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AMPLITUDE AND FREQUENCY CHARACTERISTICS OF THE VOCALIZATIONS OF CANIDAE FAMILY, GENUS CANIS

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ABSTRACT

The present study aims to present and compare the sounds produced by the representatives of the family Canidae, in particular the genus Canis, in terms of their amplitude and frequency characteristics. The results show that the power generated by the vocal apparatus of wolves is the greatest, compared to that of the domestic dog and the jackal, in which they are the lowest, presented in dB. The reflected values for the frequency characteristic of the sound signals in these three representatives of the genus *Canis* are inversely related - highest in jackals, again average in dogs and lowest in wolves.

Key words: animal sounds, sound communication, soundgrams, *Canis aureus, Canis lupus, Canis lupus familiaris.*

Introduction

Differences in behavioral responses and lifestyles imposed by the domestication process in domestic and wild canids direct attention to vocal communication in this genus. The genus *Canis* includes the following species: *Canis adustus* (side-striped jackal), *Canis aureus* (golden jackal), *Canis latrans* (coyote), *Canis lupus* (gray wolf) with 38 subspecies (ITIS, 2023), *Canis mesomelas* (black-backed jackal), *Canis rufus* (red wolf) and *Canis simensis* (Ethiopian wolf) (Myers, P., 2023). *Canis aureus* (golden jackal), *Canis lupus* (gray wolf) and its relative *Canis lupus familiaris* (domestic dog) inhabit in the latitudes of Bulgaria, therefore these three species are the subject of the present study.

The vocal range of wolves is between 70 Hz and over 9900 Hz, as when communicating over long distances or during howling, wolves mainly stick to the low frequencies. Passilongo et al. (2010) indicated that the howling of wolves inhabiting the latitudes of Central Italy has an average frequency in the range between 274–908 Hz. Palacios et al. (2007) investigated the same value in Iberian wolves and reported a range of 270–720 Hz.

Geographic isolation and genetic divergence influence the acoustic characteristics of wolf howls (Hennelly, L. et al. 2017). The howl encode subspecies-specific patterns that give individual character to different wolf clans (Kershenbaum, A. et al., 2016).

The vocal apparatus of wild representatives of the genus *Canis* anatomically does not differ significantly from that of dogs, therefore the formant structure of the sounds they produce is largely similar. Formant frequencies directly depend on the length of the vocal tract, and the latter correlated with body size, since anatomically the skeletal structures limit the vocal tract. A longer vocal tract shapes sound with low resonant frequencies and therefore large representatives emit lower frequency sound signals compared to smaller ones (Plotsky, K. 2013, Faragó, T. et al., 2014).

Wolves can produce a sustained howl by raising their head and stretching their neck, thus elongating their pharynx. As the pharynx lengthens, a separation occurs between the soft palate and the epiglottis (Alexandrova, V. et al., 2015). In this way, the air is smoothly directed to the sound formants (oral cavity, teeth, cheeks, tongue, palate), which shape the sound wave. The howl has high

amplitude, duration between 1–10 s, often with an undulating fundamental frequency ranging from 150 to 2000 Hz (Cohen et Fox, 1976). There are two main types of howling: a “flat” and a more modulated “interrupting” howl (Palacios, 2007). The “flat” type have a stable fundamental frequency with a characteristic rise at the beginning, while the intermittent howl has a higher and more variable fundamental frequency characterized by abrupt changes, even pauses (Passilongo et al. 2010). The function that the howl performs is at two communicative levels: inter- and intragroup communication. Howling is known to play a role of in-group cohesion, facilitating the gathering of members by providing information about the location of individuals (Faragó, T., 2014). The fundamental frequency, especially its variability, makes the howl individually distinctive (Hull, C. et al., 2020). The fundamental frequency also carries information about the maturity of the individual: the howls of adults have a lower fundamental frequency than the howls of juveniles, and unfamiliar packs only respond to the howls of adults. The group howl often masks the true size of the pack (Faragó, T., 2014).

Compared to wolves and jackals, which bark less frequently, in dogs this is the main type of vocalization they use. The most prominent feature of the bark is its short duration (0.2–0.6 s) and spectral shape that resembles a "Christmas tree" formation due to the progressive decrease in energy at higher frequencies (Feddersen-Petersen D., 2000). The bark has variable fundamental frequencies (150–900 Hz) and in structure shows a typical curved shape with a rapid rise and fall in frequency. Barking can be single or in series. In wolves, low frequency barking is primarily used in the context of a threat, such as territorial defense or asserting dominance, while high frequency barking occurs more in fear. A dog's barking in an aggressive situation when approaching a stranger characterizes with multiple barks in rapid succession in the low frequency range. While in a play situation, it is a larger interval between vocalizations that are in the high frequency range (Yin S., 2002).

Materials and methods

A total of 120 sounds from 6 representatives of *Canis lupus familiaris* (domestic dog), 3 of *Canis lupus* (gray wolf) and 3 of *Canis aureus* (common jackal) were included in the present study. The sounds are converted in .mp3 format, with 16-bit depth encoding, sound density (Sample Rate) 44.1 kHz, single-channel (mono) signal. Each individual bark or howl was processed into a separate file, using only the clean recordings, those without background noise. Dog barking was chosen specifically in the context of cooperation and territory guarding because, from an ethological point of view, it is also the closest analog to jackal and wolf sounds in nature.

Raven Pro 1.6 licensed animal communication signal visualization, processing and analysis software was used to represent the sound wave graphs. The same allows for Power Density analysis or more soundgram, which is applied in the present study.

Results

The soundgram plots of Figure 1 show clearly distinguishable differences in amplitude-frequency coding in the three species of the *Canis* genus. From Figure 1 A (jackal), one can see a sharp spike in the power of the sound wave around 1000–1100 Hz and an equally sudden drop around 1100 Hz, after which the bandwidth of the sound wave remains constant and almost parallel to the abscissa, with very slight amplitude fluctuations at the end. Figure 1 B, characterizing a dog's bark, has a broad and smooth spike in the form of a plateau of power between 500 and 3000 Hz. Here, the power of the sound wave is distributed over a much wider section of the frequency band, which also

shows the greater vocal capabilities of the domestic dog, compared to the jackal. At high frequencies, here too, the amplitude fluctuations are weak. A different view is given by the plot of Figure 1 C, in the wolf, which shows fewer but sharper and stronger amplitude spikes, especially in the range between 300 and 5000 Hz.

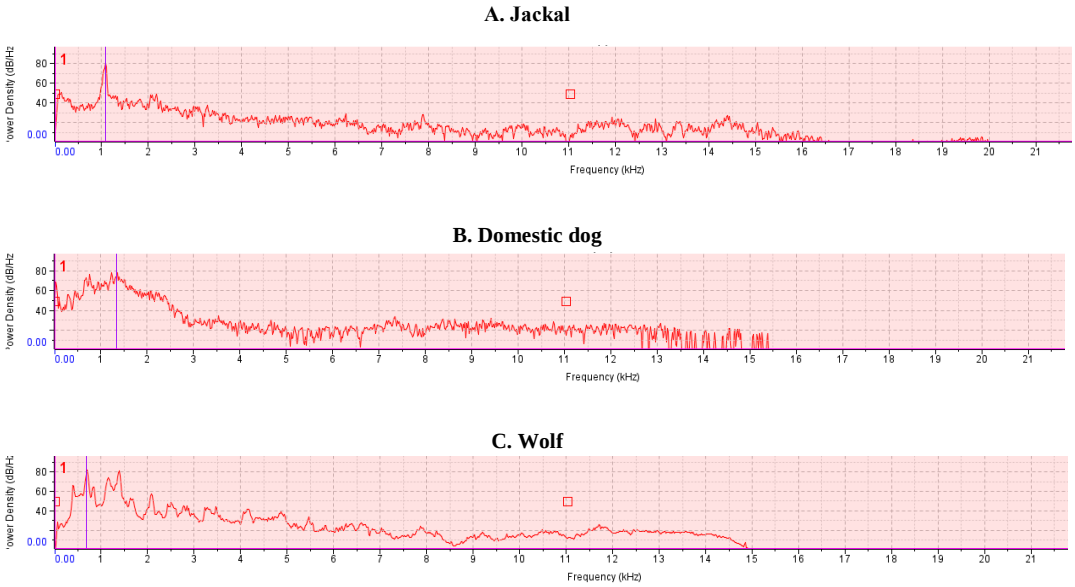

Figure 1*:* Soundgrams (spectrums) of vocalizations of A. Jackal, B. Domestic dog, C. Wolf

The power generated by the vocal apparatus of wolves (expressed in dB) was the greatest (89.17 dB), compared to that of the domestic dog and jackal, which were 87.9 dB and 83.3 dB, respectively. The frequency of the generated sound wave in wolves shows the lowest value of 678.3 Hz, while the same in the domestic dog is 695.75 Hz, and in the jackal – 1020.99 Hz. These data reflect Table 1 and Figure 2 A. and B.

Table 1*:* Mean values of amplitude (dB) and frequency (Hz) of vocalizations from jackal, domestic dog and wolf.

Animal species	dB	Hz
Jackal	83.3 dB	1020.99 Hz
Domestic dog	87.9 dB	695.75 Hz
Wolf	89.17 dB	678.3 Hz

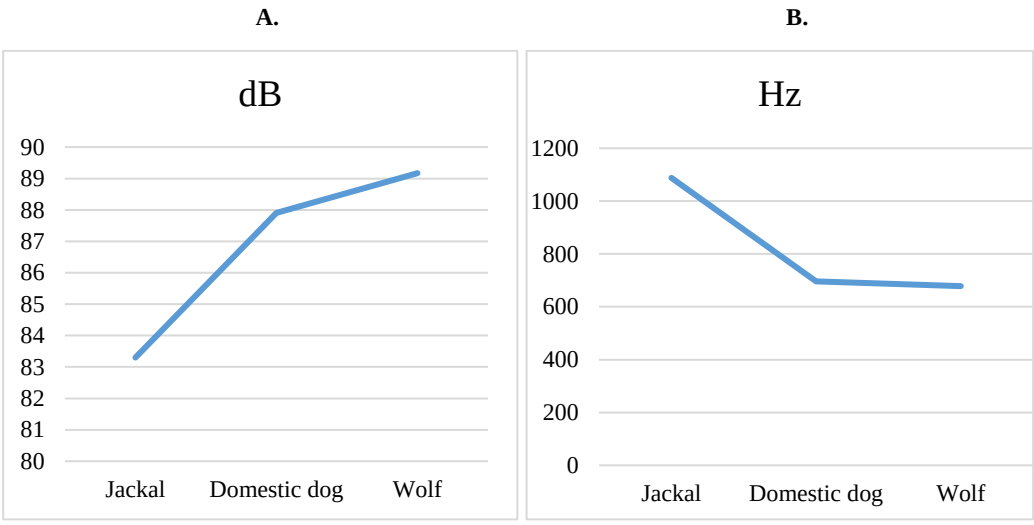

Figure 2: Mean values of A. amplitude (dB) and B. frequency (Hz) of vocalizations from jackal, domestic dog and wolf.

Discussion

The calculated mean values of the amplitude and frequency characteristics of sounds in a domestic dog, jackal and wolf show an interesting dependence in the parameters of the sound waves used in the intraspecies communication of these species. The sound power generated by the vocal apparatus of wolves (expressed in dB) was the greatest (89.17 dB), compared to that of the domestic dog and jackal, which were 87.9 dB and 83.3 dB, respectively. And the frequency of the generated sound wave in wolves shows the lowest value of 678.3 Hz, while the same in the domestic dog is 695.75 Hz, and in the jackal – 1020.99 Hz. This is explainable due to the fact that the howling of wolves can be heard at a distance of up to 10 km, and sound waves of the greatest length, from a physical point of view, have low frequencies and high amplitudes. The wave-like fundamental frequency is a confirmation of the research conducted by the pioneers of the bioacoustics - Cohen et Fox, 1976.

Our results for the mean wolf howl frequency of 678.3 Hz are also consistent with the data reported by Passilongo et al. (2010) and Palacios, (2007), Kostov Y. et al. (2012, 2011, 2010, 2009).

Barking has variable fundamental frequencies (150–900 Hz) according to Yin S., (2002), and these limits are comparable and include the parameters we established for the frequency response of dog barking. The obtained results for dog barking are also in confirmation of our previous studies (Alexandrova V. et al., 2021, 2020, 2010)

Communication in the domestic dog and in jackals is related to the transmission of information over shorter distances, therefore they also rarely make sounds with very low frequencies, and the amplitude is on average 85 dB.

Scientific data on the amplitude and frequency characteristics of the sounds emitted by the representatives of the family *Canidae*, genus *Canis*, are scarce, therefore the results presented by us at this stage are difficult to compare with those of other authors.

Conclusion

Thanks to its acoustic structure, the wolf's howl propagates unchanged over long distances, and therefore the information content remains reliably preserved. Jackals, given their smaller body size, produce sounds with a higher frequency and lower amplitude than wolves. Dogs occupy an intermediate place in this group of the three representatives of the genus *Canis*, distributed throughout the latitudes of the Republic of Bulgaria.

1. The power generated by the vocal apparatus of wolves is the greatest, compared to that of the domestic dog and the jackal, in which they are the lowest, presented in dB.

2. The reflected values for the frequency characteristic of the sound signals in these three representatives of the genus *Canis* are inversely related - highest in jackals, again average in dogs and lowest in wolves.

3. Evolution has shaped and differentiated these three representatives of the genus *Canis* in terms of some anatomical and physiological features, which has also affected their behavior and the characteristics of sound signaling and communication.

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