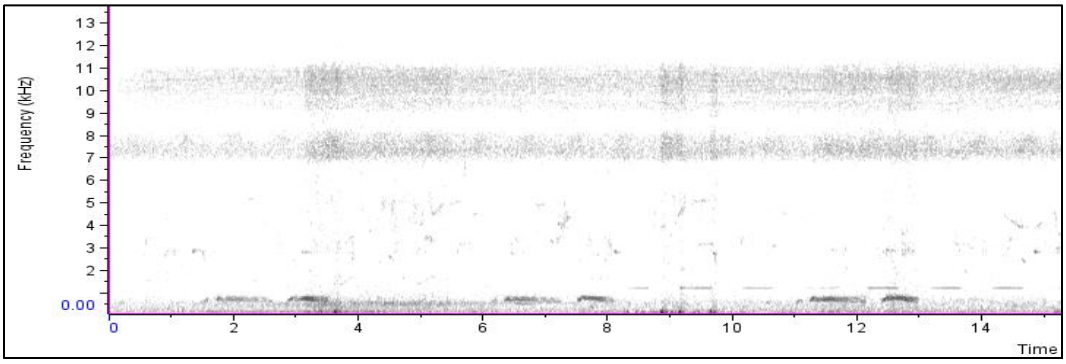

(b)

**Fig No. 15:-** Spectogram showing (a) Alarm call (b) Contact Call

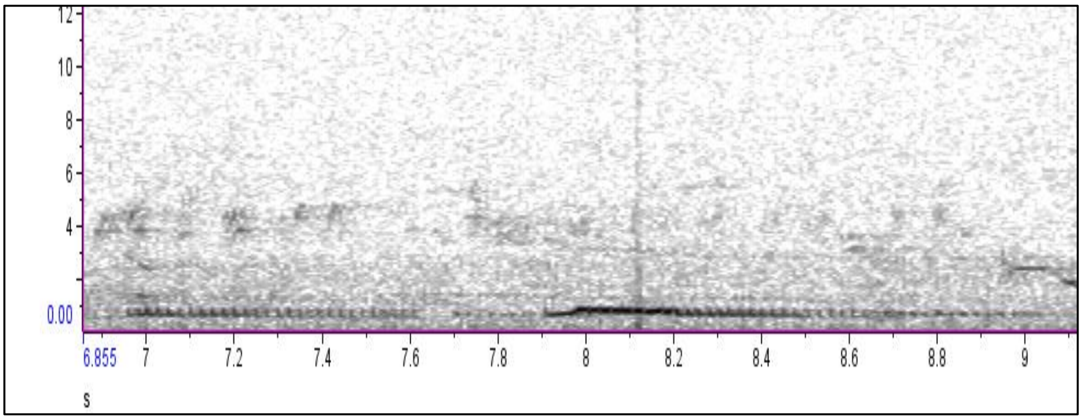
**Spotted Dove(*Spilopelia chinensis)***




(a)




(b )




(c)

**Fig No. 16:-** Spectrogram of birds **(a)** Zoom image of call **(b)** Continuous call **(c)** Long call

**White-cheeked Barbet (*Psilopogon viridis*)**

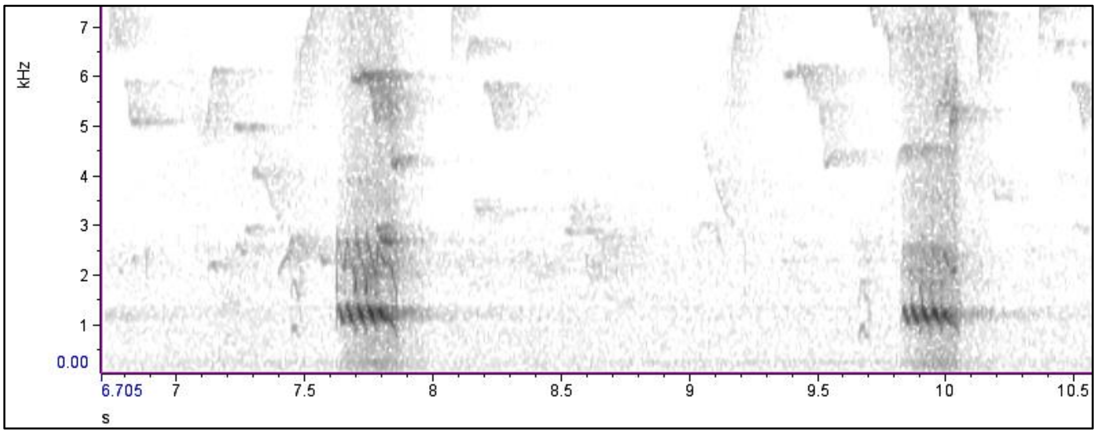



**Fig No. 17**: Spectogram of Barbet call

## Disscussion

Bird vocalizations play a crucial role in communication, and each species has a unique vocal repertoire that serves different functions, including mate attraction, territorial defense, and individual recognition (Catchpole & Slater, 2008). Over the years, researchers have studied the variations in bird vocalizations to understand the evolutionary significance of bird songs and their functions.

In this study, we focused on five bird species belonging to five different Orders, namely Bucerotiformes, Charadriformes, Columbiformes, Piciformes, and Passeriformes, to observe the variation in their vocalizations. Our findings revealed that each species had a distinct vocal repertoire differed with behavior and in frequency and type of sound.

Passeriformes, the largest Order of birds, is known for its complex and fast-paced songs. Donald J. Borror (1961) conducted a study on passerine birds and found geographic, diurnal, and seasonal variations in their vocalizations. He also observed variations in the number of notes and the reporter in individuals as well as between species. Our study confirmed the findings of Borror's (1968) study and further emphasized the complexity of passerine bird songs.

Bucerotiformes, another Order of birds, is known for its loud calls. The Malabar Grey Hornbill (*Ocyceros griseus*), which belongs to this Order, makes a loud call in chorus. Plicht *et al.* (2009) studied two species of hornbills and found that the frequency parameters in Rufous-headed Hornbills (*Aceros waldeni*) are lower than Visayan Hornbills (*Penelopides panini*). Our study further supports the findings of Plicht *et al.* () and revealed that the Malabar Grey Hornbill has a distinct frequency range compared to other bird species. Charadriformes, a diverse Order of shorebirds, has a vocal repertoire that is characterized by more distance in their harmonics compared to Bucerotiformes.

The Red-wattled Lapwing (*Vanellus indicus*) belonging to this order has the highest frequency of 16,701.8 Hz, while other bird species in this order have different frequency ranges. Our study confirmed the diversity in the vocalizations of Charadriformes and the unique frequency range of the Red-wattled Lapwing.

Piciformes, an Order of birds that includes woodpeckers, toucans, and barbets, has a unique buzzing sound in their vocalizations that is similar to a stringed instrument. The White-cheeked Barbet (*Megalaima viridis*) belonging to this order makes a call that starts with "kurr" and then "kutroo kutroo" for a few seconds, which is louder during the breeding season, and females respond to the male's voice. Our study supports the findings of Roopa V. (2019), who observed that neighboring individuals also start giving a call when one White-cheeked Barbet gives a call.

Columbiformes, an Order of birds that includes doves and pigeons, has a distinct low frequency in their vocalizations. Rafael Martos-Martins *et al.* (2018) observed that the vocal repertoire of the *Geotrygon violacea* species in this order consists of only one type of element, which begins at a higher sound frequency and lasts only a short time before dropping to minimum values. Our study confirms the low-frequency range in the vocalizations of Columbiformes and the unique vocal repertoire of the *Geotrygon violacea* species.

The zero values in the batch correlator suggest that there is variation in vocalizations across all five orders of birds, which could be related to differences in frequency and other behaviors. However, it's important to keep in mind that the batch correlator is just one tool used to analyze bird vocalizations, and other factors could also be contributing to the variation observed. For example, the environment in which birds live could also influence the way they vocalize. Birds in noisy environments, for example, may need to adjust their vocalizations to be heard over background noise, which could lead to differences in frequency or other vocal characteristics. ( Paige S. Warren et.al. 2009). Similarly, different bird species within the same order could exhibit variations in vocalizations due to differences in mating behavior, territoriality, or other factors. (Donald J. Borror 1961)

While the non-zero values in the batch correlator may suggest that there is variation in vocalizations across all five orders of birds, additional analyses and data would be needed to confirm this and to better understand the underlying factors driving the observed variation.

Overall, the study of variations in the vocalizations of birds is fascinating and important field of research. By studying the vocal behaviour of birds, scientists can gain insights into the ways in which birds communicate and adapt to their environment. Furthermore, understanding the vocalizations of birds can have practical applications, such as in the development of noise reduction strategies for urban areas or in the conservation of endangered species.

## Conclusion

In conclusion, this study highlights the importance of bird vocalizations in communication and their unique vocal repertoires. The research focused on five bird species belonging to five different Orders and revealed that each species had a distinct vocal repertoire that differed in frequency, behavior, and type of sound. However, it is important to note that most of the studies on birds are from outside the country and there is still a lot to explore in terms of variation and the importance of calls in different bird orders. The study of bird vocalizations is a never-ending journey that continues to fascinate and inspire us.

## Limitation

1. Sample size: The study was conducted on a limited number of bird calls of each species. A larger sample size could provide more comprehensive understanding of bird vocalizations.
2. Time constraints: The study was conducted over a limited period of time. Observing bird vocalizations throughout the year may provide more information on seasonal variations in vocalisations.
3. Funding: Like many scientific studies, funding can be a significant limitation. The unavailability of funds may limit the scope and scale of the study.
4. Equipment limitations: The equipment used to record bird vocalizations may have limitations in terms of frequency range and sensitivity, which may have affected the accuracy of the data collected.
5. Data analysis: The analysis of bird vocalizations is complex and requires specialized software and expertise. This study was limited by the available resources for data analysis.
6. Statistical power: Given the complexity of bird vocalizations, statistical power can be a limitation in these types of studies. Increasing the number of samples can help to increase the statistical power of the study.

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