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The advertisement call of the Santa Marta robber frog *Serranobatrachus sanctaemartae*

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The recently erected genus *Serranobatrachus* Arroyo et al. (2022) — superfamily Brachycephaloidea — is a group of frogs that undergo direct development, and currently comprises seven species (Frost, 2024). All these species are endemic to the Sierra Nevada de Santa Marta in Colombia, a unique mountain range with high rates of endemism (Arroyo et al., 2022; Rada et al., 2019; Sánchez-Pacheco et al., 2017). One of these endemics, the Santa Marta robber frog, *Serranobatrachus sanctaemartae* (Ruthvens, 1917), is a nocturnal species that occurs in the cloud forest of the north-western flank of the Sierra Nevada de Santa Marta between 1100–2450 m a.s.l. (Arroyo et al., 2022; Ruthven, 1917), but little more is known about the natural history of this species.

The advertisement call is the most widely studied acoustic signal of frogs. It is broadly recognised as a prezygotic isolation barrier and thus a tool for species recognition (Köhler et al., 2017; Rivera-Correa et al., 2021; Toledo et al., 2015). To date there are no detailed descriptions of the advertisement calls of any *Serranobatrachus* spp. Herein, I describe the advertisement call of *S. sanctaemartae*.

Advertisement call recordings were made at a sampling rate of 48 kHz and 16-bit resolution with a Marantz PMD661MKII digital recorder with a coupled Sennheiser ME 66/k6 shotgun microphone and a Xiaomi Redmi Note 8 mobile phone using the default recording app set in WAV format. No temperature and humidity data were taken. The recording devices were positioned about one metre from the calling males. 'Voucher' recordings of the original calls have been deposited in the Banco de Sonidos OcainaCua (BSOC) from the Museo de Ciencias Naturales de La Salle (BSOC204–206).

All measurements of the call traits were made using the Raven Pro Software Program 1.6 (Lisa Yang Centre for Conservation Bioacoustics, 2023) and follow standard terminology and methodology (Köhler et al., 2017; Zollinger et al., 2012). Based upon the call type of *S. sanctaemartae*, the note-centred approach proposed by Köhler et al. (2017) was adopted. The temporal features of the call (call/note duration and note/call interval) were measured in oscillograms, and power spectra diagrams were used to obtain the spectral features of the call (bandwidth, dominant frequency, low frequency and high frequency). Spectrograms were only used for visual support, as suggested by Zollinger et al. (2012). Recordings were analysed using a Hann window function, a DFT of 512 points and overlap of 50%. A 20 dB threshold from the peak amplitude was used to select the sound of interest (Fig. 1B). The Seewave 2.2.3 (Sueur et al., 2008) package in R 4.4.1 (R Core Team, 2023) was used to create spectrographic depictions.

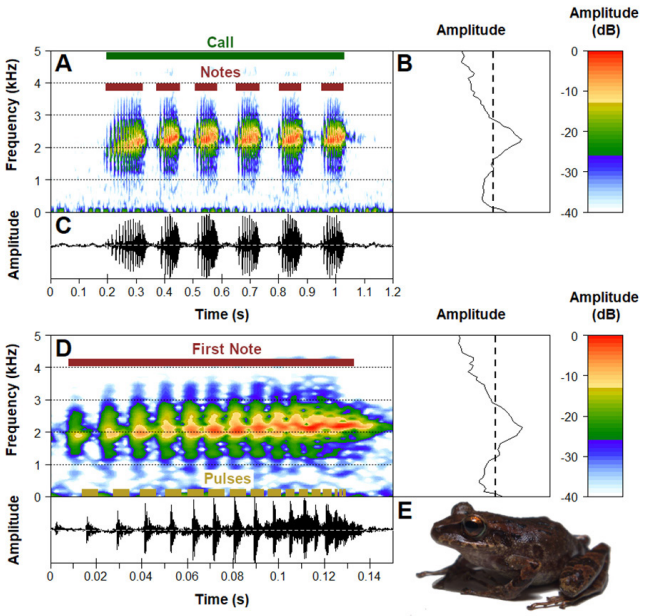

Figure 1. The advertisement call of *Serranobatrachus sanctaemartae* - **A.** Spectrogram, **B.** Power spectrum diagram, **C.** Oscillogram, and **D.** Zoom of the first note of the six-note call, **E.** *Serranobatrachus sanctaemartae*. Sound recording was from male EAFIT-Am 0658, archived in Banco de Sonidos OcainaCua (BSOC206). Dotted line in the power spectrum diagrams represents the 20 dB threshold from the peak amplitude.

For the statistical description, the recorded males were defined as the sampling unit for analysis. In other words, the mean of the spectral and temporal parameters of the call and note for each male was calculated, and then a new weighed mean and standard deviation were calculated for the population. In the text, measurements were given as mean ± standard deviation (min–max).

Given that this is the first report of the advertisement call of this species, voucher specimens that complement the voucher recordings have been deposited for the purpose of taxonomic traceability (Obrist et al., 2010). Specimens were sacrificed with an overdose of 5% xylocaine, fixed in 10% formalin and preserved in 70% ethanol. The specimens

Table 1. Descriptive statistics of advertisement call parameters of two specimens *Serranobatrachus sanctaemartae*. mean ± standard deviation (min–max). Unless otherwise noted n = 5.

Parameters	Pulses per note	Call/note duration (s)	Call/note interval (s)	Low freq (Hz)	High freq (Hz)	Bandwidth (Hz)	Dominant freq (Hz)
Call	77.8±20.62 (69–98)	0.828±0.213 (0.668–1.014)	90.877±16.069 (79.514–102.240; n = 2)	1793.9±178.9 (1671.9–1916.3)	3003.9±420.6 (2720.9–3303.3)	1209.9±265.8 (1027.2–1386.9)	2266.6±63.9 (2239.4–2343.7)
First note	16.6±3.04 (15–19)	0.133±0.008 (0.126–0.140)	0.036±0.012 (0.024–0.043)	1512.6±373.2 (1242.3–1699.2)	3020.3±366.1 (2764.7–3303.3)	1507.7±294.8 (1218.4–1639.9)	2193.1±80.4 (2153.3–2250)
Second note	10.6±0.93 (10–11)	0.079±0.014 (0.069–0.091)	0.051±0.005 (0.048–0.055)	1874.7±229.7 (1721.5–2051.5)	2994.9±390.6 (2742.8–3299.4)	1120.2±222.3 (967.1–1321.3)	2304.1±89.9 (2239.4–2343.7)
Third note	12.8±5.24 (10–18)	0.083±0.008 (0.074–0.088)	0.057±0.00 6(0.052–0.063)	1892.5±240.8 (1714.4–2055.4)	2981.8±415.4 (2688.2–3276.2)	1089.2±236.4 (917.9–1244.0)	2285.4±82.8 (2239.4–2343.7)
Fourth note	12.2±4.11 (10–16)	0.086±0.006 (0.081–0.090)	0.060±0.006 (0.054–0.063)	1862.9±242.9 (1693.1–2032.2)	2997.2±424.4 (2704.6–3291.7)	1134.2±234 (972.5–1278.8)	2285.4±82.8 (2239.4–2343.7)
Fifth note	13.2±4.96 (11–18)	0.085±0.010 (0.079–0.094)	0.070±0.017 (0.063–0.091)	1864.9±242.4 (1693.1–2020.6)	2995.7±441.9 (2688.2–3318.7)	1130.8±264.4 (956.1–1325.2)	2286.9±141.6 (2153.3–2343.7)
Sixth note	12.4±3.59 (11–16)	0.085±0.016 (0.071–0.097; n = 4)		1880.6±195.9 (1717.9–2009.0)	3038.8±433.7 (2818.3–3376.7)	1158.1±271.5 (988.9–1367.7)	2247.9±8 (2239.4–2250)

were prepared following Heyer et al. (1994) and identified following Arroyo et al. (2022), Lynch & Ruiz-Carranza (1985) and Ruthven (1917). Specimens were deposited at the Amphibian Collection of Universidad EAFIT (EAFIT-Am). Snout-vent length (SVL) was measured with a Mitutoyo digital caliper (precision ± 0.01 mm).

From the 6–9 May 2024 at the Reserva las Nubes, Santa Marta, Magdalena (11.15365°, -74.06770°; 1,486 m a.s.l.), a locality at 5.67 km in a straight line from the type locality, a population of actively calling males of *S. sanctaemartae* was found around a river canyon. Individuals started calling from approximately 19:00 h onwards. On 8 May 2024 at around 21:00 h, a total of five calls were recorded from two collected males (EAFIT-Am 0657, SVL:32.78 mm, two calls and EAFIT-Am 0658, SVL:32.88 mm, three calls). Both males were found in a riparian forest, perched 30 cm above ground on the edge of a 3 m long cleft leading to a creek.

The advertisement call of *S. sanctaemartae* consists of five to seven (mode = 6) loud, non-frequency modulated, rapidly repeated, pulsed notes (Fig. 1). The call duration was 0.828 ± 0.213 s (0.668–1.014 s; n = 5; Fig. 1C; Table 1), and the call interval was 90.877 ± 16.069 s (79.514–102.239 s; n = 2). The dominant frequency of the call when the energy reached peaks in the band was 2266 ± 63.9 Hz (2239–2343 Hz; n = 5; Fig. 1B; Table 1). The duration of the first note appears to be longer than the remaining notes (Table 1). The silent interval between notes appears to be shorter at the beginning and longer at the end of the call (Table 1). A complete report of the spectral and temporal parameters is given in Table 1.

Although the lack of formal descriptions for any other species of the genus *Serranobatrachus* prevents comparisons, there are descriptions of the advertisement calls for a couple of species of the genus *Tachiramantis* — *T. douglasi* and *T. lassoalcalai*, the sister clade of *Serranoatrachus*. The advertisement call of *S. sanctaemartae* differs from *T. douglasi* by the lower number of notes (5–7 vs 7–9) and the shorter duration (0.82 s vs 1.66 s). From *T. lassoalcalai*, it differs in call structure, since the call of *T. lassoalcalai* is composed of a single note (or call, see Köhler et al., 2017), while the call of *S. sanctaemartae* is composed of several notes (5–7 vs 1). Also, the call of *S. sanctaemartae* has a longer note duration (0.828 s vs 0.72 s) and lower dominant frequency (2.26 kHz vs 2.88 kHz). However, it should be noted that in the case of the advertisement call of *T. douglasi*, it was difficult to understand the methodology and approach employed in its description by Mendoza-Roldán et al. (2019). As for example, they do not state which approach they took for the designation of the main unit of "call", and thus, in their description, the distinctions between call, notes and pulses are not clear; moreover, their definition of peak frequency is not clear. In that sense, comparisons were only made in temporal characteristics, as these were less ambiguous.

As stated by Köhler et al. (2017) and Rivera-Correa et al. (2021), the acoustic signals are powerful tools to study anuran diversity, and there is still a lot of acoustic diversity to discover. The current report represents the first description of an advertisement call for a *Serranobatrachus* species, which represents an advance in elucidating the natural history of the enigmatic species of the Sierra Nevada de Santa Marta, especially those that are part of the superfamily Brachycephaloidea, as well as a step towards the conservation of the Santa Marta robber frog.

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