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Original Research Article

Acoustic Behaviour and Responses of Stray Cows and Calves in Different Conditions

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Abstract

The main objective of this study is to identify the measurable difference in acoustic behaviour of street cows (*Bos indicus*) in different conditions. This study analyzes acoustic differences in animal vocalizations, focusing on call duration, pitch, formants, and pulse. Significant variations were observed in call duration, particularly for Low-Frequency Calls (LFC), which differed from all other types. Pitch also varied notably between LFC and High-Frequency Calls (HFC). Formant analysis revealed differences in the first and fourth formants, especially between HFC and calf calls. Pulse rates showed further variation across vocalization types. These findings highlight call duration and pitch as key features distinguishing different behavioural and emotional vocalizations.

Keywords: Acoustic, Formants, Pitch, Jitter, Shimmer, Pulse.

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INTRODUCTION

India has the largest cattle population in the world with 193.46 millions of cattle (*Launch of 21st Livestock Census*, 2024). As dairy farming has great economic benefits, the dairy industry is expanding further and assisting millions of jobs in India. The reverence of cows in India, rooted in ancient traditions, is being overshadowed by the growing exploitation of these animals in the dairy industry. Cattle barely express their injury and pain but by analyzing their behavioural indicators we can identify their body condition (Morgan & Doyle, 2015). Compared to humans, other animals are unable to relocate themselves and evacuate from harsh environmental conditions especially domesticated animals. Heat stress is the most common problem that is faced by both stray and dairy farm animals and it detrimentally influences the health and productivity of livestock (Chen *et al.,* 2024; Frigeri *et al.,* 2023; Gupta *et al.,* 2022; Oliveira *et al.,* 2025). Advance technologies and good welfare techniques can improve the living conditions of cattle because acoustic parameters also contain information of growth and development of animals (Briefer & McElligott., 2011).

Observations of street cattle vocalizations reveal that sounds of street cattle are rich, complex, and dynamic in occurrence with various characteristics, patterns, or features that needs closer examination and analysis. Cows produce different types of vocalizations like grunts, moos, snorts to communicate and express their emotional states like stress or hunger (Jobarteh *et al.,* 2024). A comprehensive examination of these vocalizations is essential to decipher their functional significance, including potential roles in communication, stress signalling, and environmental adaptation (Chhaya *et al.,* 2021; Farina, 2018). Elucidating the complexities of street cattle vocalizations can provide valuable insights into the behavioural ecology of these animals and inform strategies for managing their interactions with environments.

Due to limited access to veterinary care and the challenges of unstable urban settings and changing environmental conditions, stray or native cattle can be affected by diseases and can contribute in spreading any contagious infections and can cause economic loss (Pandey *et al.,* 2022). Non-invasive techniques such as acoustic monitoring offer a valuable approach for monitoring the health and behaviour of stray cows (Devi *et al.,* 2019; Green *et al.,* 2019). Stray animals, especially cattle, dwell in ever-changing town environments characterized by high levels of noise, multiple vehicles, unstable food supplies, and exposure to waste materials. These conditions differ significantly from the stable environments of farms, where animals receive regular care and nutrition. Due to the difference in environment, social interaction and psychological state, the difference in vocalization pattern can be seen between free ranging and captivated animals (Golosova *et al.,* 2017). Such unpredictable urban stressors are likely to influence vocalization patterns, physiological stress responses, and foraging behaviour (Yoshihara & Oya, 2021). However, these behavioural shifts are often overlooked in studies conducted under controlled farm settings, underscoring the importance of studying urban cattle in situ to gain a more accurate understanding of their welfare.

The main objective of our study is to gain more information on stray cow vocalization and understanding the context in which stray cows vocalize. Studying stray cow vocalization can help further comparative behavioural studies of both stray and domesticated cows.

MATERIALS AND METHODS

Study area

We conducted our study on stray cows- *Bos indicus* (Indian zebu cattle) at different locations in Udaipur region of Rajasthan, India (23°03′N to 30°12′N latitude and 69°30′E to 78°17′E longitude). Since stray cows tend to roam freely, they remain cautious, ever-aware of their surroundings. Collecting their acoustic data is quite challenging as they tend to move from one place to another. Stray cows may form bond with other animals and graze alongside them and can also stay vigilant around dogs and other animals. To find food, stray cows often wander around streets, market and fields. Many local people also offer food to stray cows as they are considered sacred in Hinduism. The acoustic behaviour of the stray cows was recorded between February 2022 to February 2024. We recorded normal cow communication calls (when cows produce vocal signal to maintain contact with herd members), cow-calf contact calls (when cow and its calf get separated from each other), feeding related calls or feed anticipation calls (when cows vocalize outside any home to get some food) and distress calls of street cows and calf (when cow or calf gets scared).

Data collection

The audio recordings were collected using ZoomH1n handy recorder (sampling rate- 44.1, 48 or 96kHz) and smartphones, placed 5 to 30 meters away from the subjected animals. We used field based observational and acoustic data collection process to collect the acoustic calls of the stray cows. The areas where stray cows frequently roamed were identified and the target area and subjected animal was chosen. We passively observed the subjected animals and recorded the vocalization from safe distance. Individual animals were followed to understand the behaviour and condition in which they vocalize. We observed whether the cow was searching for a calf or other conspecific, reacting to a stressor or in search of food, or when calf gets separated from its mother.

Sound Measurement and Data Analysis

The vocal calls of subjected animals were extracted with the help of AudioLab software which is an audio editing app from HitroLab. Then all the extracted vocal recordings were analyzed using Praat software (Boersma P. & Weenink D., University of Amsterdam, the Netherlands) version 6.4.27. Praat utilizes Fast and Fourier Transform to create spectrogram of acoustic files, showcasing frequency and time on a plot with sound density represented by different shades of grey. We measured call duration (time duration of individual vocal call), pitch (perceptual attribute of sound that corresponds to fundamental frequency, and is determined by the rate at which vocal folds vibrate or simply highness or lowness of sound), intensity (strength or loudness of sound), first four formants (resonant frequencies of vocal tract), pulse (brief, transient sound event characterized by sudden increase in amplitude followed by rapid decay), jitter (small, rapid fluctuations in the fundamental frequency) and shimmer (measure of cycle to cycle amplitude fluctuation) of each vocal signals.

Statistical Analysis

We analyzed total 260 calls of subjected animals, 33 general communication calls, 31 maternal Low Frequency Calls (LFC) and 76 maternal High Frequency Calls (HFC) of cow during mother-calf contact calls during separation (Padilla De La Torre *et al.,* 2015), 88 calf calls during separation, 18 distress calls when cows get scared from any other animal, vehicle or any other object and 14 feeding related calls, that is when cow produce acoustic signals outside home for attention to get food. Acoustic parameters like call duration, pitch, intensity, formant 1-4, pulses, jitter and shimmer of different types of cow and calf calls were recorded under various behavioural contexts. The data of each parameter were organized into separate excel sheet corresponding to each vocalization type. A one-way analysis of variance (ANOVA) was conducted to assess whether there were statistically significant differences in the measured acoustic features across different types of calls. Following ANOVA, post Hoc tests (Bonferroni Corrected) were performed to reduce false positive results and to identify specific group differences and determine which vocalization types or groups differed significantly from each other in their acoustic characteristics.

By selecting 2 columns at a time for six different types of calls, the number of unique pairwise comparison groups formed for the Bonferroni correction is: 15
$\alpha_{corrected}$= 0.05/15= 0.00333
So, (Bonferroni Corrected) α (alpha): 0.00333

The p-value of all the 15 groups were first calculated using t-test and then for a pairwise comparison to be considered statistically significant, its p-values were observed whether it is less than Bonferroni corrected alpha (0.0033) or not.

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RESULTS AND DISCUSSION

Our analysis focused on variables across different animal states, such as routine communication calls, calf calls, distress calls, maternal interaction and calls related to feeding as shown in the spectrograms given in Figure 1.

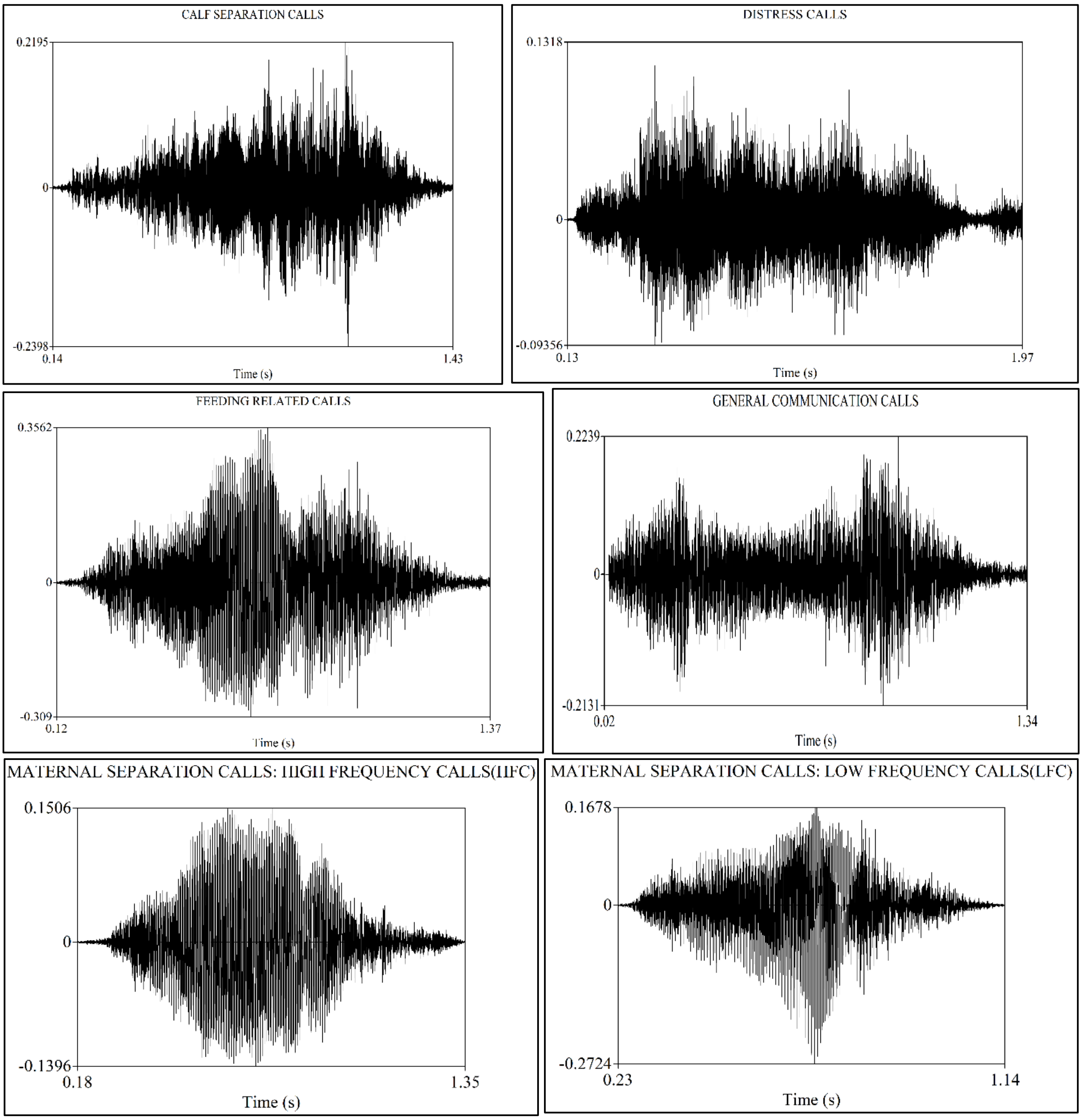

Figure 1: Spectrograms of different types of calls produced by cows and calves in different conditions. The x-axis represents time (in seconds), and the y-axis represents normalized amplitude. The waveform illustrates the temporal structure and intensity variation of the vocal signal over a duration of time

Significant differences were observed in call duration in the different types of vocalizations produced by subjected animals (Figure 2(A), $p < 0.001$, df = 5, 259, F 13.92 > F Crit 2.24). Post hoc test indicates that maternal LFC is significantly different in call duration compared to all other groups, and call duration of communication calls differs significantly from LFC, while maternal HFC call duration differs from distress call duration. Other groups (communication call, HFC, calf, distress, feeding) call duration show limited or no significant differences among themselves. The comparisons indicate that pitch significantly differs between some specific groups (Figure 2(B), $p < 0.001$, df = 5, 259, f 9.48 > F Crit 2.24). The Pitch differs significantly between specific group pairs, particularly involving LFC and HFC. These results suggest that Pitch is a distinguishing acoustic feature among several of the behavioural/emotional call types, especially involving

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LFC. LFC is again a strong differentiator, showing significant pitch differences from HFC, calf calls, distress, and communication calls. Only first and fourth formant show significant difference, in which Formant 1 values differ significantly only between the HFC (High-Frequency Call) and calf call groups (Figure 2(C), p value 0.0006 which is < 0.001, df = 5, 259, f > F Crit). Fourth formant shows significant differences between communication call and calf calls, HFC and calf calls, and calf calls and feeding related calls (Figure 2(D), p < 0.001, df = 5, 259, f 6.55 > F Crit 2.24). Pulse significantly differs between these pairs of groups. Specifically, LFC (Low-Frequency Call) and HFC (High-Frequency Call) are strong differentiators, showing significant differences with multiple other groups and vocalizations tied to behaviour and emotion can be effectively distinguished by variations in call duration and pitch (Figure 2(E), p < 0.001, df = 5, 259, F 12.74 > F Crit 2.24). No significant difference was found in intensity, formant 1, formant 2, jitter and shimmer of different types of calls in stray cows and calves.

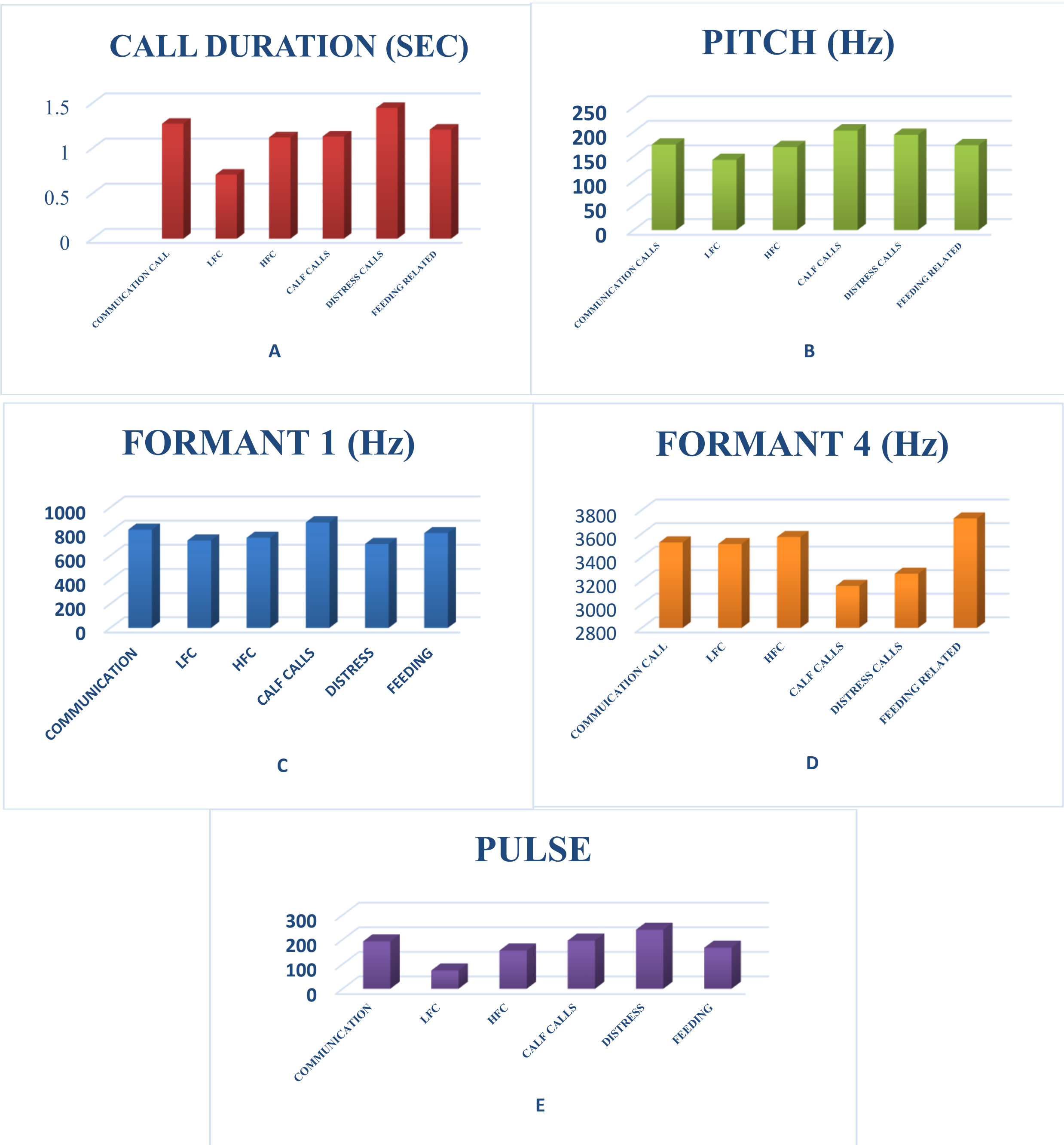

Figure 2: Characteristics of vocalization calls of cows and calves in different types of calls from spectrogram analysis: (A)3D Bar graph showing average call duration of different types of calls. (B) 3D Bar graph showing average Pitch of different types of calls. (C) 3D Bar graph showing average first formant of different types of calls. (D) 3D Bar graph showing average fourth formant of different types of calls. (E) 3D Bar graph showing average pulse of different types of calls

A growing body of research has established a significant connection between the acoustic characteristics of animal vocalizations and their emotional valence (Mcloughlin *et al.,* 2019). Specifically, studies have consistently demonstrated that shorter vocalizations are typically linked to positive emotional states, whereas longer vocalizations are often associated with negative emotions. (Briefer *et al.,* 2015). Call duration is a crucial parameter in acoustic research, as it exhibits variability in vocalizations produced by animals under different conditions (Bee *et al.,* 2013; Golosova *et al.,* 2017). Furthermore, the pitch of animal sounds has been found to be closely tied to arousal levels, with higher-pitched sounds indicating increased excitement or energy. Also some studies suggests that pitch modulates behaviour of animals (Chabert *et al.,* 2015). These findings lend strong support to the theory of acoustic universals, which posits that certain acoustic features are universally associated with specific emotional states across species. In our study only first and fourth formant differ significantly among groups and this result aligns with source filter theory.

CONCLUSION

The present study revealed significant differences in several acoustic parameters between cow and calf vocalization in different situations, indicating that these animals modify their calls depending on context and development stage. However, some acoustic features did not show significant variation, suggesting that certain stable vocal characteristics are maintained regardless of the condition. These findings contribute to deeper understanding of the vocal communication system in cows and calves, highlighting both flexibility and consistency in their acoustic signals.

Acoustic studies on stray cows are particularly important because these animals often face unique environmental stresses and social dynamics compared to farm animals. Understanding their vocal behaviour can aid in monitoring their welfare, managing human-animal conflict.

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