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Bioacoustic description of the alarm call of the stump-tailed porcupine (*Coendou rufescens*)

Descripción bioacústica del canto de alarma del puerco espín de cola corta (*Coendou rufescens*)

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Acoustic communication in rodents is complex and varied. However, bioacoustic studies of rodents in the wild are limited and scarce, most are performed, under controlled laboratory conditions. We recorded the alarm call of the short-tailed porcupine in the wild for the first time. Recordings were obtained in Guabisai, Sangay National Park, Ecuador. We opportunistically recorded the alarm call of an adult female *Coendou rufescens* in a direct encounter during its capture process. We analyzed 37 notes of 21 calls, categorizing the notes into 4 different types based on their spectral, temporal, and intensity characteristics (*i.e.*, fundamental, dominant and harmonic frequencies). The alarm call of *C. rufescens* consists of up to 4 notes. The sounds vary, ranging from chirps to nasal sounds, with the dominant frequency ranging from 0.34-2.50 kHz. The notes have different spectral and temporal characteristics. Therefore, the alarm call of *C. rufescens* presents a repertoire with different types of notes. Our preliminary observations suggest that their different types of sound are probably associated with anti-predatory behaviors, therefore we considered these sounds as alarm calls. This report provides baseline information for future bioacoustic studies on this species.

Key words: Alarm calls; dominant frequency; notes; repertoire; rodents.

La comunicación acústica en los roedores es compleja y variada. Sin embargo, los conocimientos sobre la acústica de los roedores en ambientes naturales son limitados y escasos. La mayor parte de estudios acústicos, han sido realizados en condiciones de laboratorio. Hemos grabado por primera vez los cantos del puercoespín de cola corta en un entorno natural. Las grabaciones fueron obtenidas en Guabisai, Parque Nacional Sangay, Ecuador. Grabamos de manera oportunista el canto de alarma de una hembra adulta de *Coendou rufescens* en un encuentro directo durante su proceso de captura. Se analizaron 37 notas de 21 cantos, clasificando las notas en 4 tipos diferentes basados en características espectrales, temporales y de intensidad (*i.e.*, frecuencias fundamentales, dominantes y armónicas). El canto de alarma de *C. rufescens* consta de hasta 4 notas. Los sonidos varían y van desde chirridos a sonidos nasales, con una frecuencia dominante que oscila entre 0.34 y 2.50 kHz. Las notas tienen características espectrales y temporales diferentes. Por lo tanto, el canto de alarma de *C. rufescens* presenta un repertorio con diferentes tipos de notas. Nuestras observaciones preliminares sugieren que sus diferentes tipos de sonido están probablemente asociados a comportamientos antipredadores, por lo que consideramos estos sonidos como cantos de alarma. Este reporte proporciona información de referencia para futuros estudios bioacústicos en esta especie.

Palabras clave: Canto de alarma; frecuencia dominante; notas; repertorio; roedores.

Acoustic communication in animals is very varied, using different types of sounds (*e.i.,* acoustic signals) to transmit a specific message or information (Simmons *et al.* 2003; Bradbury and Vehrencamp 2011). Rodents are a group of animals with very stealthy and silent behaviors, as they are under a high level of predation pressure. Because of this characteristic and despite being the most numerous order of mammals, very little is known about their acoustic communication (Brudzynski and Fletcher 2010). Much of the knowledge about rodent acoustic communication comes from controlled environments in the laboratory and few studies have described calls in the wild (Dent 2018).

The stump-tailed porcupine *Coendou rufescens* (Gray, 1865) is a medium-sized species, with a characteristic reddish color and a short non-prehensile tail (Voss 2015; Barthelmess 2016). It is a nocturnal arboreal and solitary species, that feeds mainly on wood, small insects and larvae (Vallejo and Boada 2021). It is distributed in the Andes of Colombia, Ecuador, northern Perú and Bolivia, across an altitudinal range from 800–4,387 m (Alberico *et al.* 1999; Voss 2011; Ramírez-Chaves *et al.* 2016; Acosta *et al.* 2018).

The bioacoustics studies in *Coendou* Lacépède, 1799 are somewhat scarce (Roberts *et al.* 1985). Even though research is available that presents integrative results (*e.g.*, Woods 1973; Voss *et al.* 2013; Torres-Martínez *et al.* 2019), the information about the calls in the wild is limited to observations and qualitative analysis (*i.e.*, anecdotal reports available in handbooks, videos and websites). This information gap occurs in the genus *Coendou* and most of the Old and New world porcupines.

The most comprehensive study describing the calls of this genus was done by Roberts *et al.* (1985). They described and categorized the calls of *Coendou prehensilis* (Linneo 1758) into different types of sound, assigning to each one a specific social context. Therefore, considering that the calls and most of the behavioral repertoire of *Coendou rufescens* are unknown (Voss 2015), we contribute to the knowledge of this species by describing for the first time the calls of *C. rufescens*, with quantitative information about its spectral and temporal parameters.

On April 28, 2015, 2 individuals of *C. rufescens* approached our cabin (basecamp) in Guabisai, Sangay National Park, Ecuador (2° 23' 19'' S, 78° 18' 59'' W, datum WGS84; 2,554 m) at 18:50 hr. We unexpectedly and opportunistically recorded an adult female *C. rufescens* while emitting calls in a direct encounter, being intercepted and cornered for capture. The individual was detected approached the cabin (basecamp), apparently searching pieces of wood to gnaw (Brito and Ojala-Barbour 2016). We recorded the calls using an Olympus® WS-802 digital recorder with a sample rate of 44.1 kHz and 16-bit resolution and saving the files in an uncompressed WAV format.

We performed acoustic analyses using Raven Pro v1.6 (K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology 2022), with the following settings: Hann window, 90 % overlap and DFT size of 512 points. We plotted the oscillograms and spectrograms with the Seewave R-package v2.2.0 (Sueur *et al.* 2008; R Development Core Team 2022). We used a Hanning window type with 90 % overlap, FFT window width of 512 points. We also used a frequency limit of 18 kHz and a dynamic range of -80–0 dB. We imported the WAV files using the tuneR package v1.4.1 (Ligges et al. 2018).

We analyzed 37 notes from 21 calls, corresponding to a single individual. We classified the notes of the calls, using their spectral structure as the main classification criterion (*i.e.*, fundamental, dominant and harmonic frequencies). We calculated the mean, maximum, minimum and standard deviation of the analyzed parameters.

We determined the following temporal and spectral parameters (see Figure 1): Fundamental frequency (FF): is the first harmonic or is the lowest frequency in the frequency spectrum; Dominant frequency (DF): frequency of highest energy or with the highest intensity determined

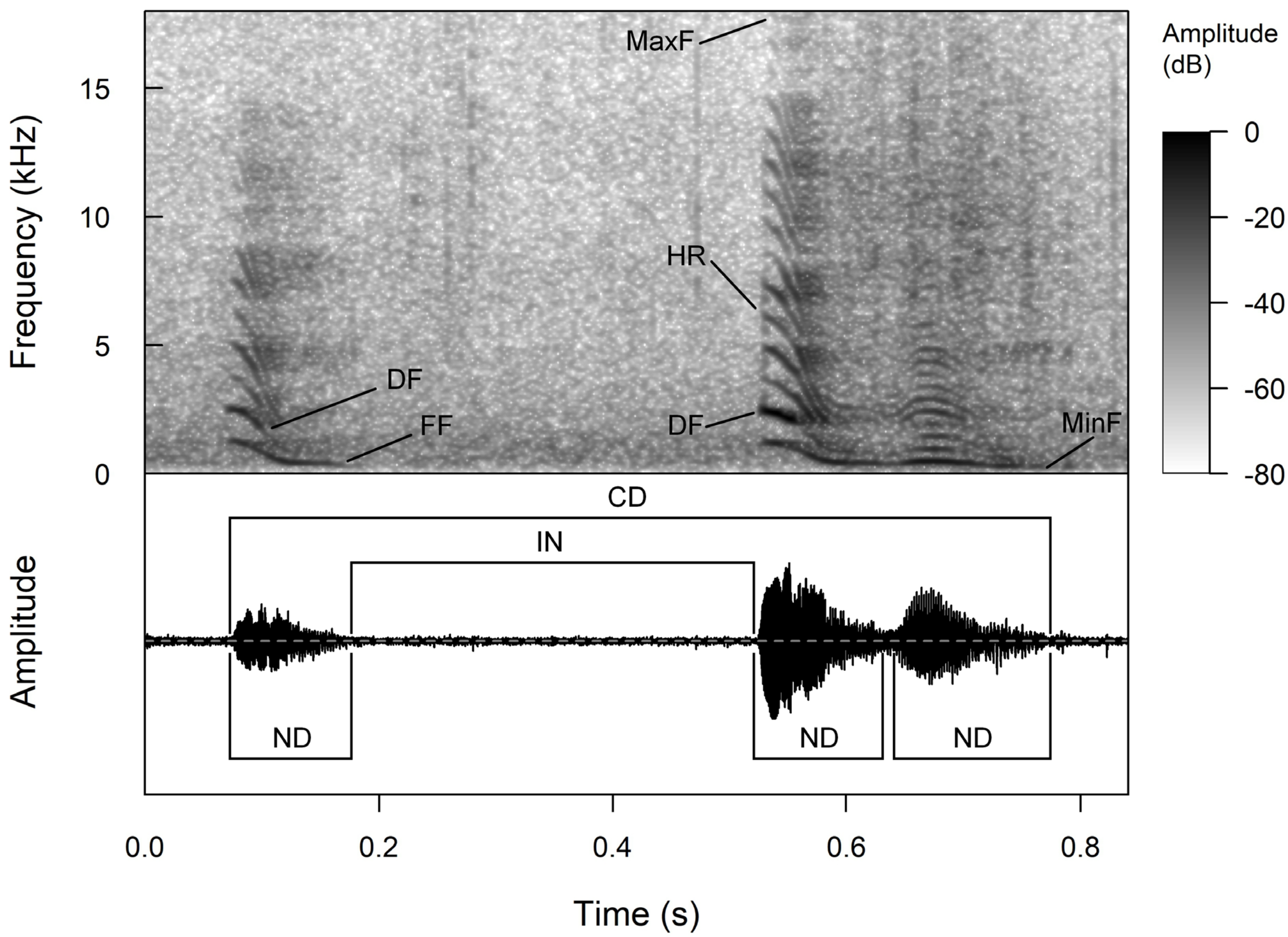

Figure 1. Acoustic parameters analyzed in the call of *Coendou rufescens* (MECN 4343). Abbreviations correspond to: FF = Fundamental frequency; DF = Dominant frequency; MinF = Minimum frequency; MaxF = Maximum frequency; HR = Harmonics; CD = Call duration; ND = Note duration; IN = interval between notes; kHz = kilohertz; dB = decibel; s = second.

from the Fourier transform; Frequency modulation (FM): difference of frequencies between the initial and final points in an acoustic structure; Minimum frequency (MinF): lowest visible frequency in the spectrum; Maximum frequency (MaxF): highest visible frequency value in the spectrum; Number of harmonics detected (NH): number of bands present in the frequency spectrum. A harmonic is an overtone that is a multiple of the fundamental frequency; Call duration (CD): time from beginning to end of one call; Interval between calls (IC): time between distinct calls; Call rate (CR): total number of calls calculated over a given time; Notes per call (NC): Number of notes that make up a call. In this analysis we consider a note to be the main subunit of a call; Note duration (ND): time from beginning to end of one note; Note rise time (NRT): time from the beginning to the point of maximum amplitude of note; interval between notes (IN): time between distinct notes; Note rate (NR): total number of notes calculated in a given period of time.

Definitions, terminology and acoustic measurements followed methodology detailed on Francescoli (1999), Tokumaru *et al.* (2004) and Brito *et al.* (2017). We complement the information on the acoustic parameters, following the measures and definitions proposed by Cocroft and Ryan (1995), Hartmann and Candy (2014), Köhler *et al.* (2017) and Sueur (2018).

Recordings can be accessed through the Fonoteca Zoológica del Museo Nacional de Ciencias Naturales (CSIC), Madrid, Spain (FZ sound code 12023) in the following link (http://bit.ly/3UO9vSs). In addition, we collected the specimen and deposited it at the Instituto Nacional de Biodiversidad, Quito, Ecuador (MECN 4343; skin and skull). The specimen collected is part of the reports and observations obtained in the project "Diversidad de pequeños vertebrados en dos áreas del Parque Nacional Sangay" (see Brito and Ojala-Barbour 2016; Romero *et al.* 2018).

The alarm call of *C. rufescens* is composed by the emission of a series of 1 to 3 short notes, with a mean dominant frequency of 1.30 kHz. Their sounds are very varied, ranging from chirps to nasal sounds that can be described as moan, gasp or growl. We report the spectral and temporal parameters in Table 1.

The call of *C. rufescens* do not present stereotyped notes. They have 4 different types of notes, emitted as a single call, or as a series of notes in the same call. The different types of notes present differences at the level of its spectral and temporal structure. Type 1 note shows many visible harmonics and a frequency with descending modulation (Figure 2A). Type 2 note is very similar to type 1; however, it has a lower number of harmonics and a higher value at the frequency modulation (Figure 2B). The sounds of these 2 types of notes are high-pitched squeaks, which show a higher intensity compared to the other types of notes, therefore, they are easily heard and are the most common in the repertoire. Type 3 note has a slight modulation in its first harmonic, with an ascending-descending modulation (∩-shaped) that is most noticeable from the fourth harmonic. It is a nasal sound that can be described as subtle moans or growls of short duration and medium intensity (Figure 2C). Type 4 notes are constant frequency, with undifferentiable harmonics. Their sounds are very similar to low intensity exhalations or gasps (Figure 2D). Temporal and spectral measurements of the notes are shown in Table 1.

The call of *C. rufescens* is a repertoire of different types of notes, which can be associated with defensive behaviors

Table 1. Descriptive statistics of call parameters of one individual of *Coendou rufescens*. The measurements of the 4 types of notes are also shown (see text for description of each one). The abbreviations correspond to: FF= Fundamental frequency; DF= Dominant frequency; FM= Frequency modulation; MinF= Minimum frequency; MaxF= Maximum frequency; NH= Number of harmonics; CD= Call duration; IC= Interval between calls; CR= Call rate; NC= Notes per call; ND= Note duration; NRT= Note rise time; IN= interval between notes; NR= Note rate. The abbreviations used in units of measurement correspond to: kHz = kilohertz; ms = milliseconds; /min= per minute; /s = per second.

Parameters	Call	Notes			
	(general)	Type 1	Type 2	Type 3	Type 4
FF (kHz)	0.34-1.21 (0.67 ± 0.33)	0.34-0.82 (0.51 ± 0.17)	0.34-1.21 (0.93 ± 0.34)	0.47-0.52 (0.49 ± 0.02)	0.34-0.39 (0.38 ± 0.02)
DF (kHz)	0.34-2.50 (1.30 ± 0.82)	0.47-2.15 (0.80 ± 0.44)	0.99-2.50 (2.06 ± 0.42)	0.47-2.02 (0.99 ± 0.90)	0.34-0.39 (0.38 ± 0.02)
FM (kHz)	0.13-0.90 (0.67 ± 0.21)	0.43-0.73 (0.55 ± 0.11)	0.73-0.90 (0.82 ± 0.05)	0.13-0.17	–
MinF (kHz)	0.10-0.32 (0.21 ± 0.06)	0.10-0.20 (0.17 ± 0.03)	0.11-0.32 (0.23 ± 0.06)	0.21-0.32 (0.26 ± 0.06)	0.20-0.29 (0.24 ± 0.04)
MaxF (kHz)	12.26-20.62 (15.03 ± 1.65)	13.40-20.62 (15.24 ± 1.97)	13.17-19.07 (15.49 ± 1.53)	13.16-15.32 (14.09 ± 1.11)	12.26-14.80 (13.89 ± 0.87)
NH	6-21 (12.74 ± 3.89)	11-21(17 ± 3.51)	10-16 (12.38 ± 1.41)	10-14 (12.33 ± 2.08)	6
CD (ms)	47-1088 (348.90 ± 327.52)	–	–	–	–
IC (ms)	932-4641 (2227.45 ± 1025.39)	–	–	–	–
CR (/min)	12.77-55.61 (26.83 ± 10.51)	–	–	–	–
NC	1-3 (1.62 ± 0.74)	–	–	–	–
ND (ms)	47-180 (97.53 ± 23.76)	72-132 (101.05 ± 17.22)	81-180 (108.14 ± 21.08)	67-120 (86.93 ± 28.87)	47-84 (67.52 ± 14.32)
NRT (ms)	8-46 (28.67 ± 8.58)	12-46 (34.86 ± 11.76)	16-40 (26.94 ± 6.43)	29-31 (29.37 ± 1.26)	8-44 (26.16± 14.45)
IN (ms)	86-685 (29.20 ± 15.19)	–	–	–	–
NR (/s)	1.18-6.67 (1.84 ± 3.47)	–	–	–	–

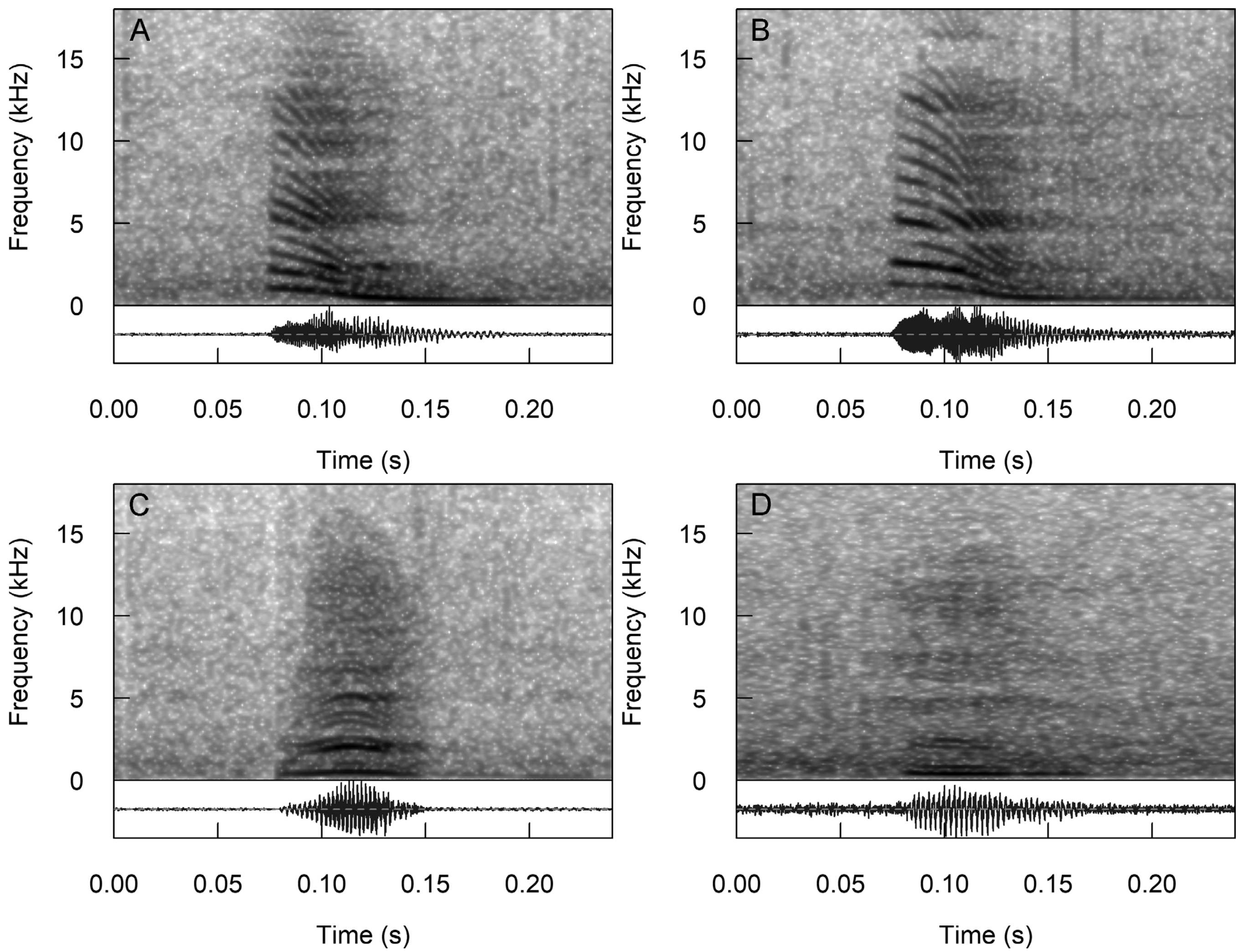

Figure 2. Types of notes present in the call of *Coendou rufescens* (MECN 4343). A= type 1; B = type 2; C = type 3; D = type 4; kHz = kilohertz; s = second.

(alarm calls). In this report, we classified and characterized 4 types of notes that compose the call of *C. rufescens* from recordings obtained in the wild for the first time.

A previous description of the calls of a *Coendou* species was made by Roberts *et al.* (1985). They classified the calls of *C. prehensilis*, based on Eisenberg *et al.* (1975), into 2 general categories: broadband and tonal sounds. According to this classification, the calls of *C. rufescens* would be classified as tonal sounds because their duration and harmonic characteristics. The calls of *C. rufescens* differ from those of *C. prehensilis*, because they present higher values of maximum frequency (3–10 kHz in *C. prehensilis*) and a lower fundamental frequency (0.2–2.5 kHz in *C. prehensilis*). In both species, the dominant frequency typically coincides with the fundamental frequency.

We do not associate any sound emitted by *C. rufescens* with a specific context due to the preliminary and descriptive character of our study. However, Roberts *et al.* (1985) mention that sounds with descending modulation are related to aggressive or threatening contexts. In rodents, alarm calls are emitted as part of an antipredator behavior and its purpose is to discourage or evade attack (Shelley and Blumstein 2004; Okanoya and Screven 2018). For the peculiarity of the recording event (*i.e.*, emitting calls in a direct encounter when it was cornered), these calls could be alarm calls (Blumstein 2007). It is important to highlight that the recordings analyzed in this study were obtained opportunistically and we cannot completely infer the function of the calls. However, this descriptive report can be useful as baseline information for future acoustic studies on the species. Future studies should take into account the behavioral context in order to infer specific functions (*e.g.*, alarming, anti-depredatory, aggression, distress) of different types of calls emitted in natural conditions.

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