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Vocalization Repertoire of the Five Striped Palm Squirrel, *Funambulus pennantii pennantii*: An Ethological Study

Deepali Agarwal[1] and Reshma Bhatnagar[2]

Department of Zoology Dayalbagh Educational Institute (Deemed to be University) Agra

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ABSTRACT

The five striped palm squirrel, *Funambulus pennantii pennantii* is native to Northern India, Iran, Pakistan and Bangladesh. The vocal communication of *F. p. pennantii* was studied at four different sites at Agra district of Uttar Pradesh, India. These sites were selected on the basis of maximum cluster locations and movements of squirrels tracked by the GPS tracking device GARMIN eTrex 10. The locations data was uploaded on QGIS open access software to map the sites. To record the vocalizations of squirrels, the AE mini digital recording device was used. Since this species enjoys the Least Concern (LC) status, Godden's formula for infinite population was employed to determine the sample size, which was approximately 400 squirrels. To generate the audio spectrograms of squirrel vocalizations, MATLAB software version R2019b was used. Photography and videography were done through *ad libitum* sampling technique with NIKON COOLPIX 500 camera. Four distinct patterns emerged in the audio spectrograms, and they were identified as four distinct call types. The Buzz is a mating and play call. It is also used by mothers to communicate with their juveniles. The Growl is a threat call and is followed by chase or attack. The Bark is an alarm call which is of two types- a predator class specific alarm call for aerial predators and another predator class specific alarm call for terrestrial predators. The Rattle is a territorial declaration by squirrels as their routine at a specific time of a day. This is the first report of acoustic identification and analysis of calls of *F. p. pennantii* in their behavioral contexts.

Key words: Funambulus, Vocalization, MATLAB, Acoustic, Ethology.

INTRODUCTION

Communication is the way by which animals of same or different species interact with each other. The animals communicate with each other for many reasons like foraging, mating, playing, intraspecific and interspecific interactions, mother-child interactions, territoriality and vigilance **(Rogers and Kaplan, 2002).** Visual displays, olfactory markers, scent deposits, urine marking, tactile signals and sound signals are the means through which the animals communicate **(Rogers and Kaplan, 2002).** Vocalizations or sound signals are produced by an animal to communicate with conspecifics or members of other species. Vocalizations of animals and responses they give in different situations provide insights into their behavior.

Vocalizations may be used by territorial animals that don't often engage physically as long- distance signals to aid in discrimination **(Wilson *et al.*, 2015).** In rodents, acoustic communication signals serve a wide range of purposes, such as eliciting conspecifics to approach, warning adjacent animals of the presence of a predator, and drawing mothers' attention to their juveniles **(Okanoya and Screven, 2018).** The five striped palm squirrel, *Funambulus pennantii pennantii* native to Northern India, Iran, Pakistan, Bangladesh and is considered as an exotic species in Australia, Oman and UAE **(Rajaratnam and Redman, 2001; Judas and Hellyer, 2016; Victor and Soto, 2020).** According to the IUCN Red list, it is listed under Least Concern category (LC). It is diurnal **(Khan and Khan, 1980; Malhi and Kaur, 1995; Rajaratnam and Redman, 1997; Rajaratnam and Redman, 1998; Sharma, 2016)** and is successfully thriving in varied habitats such as residential areas, gardens, crop lands **(Agarwal and Bhatnagar, 2019)**. They are semi-arboreal in nature and spend most of the time on trees. They descend on grounds for foraging, playing and mating **(Ghose *et al.*, 2004; Csurhes, 2016)**. They communicate through the different sounds they produce. Acoustic behavior of four species of ground squirrels

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was studied by **Koeppl *et al.*, (1978). Greene and**

Meagher (1998) analysed the predator class specific alarm calls in red squirrels in Montana. Vocalization function of tree squirrels of Columbia was studied by **Smith (1978).** Vocalizations of the Belding's ground squirrel, *Spermophilus beldingi*, were studied by **Leger *et al.*, (1984)** in California. There are many studies on the acoustic behavior of various squirrels, but no such work has been reported for *F. p. pennantii.* Thus, the present work is an attempt to study the vocalizations of *F. p. pennantii* and analyse the situations in which they are used.

METHODS

Sampling area

The study was conducted in the Agra District (27.1767°N, 78.0081°E) of Uttar Pradesh, India. Firozabad district lies on its East and Bharatpur on its West. To the North, the boundary touches the Mathura District. It is surrounded by Dholpur district towards South **(agra.nic.in, Government of Uttar Pradesh).** Agra has semi-arid type of climate **(Deshwal *et al.*, 2017)** which is enriched with varied habitats. Temperature of Agra city shows broad variation range in day and night. Summers occupied maximum part of the year. January is the coldest month of the year with average maximum temperature of 14°C. It gradually increases and reaches

average maximum temperature about 45°C during summers. The average annual rainfall of Agra is 523mm and humidity remains high during the monsoon season.

Sampling sites

Four different sites were selected on the basis of availability of the squirrels- Balkeshwar, Sikandra, Dayalbagh and Shahjahan Gardens. To track the movements and maximum availability of clusters of squirrels, GPS tracking device GARMIN eTrex 10 was used. Then the data was uploaded to QGIS open access software and the positions of squirrels were imposed **(Figure 1).** The timings of field visits were usually 6-8 am in the morning and 6-7pm in the evening as squirrels are most active during these hours. However, time varies also according to the changing weather conditions in Agra. The study was conducted in 2018 and 2019 throughout the year.

Sampling tools

To record the vocalizations of squirrels, AE mini digital recording device with mp3 audio format, microSD, USD 2.0 and secure digital card was used. To map the locations of squirrels, GARMIN eTrex10 and QGIS software was used. To prepare the audio spectrograms of the squirrel vocalizations, MATLAB version R2019b was used. Photography and videography

were done through *ad libitum* sampling technique **(Altman, 1974)** with NIKON COOLPIX 500 camera.

Sampling method

Observations were made at the selected sites of Agra. Sites were visited regularly. We visited a site only once a week so that the squirrels did not get habituated with the presence of observers. To record the vocals and identify the producer of vocals, we tracked solitary squirrels only. To avoid bias, we preferred only natural encounters of squirrels with conspecifics or predators. If under any circumstances, the squirrel got disturbed by the presence of observers or other factors, the recording was discarded. Audios with maximum clarity of squirrel vocalizations were analyzed and rest of the audios were discarded. The selected recordings were run repeatedly and then uploaded to MATLAB software to generate audio spectrograms.

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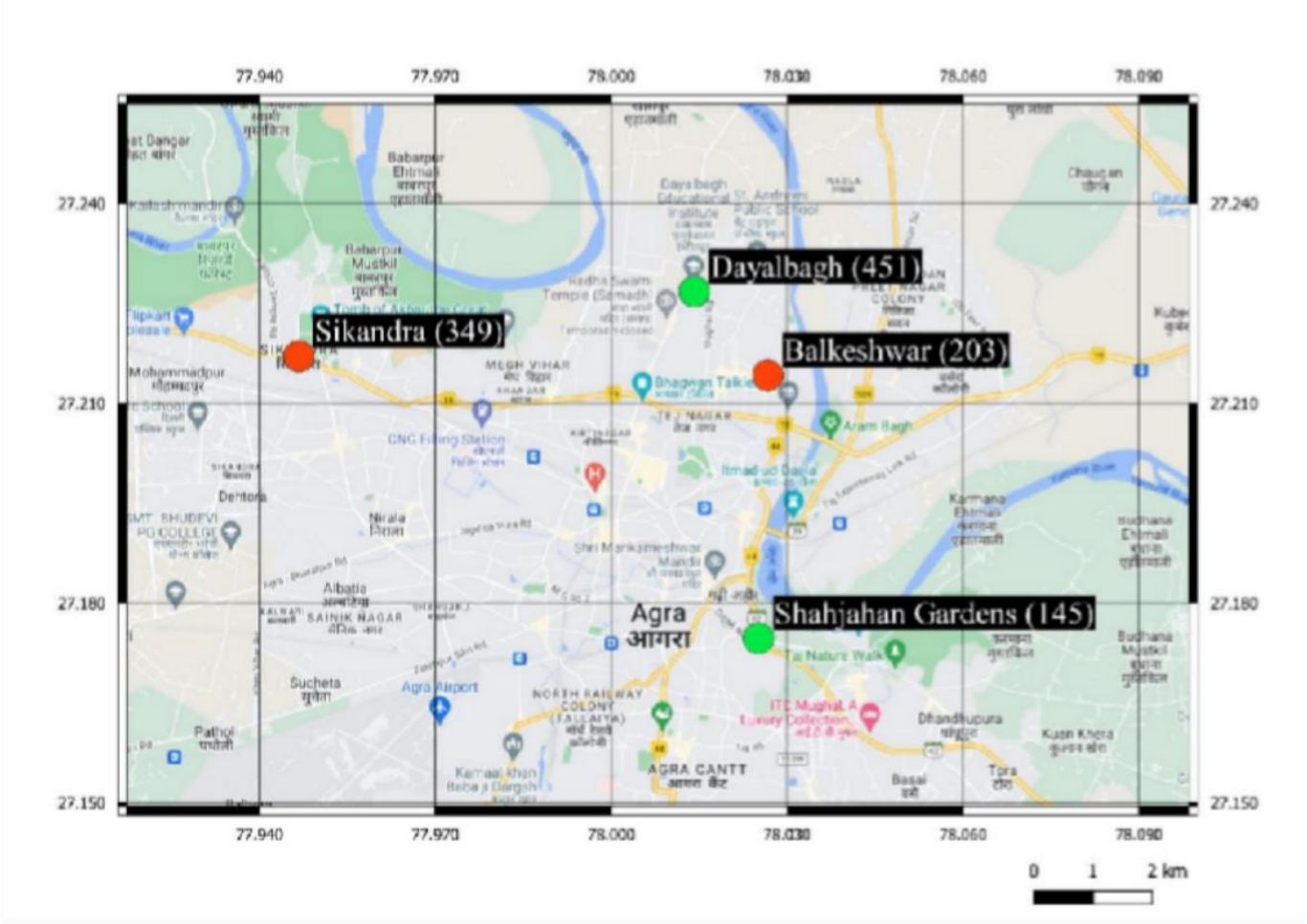

Figure 1: Location of clusters of squirrels at selected sites of Agra

Sample Size

There was no information on population trends at different sites. Thus, sample size was determined by applying Godden's formula for infinite population size **(Godden, 2004).**

$SS = Z^2 \times P \times (1-P) \; C^2$

Where, SS = Sample size

Z = Z value (1.96 at 5% confidence level) P = Percentage of population

C = confidence interval

Sample size obtained was approximately 400

RESULTS & DISCUSSION

This is the first report on vocalization patterns of *F. p. pennantii.* At all the four sites, the vocalization behavior was same and no differences were recorded. Squirrels actively communicated with the conspecifics and with individuals of other species viz House Crow (*Corvus splendens*), Human (*Homo sapiens*), Laughing Dove (*Spilopelia senegalensis)* and Rose ringed Parakeet (*Psittacula krameri)*. Usually, squirrels vocalized from the top of trees or walls. According to **Davis (1964),** "Syllable" is defined as a pattern separated from other such units in time. A "Preface syllable" is described as the first two or more syllables of a call that are significantly distinct from the rest of the call. The term "Call" is used for different and distinct types of acoustic signals. The vocalizations were identified as four distinct call types. Each pattern clearly translated into a distinct type of call.

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No intraspecific variations were observed. The frequency and duration, two basic characteristics of acoustic signals were different for each type of call as clearly identifiable patterns in the audio spectrograms.

Buzz calls

The preface syllables of this sound, which has a low frequency and pitch, remained between 2 and 5 kilohertz. This call is utilized by mother squirrels as a teaching tool to employ with their litter and juveniles. This sound is also produced by *F. p. pennantii* to interact with

conspecifics for mating chase and play. It is a long, looping sound that is frequently heard in quiet settings, like in the early morning **(Graph 1; Plate I).**

Our findings are supported by similar findings in the North American red squirrels. The mothers of this species use buzz calls to communicate with their young ones. It is a call related to juvenile play and considered under non aggressive behavior **(Lair, 1990).** According to **Smith (1978),** low frequency of this call indicates that the approaching squirrel is close by and that the caller is engaged in activities other than predator avoidance.

Growl calls

The preface syllables have frequencies that range from 2-4 kHz at their lowest and up to more than 9 kHz at their highest **(Graph 2; Plate II)**. It is a warning before a chase or assault on other species or conspecifics. When squirrels get ready to attack or chase away members of their own species or members of other species, they elicit this threat call. It is a short, sharp, and aggressive call that keeps repeating. After every syllable, there is a pause of 5–6 seconds. The squirrels fluff up and flick their tails during growls in order to appear bigger, imposing and frightening during assault or pursuit. This is because they typically pair their calls with visual signals. As a result, vocalization behaviour is displayed in a clear space, making it simple for the receiver to identify the caller visually.

Our findings are like those among ground squirrel species of the genus *Spermophilus* frequently **(Koeppl *et al*., 1978)**. Unreceptive estrous females of North American red squirrel (*Tamia sciurus*) produce growl calls when any male tries to approach them **(Smith, 1978; Lair, 1990).**

Bark calls

It is a cry with very high frequency notes. 3 kHz is the lower frequency and 7 to 10 kHz are the higher frequency notes. Each second, 2-3 syllables are created. The Bark is an alarm call and it is a predator class specific alarm call produced by *F. p. pennantii* which is of two types:

a) Aerial danger bark: When squirrels see an aerial predator, they emit an aerial danger bark at a frequency of 7-8 kHz to alert conspecifics **(Graph 3a; Plate IIIa)**.

b) Terrestrial danger bark: When a terrestrial predator or intruder is sighted, squirrels emit a loud, intense bark in order to warn nearby conspecifics. The frequency ranges between 8 to 10 kHz **(Graph 3b; Plate IIIb)**.

There is a good chance that *F. p. pennantii* alarm calls indicate the level of risk or the urgency of the response. *Funambulus palmarum* produces whistle alarm calls due to the presence of humans in their vicinity probably due to fear **(Koli *et* al., 2011).** Our findings are supported by a report on red squirrels by **Greene and Meagher (1997)** in which they identified acoustically different alarm calls in response to aerial danger and terrestrial danger. Southern Amazon red squirrels, *Sciurus spadiceus* have also been reported to use alarm calls to alert their conspecifics **(Eason, 2010).** Among the vocalization of all squirrel species, alarm calls are the most frequently produced vocalizations **(Diggins, 2021).** According to **Shelly and Blumstein (2004),** there is a link between alarm calling and diurnality as it becomes easy for the caller to detect the predator visually.

Similarly, Magpie robins (*Copsychus saularis ceylonensis*) produce mobbing calls in the presence of predators

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which also help other animal species to detect the location of the predator **(Wanniarachchi and Wijesundara, 2016).** Alarm calls communicate with predators also, after giving an alarm call by marmots, foxes are less likely to approach **(Lenti Boero, 1992).** In our study, no predator specific calls were identified. Contradictory to our findings, Prairie dogs (*Cynomys gunnisoni*) produce distinct alarm calls to convey descriptive information about the size, color and body shape of every individual predator as well as every human they detect **(Loughry *et al*., 2019).**

Rattle calls

In this type of sound, 4-5 syllables are produced every second. Lower frequency is about 4- 5kHz and higher frequency is 10-12kHz. Even in the absence of apparent intruders, *F. p. pennantii* can be heard making this sound from the top of the wall or tree marked by the squirrel as its territory. This sound is typically made by squirrels every day at a specific time for a long duration of about half an hour. It can continue even longer. It is produced at a specific time of the day and it is a daily routine **(Graph 4; Plate IV)**. This call's message transmission features built-in redundancy, ensuring that it reaches a wider area. Acoustic signals that are repeated typically have a higher chance of being heard. This call also included information on the caller's location, therefore it qualifies as aggressive behaviour.

According to **Koli and Bhatnagar (2014),** Indian giant flying squirrel, *Petaurista philippensis,* emits the territorial call around the nest tree before entering the nest. North American red squirrels also produce rattle calls to advertise their territory **(Gurnell, 1987).** Red squirrels produce the call to advertise their boundary throughout the day **(Siracusa, 2017).**

All our sampling locations are very complex urban or semi-urban environments with large branch networks, tree cavities, tree trunks as well as grounds, fields, roadsides, gardens, buildings, homes and public areas with human footfall as well as traffic. Therefore, a signal escape or defensive behavior tactic would not be suitable against all dangers and predators. The squirrels would require various escape strategies. In this case, selection might work in favour of the development of referential acoustic communication as stated by **Macedonia and Evans, 1993**.

Plate I: Buzz

Plate II: Growl

Plate IIIa: Aerial Danger Bark

Plate IIIb: Terrestrial Danger Bark

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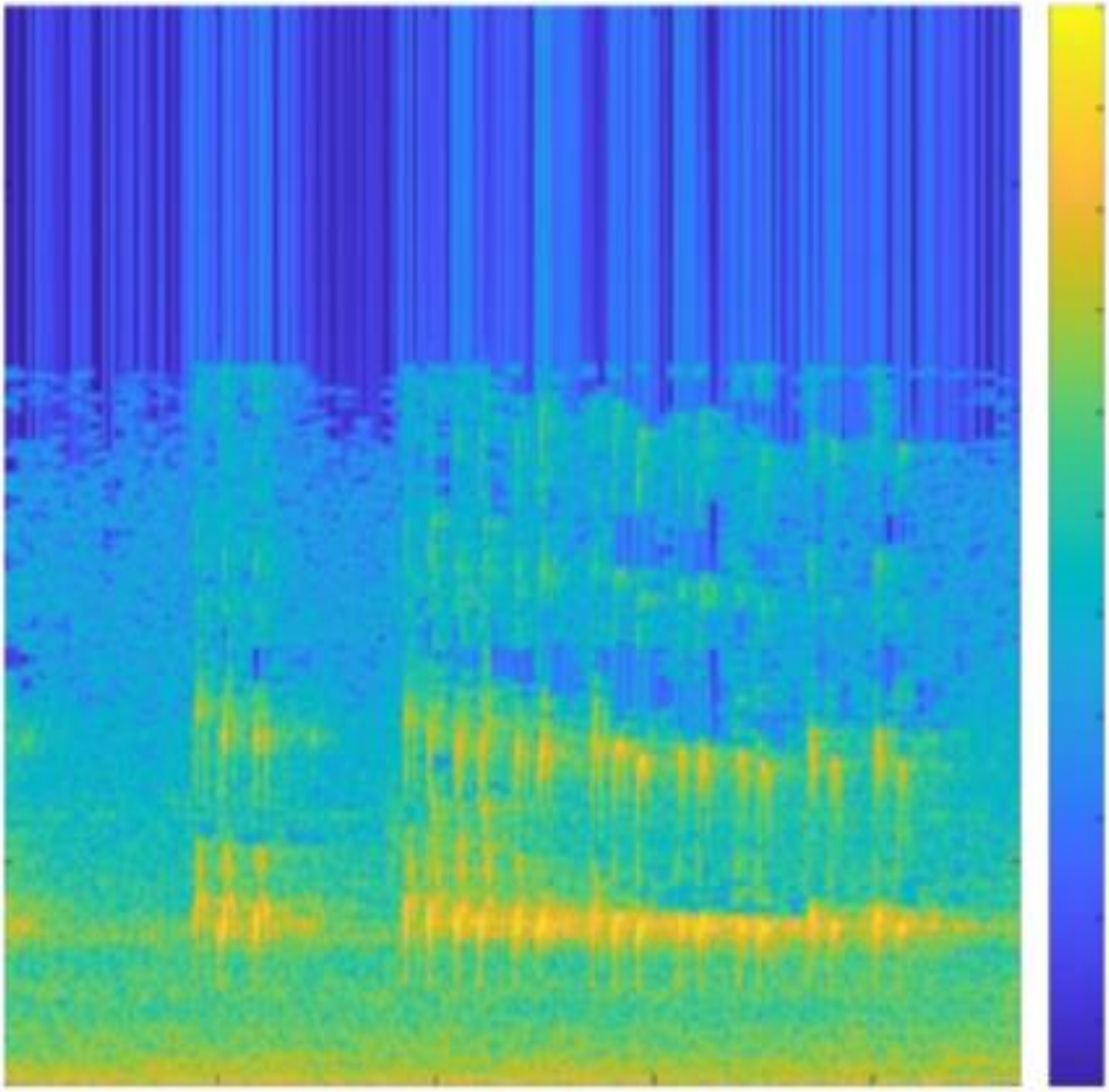
Plate IV: Rattle



GRAPH 1: SOUND ANALYSIS- BUZZ

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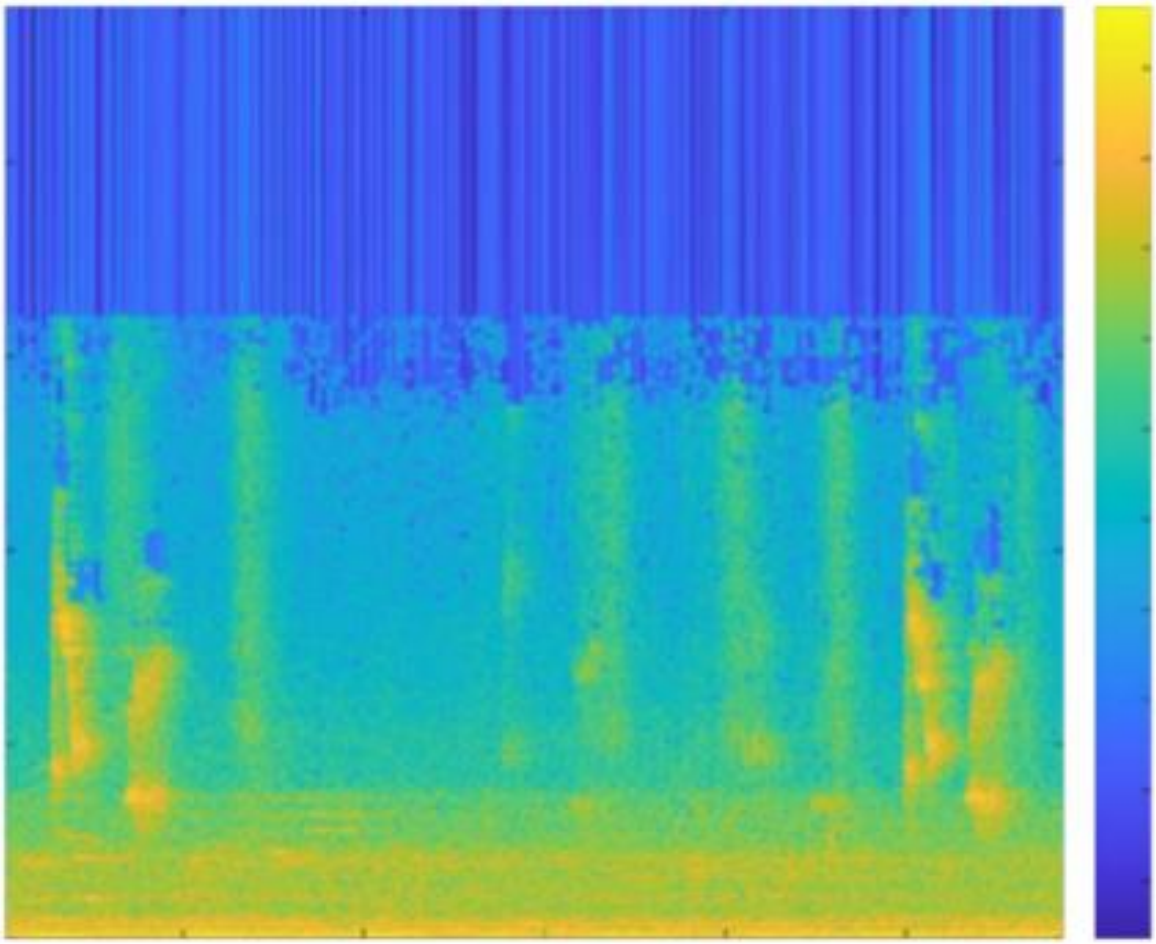
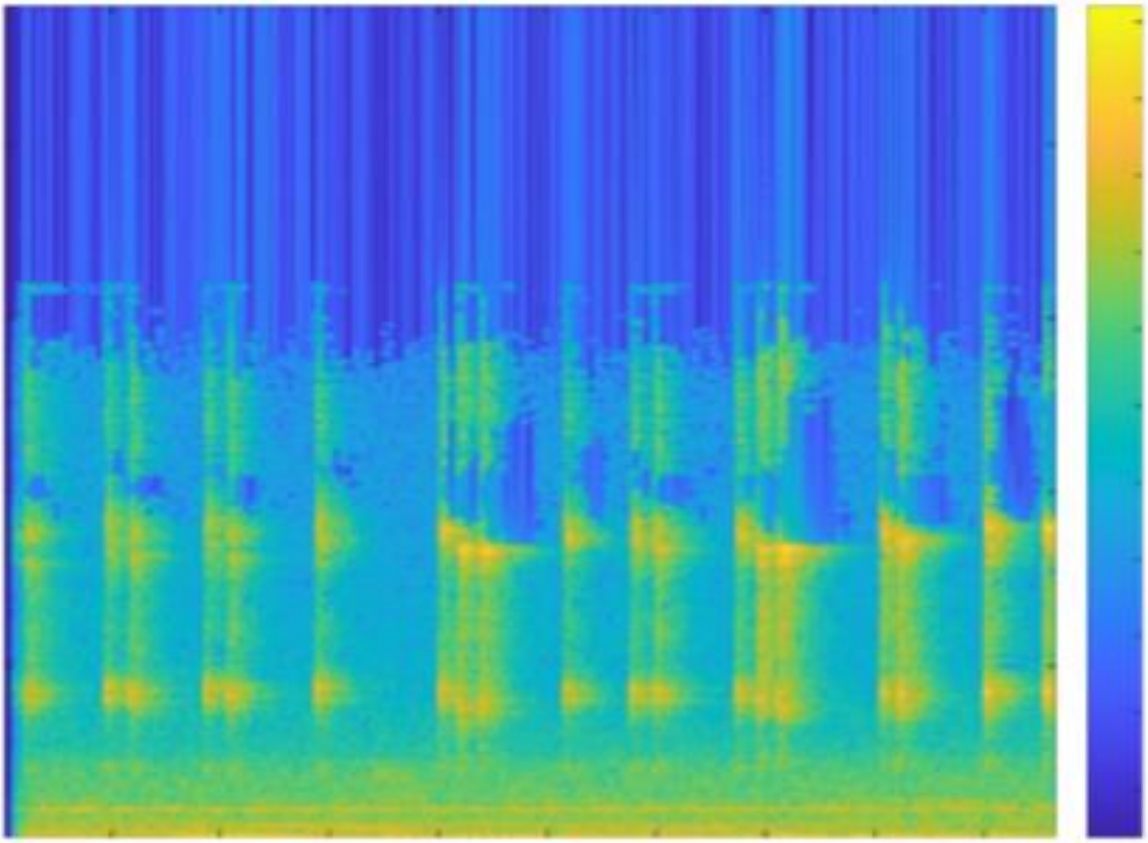


GRAPH 2: SOUND ANALYSIS- GROWL



GRAPH 3A: SOUND ANALYSIS- AERIAL DANGER BARK

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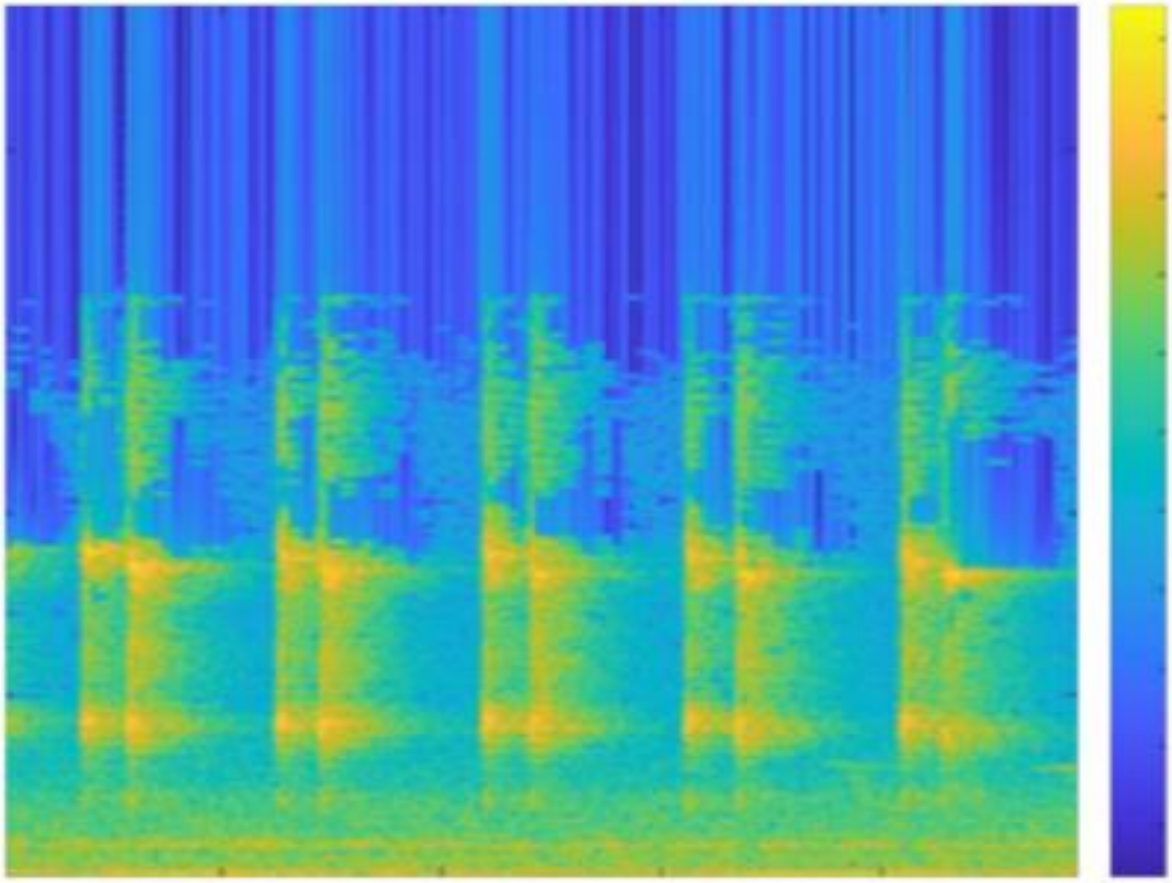
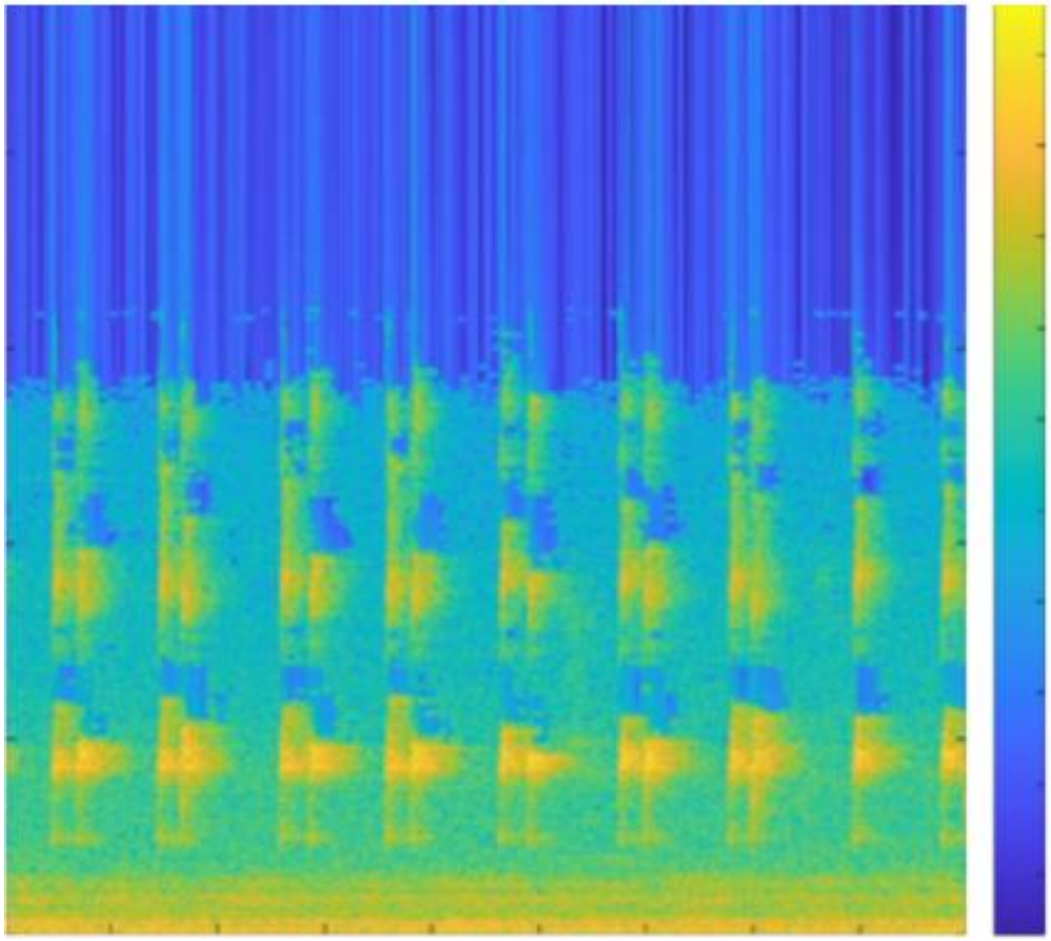


Graph 3b: Sound analysis- Terrestrial danger bark



Graph 4: Sound analysis- Rattle

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