



# Vocalizations of the Talamancan Robber Frog, *Craugastor talamancae* (Anura: Craugastoridae)

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*Craugastor talamancae* (Dunn 1931) is a species of frog that lives in undisturbed lowland forests on the Atlantic versant of Costa Rica, Nicaragua, and Panama at elevations from 0–650 m (Savage 2002; Crawford and Smith 2005; Sunyer et al. 2009; Fig. 1). The species was first described from the type locality of Almirante, Panama (Dunn 1931). *Craugastor talamancae* is a medium-sized (SVL = 30–50 mm), brownish frog with a dark bar running through the eye and often with a pale upper lip, especially in juveniles. Males of this species have vocal slits, a subgular vocal sac, and nuptial pads (Savage 2002; Hedges et al. 2008). During the day, *C. talamancae* spends much of its time in the leaf litter, becoming active at night and moving to low vegetation after dark (Savage 2002).

This species currently belongs to the *Craugastor fitzingeri* species group (Padial et al. 2014), which consists of six frogs, including the closely-related *C. crassidigitus* (Taylor 1952) and *C. fitzingeri* (Schmidt 1857). The advertisement calls of the frogs in this species group are said to consist of “a series of chirps, mews, or clacks” (Hedges et al. 2008). The advertisement call of *C. talamancae* has been described variously as a high-pitched “mew” (Savage 2002) or a “squawk” (Cossel and Kubicki 2017). However, no quantitative, formal descriptions of any vocalizations have been made for this species. Our objective was to describe the temporal and spectral characteristics of the vocalizations of this species and compare them to those of the closely-related taxa *C. crassidigitus* and *C. fitzingeri*.

We made *in-situ* recordings of *Craugastor talamancae* around 2200 h on 19–20 May 2017, at La Selva Biological Research Station, located in Heredia Province, on the Caribbean versant of Costa Rica (10.25509 N, 84.00298 W; WGS 84; elev. 75 m asl). Additional recordings were made at La Selva around 2200 h on 23–24 May 2019. Weather conditions were measured on both occasions with a digital Kestrel™ 3000 weather meter. We located frogs by walking

along existing trails and listening for vocalizations of the focal frog. We used white light to find the frogs and then switched to ambient or red LED light so the frog would not be disturbed while calling. We made ~92 minutes of audio recordings during frog vocalizations using a Tascam DR-100 audio recorder and Sennheiser MKE-600 shotgun microphone, with the microphone at a distance of 0.5–3 m from each focal frog. Sample recordings are archived with FonoZoo (accession # 14195–14197). We captured frogs temporarily to obtain morphometric measurements and photographic vouchers. Snout-vent lengths (to the nearest 0.1 mm) were recorded using calipers, and mass (to the nearest 0.1 g) was determined using a Pesola spring scale.

We analyzed and graphically constructed spectrograms and waveforms using Raven Pro 64 v1.6 (Center for Conservation Bioacoustics 2014). We found that ambient noise was loud enough in our recordings to obscure details in



**Figure 1.** Male *Craugastor talamancae* (Talamancan Robber Frog) from La Selva, Heredia Province, Costa Rica (10.25509 N, 84.00298 W; WGS 84; elev. 75 m asl). The snout-vent length was 30.6 mm (units depicted are cm) and mass was 4.3 g. Vocalization depicted in Fig. 2C was produced by this frog and is archived with FonoZoo (accession #14197), along with additional photographic vouchers of this frog. Photograph by John Cossel Jr.

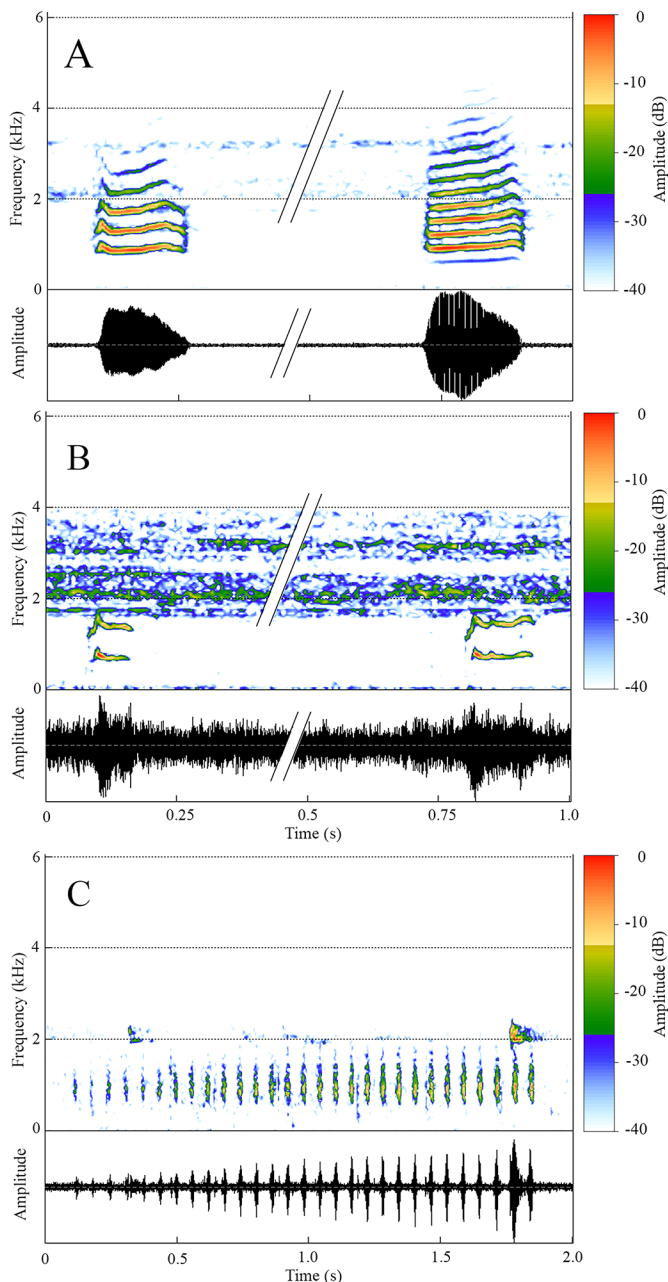
the waveform of many of the faint frog calls. Consequently, we made note selections manually via the spectrogram, and then validated when possible, using the waveform. We did not quantify fine-scale temporal measurements because we did not have the resolution as a consequence of ambient noise. Additionally, we measured inter-call intervals between similar call types (e.g., between adjacent mews and between

adjacent peeps) within call groups. We determined call groups by identifying long periods of silence between calls (> 5 min.). We used the terminology proposed by Köhler et al. (2017), and identified the temporal parameters of call duration(s) and inter-call intervals(s). We performed spectral analyses with the following presets: Hann’s sampling window with 512 samples and a 3-dB filter bandwidth of 124 Hz; time grids with a hop size of 256 samples and 50% overlap; and a frequency grid Discrete Fourier Transform size of 512 samples with grid spacing of 86.1 Hz. We used the selection power spectrum to determine the fundamental harmonic, harmonic interval, 90% bandwidth, and dominant frequency. We used Program R (R Core Team, 2021) and the software package Seewave (Sueur et al. 2008) to generate Fig. 2 with the following settings: Fig. 2A = -40 dB sensitivity, Fig. 2B = -30 dB sensitivity, Fig. 2C = -30 dB sensitivity, and low pass filter of 2.8 kHz at 24 dB applied via Audacity (Audacity Team 2019).

During our field observations, air temperature and relative humidity were as follows: 19 May 2017—23 °C, 90% RH; 20 May 2017—23 °C, 88% RH; 23 May 2019; no weather data available; and 24 May 2019—27 °C, 94% RH. All days were windstill, rainfall ranged from none to light rain, and the moon was in the third quarter. We noted frogs calling from heights of 0.3–2.5 m above the forest floor on exposed upper surfaces of palm fronds. However, due to thick surrounding vegetation, calling frogs were somewhat concealed. While calling, frogs held their entire bodies slightly above the leaf surface, with their heads elevated, and their vocal sacs distended. We recorded SVLs (30.6–30.9 mm) and mass (3.0–4.3 g) for three frogs captured on 19 and 20 May 2017, and 24 May 2019 (Table 1; Fig. 1).

Our observations revealed that *C. talamancae* makes at least three types of calls. Two call types consisted of a single note: a faint peep or a louder mew (presumed advertisement call). A third call type consisted of a multi-note trill. We were able to record four frogs, and from these we obtained 18 faint peep calls ( $n = 3$ ), 21 mew calls ( $n = 4$ ), and 5 trilled calls ( $n = 1$ ; Table 1). The peep and mew vocalizations generally occurred in a pattern of a variable number of peeps, followed by 1–3 (mode 2) mews. The presumed advertisement call (mew) was notably louder than the other two call types, audible at distances of ~5–10 m, whereas the trills were audible at ~3 m, and the peeps were the faintest (~1 m).

Our temporal analysis determined that the mean note duration of the peep calls ( $0.14 \pm 0.04$  s), was slightly shorter than the mew calls ( $0.19 \pm 0.04$  s; Table 1), whereas the note duration in trilled calls was much shorter ( $0.02 \pm 0.004$  s). The multi-note trill calls had a mean call duration of  $1.7 \pm 0.5$  s. The mean number of notes for the trilled calls was  $27.2 \pm 8.8$  notes and the note repetition rate was  $16.4 \pm 0.2$  notes / s. Inter-call intervals between mew calls were slightly variable, ranging from 6.6 to 24.4 s. However, the inter-call intervals



**Figure 2.** Vocalizations of *Craugastor talamancae* (Talamancan Robber Frog): A presumed advertisement call (“mew”) (A), vocalization of unknown function (“peep”) (B), and a third vocalization type also of unknown function (“trill”) (C). Note that temporal units are the same for Figs. 2A and 2B, but are different for Fig. 2C. Furthermore, the sound level of the peeps was very faint, hence the relatively louder ambient sound level visible in the waveform. Lastly, in Fig. 2C the two loud notes at ~2 kHz were produced by syntopic *Diasporus diastema* (Common Dink Frog).

**Table 1.** Summary of three types of vocalizations of the Talamanca Robber Frog (*Craugastor talamancae*) recorded at La Selva Biological Station (10.25509°N, 84.00298°W; WGS 84; 75 m elev.) Heredia Province, Costa Rica. Continuous variables reported as Means ( $\pm$  SD).

Call Type	Number of Calls	Mean Note Duration (s)	Mean Call Duration (s)	Mean Fundamental Freq. (kHz)	Mean Dominant Freq. (kHz)	Mean Bandwidth-90% (kHz)
Mew	21	0.19 (0.04)	0.19 (0.04)	1.53 (0.42)	2.93 (1.17)	3.21 (1.46)
Peep	18	0.14 (0.04)	0.14 (0.04)	1.65 (0.24)	1.90 (6.56)	1.84 (7.79)
Trill	5	0.02 (0.00)	1.7 (0.5)	1.72 (0.12)	3.13 (8.36)	3.20 (1.42)

between peeps was much more variable, ranging from 1.3–398.9 s. Despite the more variable nature of these intervals, most of them were still of relatively short duration (8 of 11 intervals less than a minute). The longer inter-call intervals for each call type suggests that calls may be arranged in call groups; however, further study is necessary to confirm this.

Our analysis of spectral characteristics indicated that both types of single-note calls (mews and peeps) were tonal and consisted of two or more harmonics (Köhler et al. 2017). Both of these call types exhibited frequency modulation (changes in pitch) that ranged from  $< 0.5$  to 2.0 kHz. In the mew calls, modulation was often  $< 0.5$  kHz in the lower harmonics, and in some cases increased to 1.0–2.0 kHz in the upper harmonics of the call. Modulation in the peep calls was often  $< 0.5$ –1.0 kHz. Furthermore, peep calls had fewer harmonics ( $2.1 \pm 0.8$ ; range 1–4), and a greater harmonic interval than the mew calls ( $4$ – $23$  with a mean of  $13.7 \pm 6.0$ ). Additionally, peep calls had higher mean fundamental frequencies and lower mean dominant frequencies than the mew calls. Finally, trill calls had higher mean dominant frequencies than either the peep or mew calls (Table 1).

Because they are closely related and their ranges overlap, we compared the temporal and spectral characteristics of *Craugastor talamancae* vocalizations to those of *C. crassidigitus* and *C. fitzingeri*. Ibáñez et al. (1999) and Lynch and Myers (1983) described several types of *C. crassidigitus* vocalizations that fell into three categories, the “chirp,” “chuck-chirp,” and trill. The mew calls of *C. talamancae* are most similar to the chirp calls of *C. crassidigitus*, and although both calls fall into a similar frequency range, the chirp call of *C. crassidigitus* is generally not chevron-shaped. Further, they can be frequency modulated, but the degree of modulation is highly variable, with changes ranging from  $< 0.5$  kHz to over 2.0 kHz across the duration of the call. Lastly, the number of harmonics in the mew calls was greater than the range reported for *C. crassidigitus* (Ibáñez et al. 1999; Lynch and Myers 1983).

We also compared the vocalizations of *Craugastor talamancae* to those of the closely-related *C. fitzingeri*. Various authors (Fouquette 1960; Lynch and Myers 1983; Ibáñez et al. 1999; Ospina-Sarria et al. 2015) have reported on the vocalizations of *C. fitzingeri*; however, these descriptions are

generally based on only a few individuals or calls. Two types of calls have been described. The first is a sporadic, single-note call of high frequency. From the spectrogram reported by Ibáñez et al. (1999), this single-note call appears to have a duration of  $\sim 0.05$  s and a frequency range of  $\sim 1.5$ – $4.5$  kHz. In contrast, the single note calls of *C. talamancae* are notably longer ( $\sim 1.5$ – $2$  times as long).

The second vocalization of *Craugastor fitzingeri* is a multi-note call, presumed to be the advertisement call. To summarize the call descriptions by Fouquette (1960), Lynch and Myers (1983), Ibáñez et al. (1999), and Ospina-Sarria et al. (2015), this call, which is reportedly made infrequently, consisted of 2–21 notes ranging in duration from 0.02–0.2 s, with a frequency range of 1.5–4.4 kHz. The inter-note interval of this call decreases from beginning to end. In contrast, the multi-note call of *C. talamancae* has more notes ( $27.2 \pm 8.8$ , range = 18–40) and has consistent inter-note intervals. However, the calls of both species have similar duration ( $1.7 \pm 0.5$  s) and dominant frequencies.

We documented that *Craugastor talamancae* makes three types of sounds described as a mew, a peep, and a trill. Our comparison of *C. talamancae* vocalizations to those of *C. crassidigitus* and *C. fitzingeri* revealed that all three closely-related species have similar call types, as one might expect among sister taxa. For example, all three have a call consisting of multiple notes, with those of *C. talamancae* and *C. crassidigitus* being similar but that of *C. fitzingeri* being distinctive because it is the presumed advertisement call (the call most frequently made) and it consists of fewer notes with a decreasing inter-note interval. Additionally, all three frogs have tonal, single-note calls with multiple harmonic bands and frequency modulation. Although they are similar in terms of note/call duration and frequency ranges, they differ in the types of modulation and the number of harmonics. Despite similarities, each of these species has distinctive calls, including the chuck-chirp of *C. crassidigitus*, the peep of *C. talamancae*, and the multi-note trill of *C. fitzingeri*.

Sampling from a single population with a small number of individuals ( $n = 4$ ) was the primary limitation of our study. Consequently, future work on *Craugastor talamancae* should include additional recordings from multiple frogs over



a wider geographic range, as well as the collection of tissue for genetic analysis. To create a better dataset for comparisons between closely related species, future work should also include additional recordings and tissues from *C. crassidigitus* and *C. fitzingeri*. Researchers working to characterize the bioacoustics of *C. talamancae* should use caution to minimize the disturbance of frogs. This can be done by reducing excessive light, noise, and movement of vegetation, as those can interrupt normal behavior, influence inter-call intervals, and make it difficult to elucidate call groups or bouts. Furthermore, care should be taken to adjust recording gain to the maximum possible (without causing clipping) and by being within 1 m of frogs to ensure detection of the faint peep calls.

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