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Vocalizations of four species of Asian treefrogs (Anura: Rhacophoridae) from Medog County, Xizang Autonomous Region, China

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Abstract. The Old World treefrog fauna (family Rhacophoridae) of Medog County in southeastern Xizang (Tibet) Autonomous Region, China, exhibits both underestimated taxonomic diversity and poorly understood natural history. In this study, we describe the vocalizations of four treefrog species from Medog County, *Zhangixalus burmanus*, *Rhacophorus medogensis*, *Polypedates braueri*, and *Kurixalus* naso, analyzing their sound structure, spectra, and temporal parameters. Remarkably, the vocalizations of *Z. burmanus*, *R. medogensis*, and *K. naso* are described for the first time. We emphasize the importance of continued research on the natural history of frogs inhabiting this region and anticipate that this contribution will be of value to future studies.

Key words. Amphibia, advertisement calls, bioacoustics, species diversity, Tibet.

Introduction

The treefrog family Rhacophoridae comprises a diverse group of tree frogs distributed from Subsaharan Africa to South and Southeast Asia (Frost 2024). Rhacophorids exhibit a remarkable diversity of breeding modes, including direct development (genera *Pseudophilautus* and *Raorchestes*) and foam nesting (e.g., Biju 2003, Kielgast & Lötters 2009, Yan et al. 2021). Several studies have explored the evolution of these breeding modes within a phylogenetic context (Grosjean et al. 2008, Li et al. 2009, Ellepola et al. 2022). Furthermore, rhacophorid frogs have evolved a large variety of advertisement calls, encompassing clicks, pulsatile calls, whistles, and complex combinations of these (Kuramoto 1986, Dring 1987, Zhu et al. 2017, Wang et al. 2018, Garg et al. 2021). Advertisement calls within genera are not always stereotyped and can vary considerably among sibling species (Malkmus & Riede 1996, Dehling et al. 2016, Wu et al. 2016, Garg et al. 2021). The occurrence of multiple call types within a single species, and their associated functions, remains an area of active research (Rowley et al. 2015, Vassilieva et al. 2016).

Medog County, in southeastern Xizang (Tibet) Autonomous Region, China, on the southern slope of the Himalayas, possesses a warm, rainy climate that supports a rich treefrog fauna (currently 13 recognized species), attracting herpetological attention (Hu et al. 1978, Li et al. 2010, Che et al. 2020). Despite this interest, the natural history of most amphibians from this region remains poorly known or entirely unknown. In particular, data on anuran vocalizations are limited, primarily consisting of text-based accounts (Fei et al. 2009, Che et al. 2020). In this study, based on field observations and analyses of recordings obtained in the field, we describe the vocalizations of four treefrog species from this area: *Zhangixalus burmanus*, *Rhacophorus medogensis*, *Kurixalus naso*, and *Polypedates braueri*.

Materials and methods

Two field surveys were undertaken in Medog County, Xizang (Tibet) Autonomous Region, China, during the year 2024. The first survey was conducted from April 19th to 21st, and the second from June 9th to 12th. Frogs encountered during field surveys were identified based on morphological characteristics described by Che et al. (2020) and recent taxonomic updates by Weng et al. (2025). Procedures for specimen collection, handling, and euthanasia complied with the guidelines of the Herpetological Animal Care and Use Committee (HACC). Where possible, specimens were collected and cataloged as field vouchers. Specimens were deposited at the specimen room of the Innovation Team For Amphibian Diversity Conservation, Biodiversity Conservation Center, Chengdu Institute of Biology (CIB), Chinese Academy of Sciences (CAS). Acoustic recordings of anuran vocalizations were acquired using a Zoom F3 digi-

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tal audio recorder (Japan) in conjunction with a Sennheiser ME66/K6 shotgun microphone (Germany). Concurrent environmental measurements, specifically air temperature and relative humidity, were obtained using a CEM DT-83 Temp & Humidity Meter (Shenzhen, China). Z-weighted sound pressure level (SPL) measurements were performed using an Aihua 8913 sound level meter (Hangzhou, China), with the peak SPL value recorded for calls of each individual. Supplementary video recordings of calling individuals were also obtained using a mobile telephone and are provided as Supplementary Videos S1. The digital audio recorder was configured to record at a sampling rate of 192 kHz with a 32-bit floating-point resolution to maximize the capture of acoustic information and mitigate the risk of signal oversaturation, notwithstanding the microphone's stated frequency response range of 0–20 kHz.

For subsequent analysis, sound files were resampled to 44.1 kHz and 24-bit using Audacity v3.3.3. Acoustic analyses of calls were conducted using Raven Pro v.1.6.5 (Cornell University, Ithaca, New York), employing a Hann window with 50% overlap and a DFT size of 512 samples. Acoustic terminology and measurements adhered to Köhler et al. (2017). We categorized calls as "note-centered" for all species. A "note" was defined as a fundamental acoustic unit readily distinguishable by the human ear; units within pulsed calls were designated as "pulses". Four treefrog species were identified. For the single-note calls of *Rhacophorus medogensis*, we measured call duration (ms), call interval (ms), pulse duration (ms), pulse interval (ms), pulse repetition rate (pulses/s), bandwidth (kHz), and dominant frequency (kHz). For *Zhangixalus burmanus*, *Polypedates braueri*, and *Kurixalus naso*, we measured call duration (ms), call interval (s), note duration (ms), note interval (ms), note repetition rate (notes/s), bandwidth (kHz), dominant frequency (kHz), and visible harmonics (kHz). Temporal measurements were derived from manual selections on oscillograms, while spectral measurements were obtained using the Peak Frequency and Bandwidth 90% function within Raven Pro. To analyze frequency modulation, we measured the dominant frequency and bandwidth of both entire calls and individual notes (pulses). Spectrograms and oscillograms were generated using the Seewave v.2.2.0 (Sueur et al. 2008) and TuneR 1.4.2 (Ligges et al. 2013) packages, utilizing a Hanning window size of 512 samples and 50% overlap.

Results

Acoustic recordings of *Zhangixalus burmanus* were obtained from a single male individual (specimen MT 2024008) on April 20 at the Renqinbeng temple site (29.2855° N, 95.3688° E; ca. 2360 m a.s.l.) at approximately 21:30 h. The calls were recorded for approximately 3 minutes and 39 seconds. The ambient air temperature at the recording time was estimated to be within the range of 10–15 °C. The focal individual was observed emitting advertisement calls from within a wet roadside ditch characterized by a sandy substrate and the presence of scattered deciduous leaf litter. A female conspecific was observed at a distance of approximately 3 m from the calling male. The snout–vent length (SVL) of the recorded male specimen (MT 2024008) was measured to be 57.5 mm. The advertisement calls of *Z. burmanus* consisted of single notes, with call structure typically comprising 3–5 notes (Fig. 1B). Call duration ranged from 300.5 to 580.9 ms (depending on the number of constituent notes), with intercall intervals ranging from 3.0 to 19.4 s. The amplitude of the first four notes exhibited a gradual increase, with the amplitude of the fifth note, when present, being comparatively lower than that of the second note. The dominant frequency of the call was generally observed to exhibit higher power on the third and fourth notes, with a mean dominant frequency of 1.18 ± 0.04 kHz (range 1.12–1.21 kHz). The fundamental frequency corresponded to the dominant frequency, with detectable harmonic frequencies present on the second through fifth notes. The note repetition rate ranged from 7.48 to 7.99 notes/s. The maximum Z-weighted SPL recorded for this individual was 81.8 dB at an approximate distance of 0.3–0.5 m from the sound source. Detailed acoustic measurements for each constituent note are given in Table 1.

Acoustic recordings of *Rhacophorus medogensis* were obtained on June 8 in Jiangxin (29.2199° N, 95.1285° E; ca. 790 m a.s.l.) from a single male individual (specimen XZ 2024131, Fig. 2A) with an SVL of 38.8 mm. The ambient temperature was estimated to be 26.0 °C. The observed individual was emitting advertisement calls from a leaf at approximately 0.5 m above ground level at approximately 20:30 h. The calls were recorded for approximately 6 minutes and 37 seconds. These calls were characterized as pulsatile calls consisting of a single note (Fig. 2B), typically composed of 6–9 pulses (mean ± SD: 6.7 ± 1.2 pulses), with a pulse repetition rate ranging from 28.95 to 32.64 pulses/s. Call duration ranged from 173.1 to 295.4 ms (depending on the number of constituent pulses), with relatively long inter-call intervals ranging from 24.2 to 74.5 s. The dominant frequency of the call, typically observed on pulses 3 through 6 except for the 9-pulse call (where it was observed on pulse 9), was measured as 2.34 ± 0.11 kHz (range 2.24–2.50 kHz). The fundamental frequency corresponded to the dominant frequency, and no harmonic frequencies were detected. The amplitude of pulses 1 through 3 exhibited a substantial increase, followed by an inconspicuous increase or plateau between pulses 3 and 4, with subsequent pulses (after pulse 4) exhibiting a gradual decrease or plateau. Pulses 1 and 2 were characterized by lower power, shorter duration, and longer inter-pulse intervals compared to the subsequent, higher-power pulses. The dominant frequency reached its peak value at pulses 4 and 5. The maximum Z-weighted SPL recorded for this individual was 83.5 dB at an approximate distance of 0.2 m from the sound source. Detailed measurements of each constituent pulse are presented in Table 2. The acoustic parameters of pulses 7 and 9 were summarized together due to their similar characteristics.

Calls of *Polypedates braueri* were heard during both the April and June 2024 field surveys. The high density of call-

Table 1. Acoustic measurements of individual notes within the *Zhangixalus burmanus* call. Values are presented as mean ± SD (range); N indicates sample size; – denotes unavailable data.

Note sequences	Note duration (ms)	Note interval (ms)	Bandwidth (kHz)	Dominant frequency (kHz)	Harmonic (kHz)
1st, N=11	38.1±4.4 (30.4–45.2)	85.7±4.3 (79.0–91.6)	0.27±0.15 (0.17–0.69)	0.95	–
2nd, N=11	44.1±3.9 (38.0–49.5)	83.2±4.6 (78.5–91.6)	0.34±0.03 (0.26–0.34)	1.07±0.06 (0.95–1.12)	2.13±0.04 (2.07–2.15)
3rd, N=11, with N of intervals = 10	47.6±3.1 (41.7–51.6)	83.7±4.2 (76.5–90.6)	0.34±0.04 (0.26–0.43)	1.17±0.04 (1.12–1.21)	2.29±0.04 (2.24–2.33)
4th, N=10, with N of intervals=7	46.7±5.6 (38.8–53.5)	93.3±6.9 (81.5–98.9)	0.44±0.06 (0.34–0.52)	1.16±0.06 (1.03–1.21)	2.04±0.13 (1.89–2.33)
5th, N=7	45.0±6.0 (38.7–51.8)	–	0.64±0.25 (0.43–1.03)	1.00±0.05 (0.95–1.03)	2.03±0.07 (1.98–2.15)

ing individuals observed within the paddy habitat suggested a substantial population size. These frogs were observed to vocalize during both diurnal and nocturnal periods in Medog County. The recordings described herein were obtained on June 9 in Gelin, Medog County (29.2248° N, 95.1807° E; ca. 1590 m a.s.l.) from a single unvouchered male that was located beneath plant roots on a small island within a temporary puddle (Fig. 3A) at approximately 21:00 h. The calls were recorded for approximately 14 minutes and 17 seconds. The temporary puddle was measured to have a depth of approximately 0.1 m, and several other male and female individuals were observed submerged within the water. The ambient air temperature was recorded as 26.3 °C. The advertisement calls of *P. braueri* were characterized by a range of call types, predominantly consisting of simple clicks. These clicks were observed to occur as single-click calls (duration: 23.7–27.9 ms, N = 3), as well as in combination as double-click calls (duration: 188.7–209.5 ms, N = 5) and triple-click calls (duration 386.8 ms, N = 1). In calls composed of multiple clicks, the amplitude of each successive click exhibited a gradual decrease (Fig. 3B). The dominant frequency, consistently observed within the first click of each call, was measured as 1.80 ± 0.11 kHz (range 1.55–1.89 kHz). In addition to these simpler call types, a less frequently observed, more complex call structure was also documented. This complex call type was characterized by an introductory pulsatile note (comprising 3–4 continuous pulses) of relatively low amplitude, followed by two distinct clicks, resulting in an extended call duration ranging from 428.2 to 464.9 ms (N = 2). Remarkably, the dominant frequency remained associated with the first click (corresponding to the second note) due to the relatively low power of the preceding pulsatile note. The note repetition rate of *P. braueri* calls was calculated to range from 4.56 to 6.18 notes/s. Inter-call intervals ranged from 1.82 to 6.55 s. The maximum Z-weighted SPL recorded for this specimen was 92.4 dB at an approximate distance of 0.3–0.5 m from the sound source. No harmonic frequencies were detected in

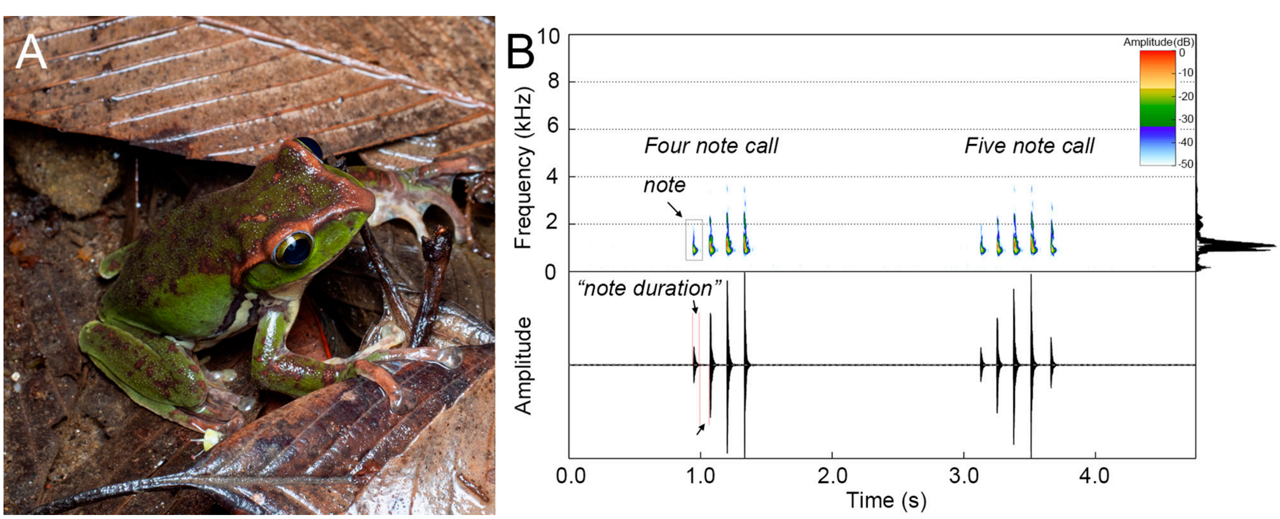

Figure 1. Photograph of an unvouchered male *Zhangixalus burmanus* (A) and a representative oscillogram of the advertisement call of voucher specimen MT 2024008 (B). The two calls were manually extracted and juxtaposed to illustrate the attenuation of the fifth pulse amplitude in the five-note call. Photograph by Tianyu Qian.

Table 2. Acoustic measurements of individual pulses within the *Rhacophorus medogensis* call. Values are presented as mean ± SD (range); N indicates sample size.

Pulse sequences	Pulse duration (ms)	Pulse interval (ms)	Bandwidth (kHz)	Dominant frequency (kHz)
1st, N=6	10.4±2.6 (6.2–13.7)	21.1±2.9 (17.7–25.5)	2.43±0.10 (2.33–2.58)	1.89
2nd, N=6	13.0±1.5 (10.9–15.5)	19.1±1.8 (16.0–21.0)	2.44±0.20 (2.07–2.58)	2.08±0.04 (2.07–2.15)
3rd, N=6	17.1±1.3 (15.5–19.3)	15.2±1.7 (12.2–17.2)	2.61±0.07 (2.50–2.67)	2.21±0.07 (2.15–2.33)
4th, N=6	17.0±1.9 (13.4–18.3)	15.5±2.9 (12.7–20.9)	2.73±0.07 (2.67–2.84)	2.40±0.04 (2.33–2.41)
5th, N=6	17.3±2.6 (14.3–21.1)	14.4±3.4 (9.7–19.8)	2.73±0.09 (2.67–2.84)	2.45±0.05 (2.41–2.50)
6th, N=6, with N of intervals = 2	18.9±1.8 (16.3–22.0)	15.4±2.1 (13.9–16.9)	2.58±0.22 (2.15–2.76)	2.38±0.04 (2.33–2.41)
7th–9th, N=4, with N of intervals = 2	18.7±0.6 (17.9–19.3)	16.9±1.4 (15.9–17.9)	2.50±0.12 (2.33–2.58)	2.30±0.04 (2.24–2.33)

any of the analyzed calls. Detailed acoustic measurements for each constituent note are presented in Table 3.

Acoustic recordings of *Kurixalus naso* were obtained during the April 2024 field survey; no calls were detected during the subsequent June survey. Calling males were frequently observed on low-lying vegetation adjacent to roadsides, often forming aggregations of calling individuals (choruses). Locating individual calling frogs proved challenging when they were concealed within dense vegetation. Recordings were acquired on April 21 in Jiangxin, Medog County (29.2361° N, 95.1654° E; ca. 820 m a.s.l.) from two male specimens encountered along a rural road. The ambient air temperature was recorded as 20.5 °C. Calling individuals were located within large chorus aggregations between the hours of 19:00 and 23:00 h on roadside vegetation (Fig. 4A). Two distinct "whistle" call types were documented from these recorded males: a single-note call and a multiple-note call characterized by an initial single note followed by 1–3 short tonal elements. A third call type, composed of pulsatile notes, was detected within the chorus context but not directly recorded from individual specimens (Supplementary Audio S2). Two individuals were captured and subsequently vouchered as specimens MT 2024004 (SVL 36.8 mm; body mass 2.23 g) and MT 2024005 (SVL 35.1 mm; body mass 2.08 g). The calls were recorded for approximately 9 minutes and 29 seconds in total. The duration of the single-note call is presented as "note duration" in Table 4. The duration of multiple-note calls varied as a function of the number of subsequent tonal elements: 476.0–484.6 ms (MT 2024004, N = 2) for calls with one subsequent tonal element, 499.6–668.4 ms (MT 2024004, N = 4) or 586.2 ms (MT 2024005, N = 1) for calls with two subsequent tonal elements, and 771.4 ms (MT 2024004, N = 1) for a call with three subsequent tonal elements. The note repetition rate was calculated to range from 2.15 to 4.28 notes/s in specimen MT 2024004 and 3.63 notes/s in specimen MT 2024005. Inter-call intervals ranged from 3.8 to 82.5 s in MT 2024004 and from 22.3 to 81.3 s in MT 2024005. Spectrographic analysis of the single-note call, as well as the initial note of the multiple-note call, revealed the presence of two distinct spectral components (Fig. 4B). The left component was characterized as pulsatile, exhibiting indistinct harmonic frequencies in MT 2024004 and weakly

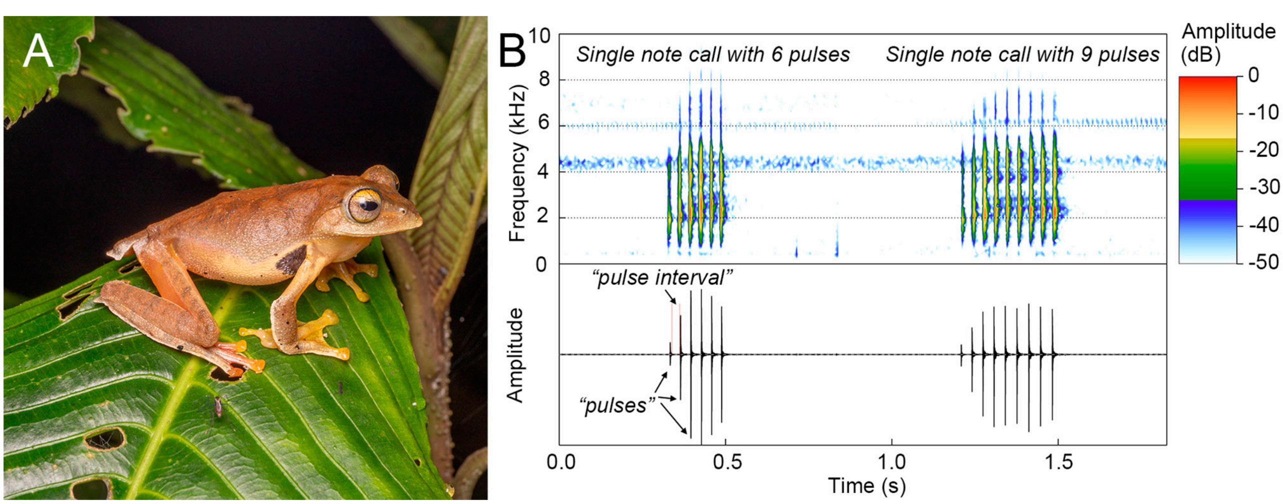

Figure 2. Photograph of a male *Rhacophorus medogensis* (voucher specimen XZ 2024131) (A) and a representative oscillogram of its advertisement call (B). The two acoustic signals were manually extracted and juxtaposed, ambient noise was retained in the recordings. Photograph by Tianyu Qian.

Table 3. Acoustic measurements of *Polypedates braueri* calls. Values are presented as mean ± SD (range); N indicates sample size; – denotes unavailable data.

Call type	Note	Note duration (ms)	Note interval (ms)	Bandwidth (kHz)	Dominant frequency (kHz)
Single-click calls, N=3	1st note	26.2±2.2 (23.7–27.9)	–	1.9±0.05 (1.89–1.98)	1.67±0.10 (1.55–1.72)
Double-click calls, N=5	1st note	26.9±1.3 (25.4–28.7)	144.9±8.7 (135.5–156.2)	1.89	1.86±0.05 (1.81–1.89)
	2nd note	26.5±1.9 (24.9–29.6)	–	1.81±0.06 (1.72–1.89)	1.71±0.04 (1.64–1.72)
Triple-click calls, N=1	1st note	28.2	137.4	1.98	1.89
	2nd note	26.4	168.5	1.72	1.81
	3rd note	26.4	–	1.72	1.64
Double-click calls introduced by a pulsative 1st note, N=2	1st note	72.0±9.3 (65.4–78.6)	164.5±3.7 (161.9–167.0)	2.11±0.06 (2.07–2.15)	2.20±0.06 (2.15–2.24)
	2nd note	26.9±1.3 (25.9–27.8)	157.2±14.6 (146.8–167.5)	1.77±0.06 (1.72–1.81)	1.81
	3rd note	26.2±0.4 (25.9–26.4)	–	1.72	1.81

visible harmonic frequencies in three of four single-note calls from MT 2024005. The right component consisted of a tonal element with reduced frequency modulation and either indistinct harmonic frequencies or weakly visible 1–3 harmonic frequencies. In some instances, a clear demarcation between these two components was absent due to their overlapping nature. The dominant frequency was almost exclusively associated with the fundamental frequency of the right component, with one exception: a single-note call from specimen MT 2024004, where the dominant frequency was associated with the left component. The second through fourth notes of multiple-note calls typically exhibited weakly visible harmonic frequencies. The tonal elements also exhibited reduced frequency modulation. The SPL from specimen MT 2024004 was measured at 76.4 dB at an approximate distance of 0.3–0.5 m from the sound source. Detailed acoustic measurements for each constituent note are presented in Tables 4–5.

Discussion

In this study, we presented descriptions of the acoustic signals emitted by four distinct species of Asian treefrogs, each belonging to a separate genus within the family Rhacophoridae. These species exhibit a wide spectrum of call types, encompassing simple clicks (as observed in *Polypedates braueri*) and complex, frequency-modulated bird-like whistles (characteristics of *Kurixalus naso*). The calls of *K. naso* demonstrate a remarkable similarity to the "type B" calls previously characterized for *K. hainanus* (Zhu et al. 2017, Deng et al. 2024). These studies propose that type B calls function as aggressive signals, serving to warn conspecific males rather than attracting females. Although *K. naso* was observed in still-water habitats with low ambient noise, which likely has limit influence on the habitat selection (Goutte et al. 2013). The relatively short duration and low sound pressure level (76.4 dB) of these signals may represent an adaptive strategy for minimizing

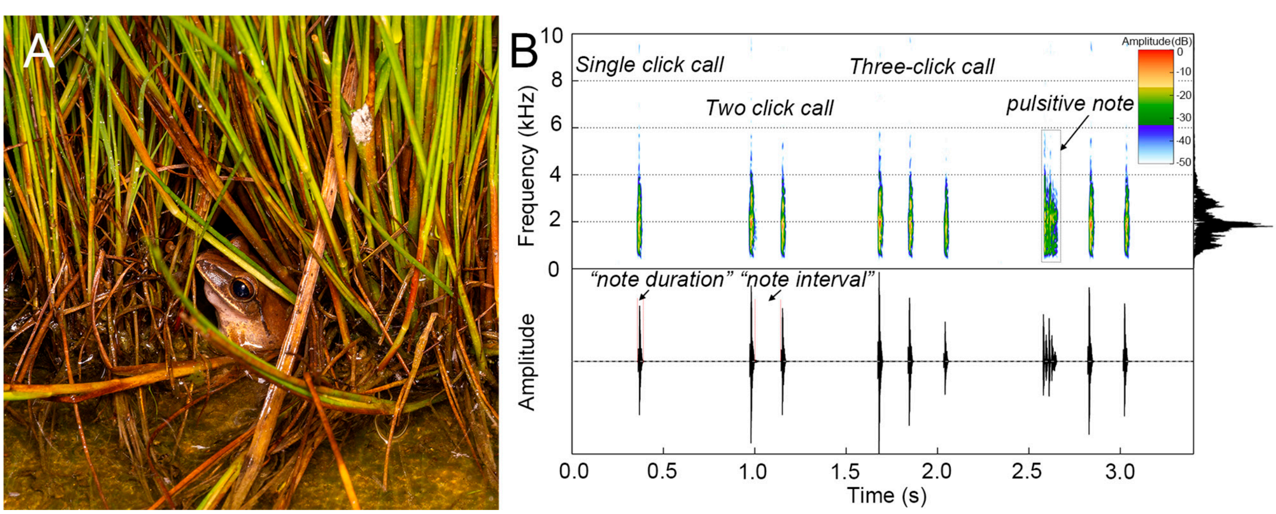

Figure 3. Photograph of an unvouchered male *Polypedates braueri* (A) and an illustration of its advertisement call (B). Four calls were manually extracted and juxtaposed to highlight the elongated first note (pulsatile note) in the final call. Photograph by Tianyu Qian.

Table 4. Acoustic measurements of single-note calls and the initial note of multiple-note calls of *Kurixalus naso*. Values are presented as mean ± SD (range); N indicates sample size; – denotes unavailable data.

Note types	Single-note calls		1st note of multiple-note calls	
Voucher	MT 2024004	MT 2024005	MT 2024004	MT 2024005
Note duration (ms)	130.0±21.7 (82.8–163.6), N=11	90.3±2.6 (88.4–94.1), N=4	127.6±7.9 (115.4–137.2), N=7	82.3, N=1
Note interval (ms)	–	–	284.4±40.2 (234.5–346.1), N=7	27.0, N=1
Bandwidth (kHz)	1.00±0.14 (0.60–1.12), N=11	0.93±0.04 (0.86–0.95), N=4	1.02±0.03 (0.95–1.03), N=7	0.86, N=1
Dominant frequency (kHz)	2.54±0.27 (1.72–2.67), N=11	2.54±0.05 (2.50–2.58), N=4	2.55±0.07 (2.41–2.58), N=7	2.58, N=1
Fundamental frequency on left (kHz)	1.75±0.20 (1.64–2.33), N=11	2.22±0.33 (1.72–2.41), N=4	1.67±0.05 (1.64–1.72), N=7	1.72, N=1
Left harmonic 1 (kHz)	Not visible	4.54±0.30 (4.22–4.82), N=3	–	–
Left harmonic 2 (kHz)	Not visible	6.43±0.30 (6.12–6.72), N=3	–	–
Left harmonic 3 (kHz)	Not visible	9.59±0.05 (9.56–9.65), N=3	–	–
Fundamental frequency on right (kHz)	2.59±0.05 (2.50–2.67), N=11	2.54±0.05 (2.50–2.58), N=4	2.55±0.07 (2.41–2.58), N=7	2.58, N=1
Right harmonic 1 (kHz)	4.96±0.13 (4.82–5.17), N=7	5.06±0.18 (4.91–5.25), N=4	4.98±0.18 (4.82–5.25), N=6	5.08, N=1
Right harmonic 2 (kHz)	7.74±0.10 (7.58–7.84), N=7	7.47±0.19 (7.32–7.75), N=4	7.68±0.18 (7.32–7.84), N=6	7.67, N=1
Right harmonic 3 (kHz)	10.12±0.31 (9.56–10.42), N=6	10.12±0.30 (9.91–10.34), N=2	9.95±0.43 (9.65–10.25), N=2	10.16, N=1

energy expenditure, as these signals are likely directed toward nearby males within a limited acoustic range, rather than serving a long-distance function in attracting females. The occurrence of multiple distinct call types has been documented in several other treefrog species (Rowley et al. 2015, Vassilieva et al. 2016). It can be hypothesized that through the evolution of distinct acoustic repertories, anuran species can optimize the tradeoff between the functional efficacy of their signals and the associated energy costs. Such adaptations are particularly beneficial for spe-

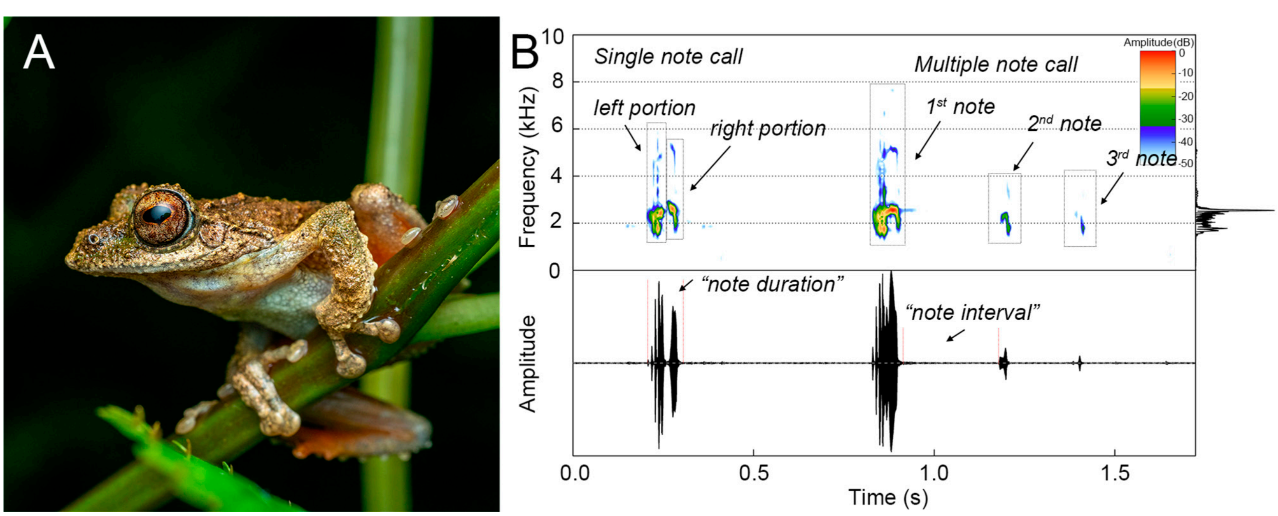

Figure 4. Photograph of an unvouchered male *Kurixalus naso* (A) and an illustration of the call of voucher specimen MT 2024005 (B). Two calls from the recording were manually extracted and juxtaposed. Photograph by Tianyu Qian.

Table 5. Acoustic measurements on the second through fourth notes of multiple-note calls of *Kurixalus naso*. Values are presented as mean ± SD (range); N indicates sample size; – denotes unavailable data.

Notes sequences	2nd note		3rd note		4th note
Voucher	MT 2024004	MT 2024005	MT 2024004	MT 2024005	MT 2024004
Note duration (ms)	26.6±8.0 (11.9–33.9), N=7	3.3, N=1	28.3±7.0 (20.3–37.3), N=5	35.7, N=1	29.9, N=1
Note interval (ms)	120.2±61.6 (82.8–228.6), N=5	16.5, N=1	213.1, N=1	–	–
Bandwidth (kHz)	1.61±0.07 (1.55–1.72), N=7	0.69, N=1	1.46±0.39 (0.78–1.72), N=5	0.69, N=1	1.55, N=1
Dominant frequency (kHz)	2.21±0.75 (1.55–3.01), N=7	2.24, N=1	1.81±0.29 (1.64–2.33), N=5	1.81, N=1	1.64, N=1
Fundamental frequency (kHz)	1.65±0.06 (1.55–1.72), N=7	2.24, N=1	1.81±0.29 (1.64–2.33), N=5	1.81, N=1	1.64, N=1
Harmonic (kHz)	3.04±0.08 (2.93–3.19), N=7	3.1, N=1	3.06±0.05 (3.01–3.10), N=4	3.19, N=1	3.01, N=1

cies that inhabit densely vegetated environments, where the acoustic environment presents significant challenges for effective signal transmission (Muñoz & Halfwerk 2022).

While differing terminologies were employed to define the fundamental acoustic units of the calls of *Zhangixalus burmanus* and *Rhacophorus medogensis*, comparative analysis revealed similar underlying structural patterns. Specifically, the call of *Z. burmanus* can be characterized as an elongated variant of the call produced by *R. medogensis*. The genus *Zhangixalus*, which was recently erected through a taxonomic split from *Rhacophorus*, is currently defined by morphological distinctions that are subject to ongoing refinement and debate within the scientific community (Jiang et al. 2019, Mahony et al. 2024). This observed similarity in call structure may provide further support for the hypothesis of a close phylogenetic relationship between these two taxa. Furthermore, the occurrence of similar call types has been documented in several other species within both the *Rhacophorus* (e.g., *R. helenae* [Vassilieva et al. 2016], *R. laoshan* [Mo et al. 2008], *R. malabaricus* [Kuramoto & Joshy 2001], and *R. qionica* [Sun et al. 2017, described under the synonym *R. rhodopus*] and *Zhangixalus* (e.g., *Z. aurantiventris* [Lue et al. 1994], *Z. chenfui*, *Z. dugritei,* and *Z. omeimontis* [Matsui & Wu 1994], *Z. dennysi* [Wang et al. 2012], *Z. jodiae* [Nguyen et al. 2020], *Z. lishuiensis* [Ding et al. 2022], *Z. moltrechti* [Kuramoto 1986], *Z. melanoleucus* [Brakels et al. 2023], *Z. pinglongensis* [Mo et al. 2016], and *Z. prasinatus* [Mou et al. 1983, who noted acoustic similarity with *Z. moltrechti*]) genera.

*Rhacophorus medogensi*s was previously identified as *Rhacophorus bipunctatus* (Che et al. 2020). When compared to the acoustic descriptions of what was identified as *Rhacophorus bipunctatus* by Deesrisai et al. (2015) from Thailand (although this population has subsequently been suggested to represent *R. rhodopus*; Poyarkov et al. 2021), the present study revealed shorter call durations (173.1–295.4 ms vs. 156.0–655.0 ms) and longer intercall intervals (24.2–74.5 s vs. 2.5–7.5 s) under comparable ambient temperature conditions (approximately 26 °C vs. 23.5–26 °C). The descriptions of *Polypedates braueri* calls presented herein were similar to those provided by Kuramoto (1986, under the prior designation *P. leucomystax*), Yang (2020) from Taiwan, and Deng et al. (2023) from Guizhou. However, a notable structural difference was observed when comparing our findings with the acoustic descriptions of Siammawii et al. (2024) from Mizoram, India, while the calls described by Siammawii et al. exhibited a consistent, relatively flat profile across each constituent note, the calls recorded in the present study exhibited a gradual decrease in amplitude. Furthermore, the calls from the Mizoram population exhibited a lower frequency range (0.84–1.14 Hz) than the dominant frequency observed in our recording (at least 1.55 kHz). Given the recognition of *P. braueri* as a species complex encompassing multiple cryptic lineages, and considering that the Medog population has been shown to represent a genetically distinct lineage characterized by several unique morphological attributes (Che et al. 2020), these observed acoustic differences may provide valuable data for future taxonomic revisions aimed at clarifying the species boundaries within this complex.

Acoustic partitioning is recognized as a key mechanism contributing to the organization of anuran communities (Duellman & Pyles, 1983). To mitigate the potential for breeding interference, closely related species that produce similar calls often exhibit temporal or spatial segregation in their reproductive activity (Qian et al., 2025). During our April survey, we frequently encountered small aggregations of *Polypedates braueri* and *Rhacophorus medogensis* inhabiting temporary roadside puddles characterized by standing water. Analysis of the dominant frequencies of their respective calls revealed minimal overlap (1.55–2.24 kHz for *P. braueri* and 1.89–2.50 kHz for *R. medogensis*, extracted from measurements of individual notes), suggesting the presence of effective spectral partitioning between these two co-occurring species. In contrast to this pattern, chorus aggregations of *Kurixalus naso* were consistently observed in isolation from the other two species. Interestingly, the dominant frequency range exhibited by *K. naso* (1.55–3.01 kHz) demonstrated a substantial degree of overlap with the frequency ranges of both *P. braueri* and *R. medogensis*. These observations serve to highlight the diverse and multifaceted strategies of acoustic resource partitioning employed within anuran communities.

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References

Biju, S. D. (2003): Reproductive mode in the shrub frog *Philautus glandulosus* (Jerdon, 1853) (Anura: Rhacophoridae). – Current Science, **84**: 283–284.

Brakels, P., T. V. Nguyen, P. Pawangkhanant, S. S. Idiiatullina, S. Lorphengsy, C. Suwannapoom & N. A. Poyarkov (2023): Mountain jade: A new high-elevation microendemic species of the genus *Zhangixalus* (Amphibia: Anura: Rhacophoridae) from Laos. – Zoological Research, **44**: 374–379.

Che, J., K. Jiang, F. Yan & Y. Zhang (2020): Amphibians and Reptiles in Tibet – Diversity and Evolution. – Science Press, Beijing.

Deesrisai, S., V. Chimchome, P. Duengkae & B. Thongnumchaim (2015): Call structure and population estimation of anurans (order Anura) by auditory surveys in Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao Province. – Journal of Wildlife in Thailand, **22**: 81–89.

Dehling, J. M., M. Matsui & P. Y. Imbun (2016): A new small montane species of *Philautus* (Amphibia: Anura: Rhacophoridae) from Gunung Kinabalu, Sabah, Malaysia (Borneo). – Salamandra, **52**: 77–90.

Deng, K., Q. L. He, T. L. Wang, J. C. Wang & J. G. Cui (2024): Network analysis reveals context-dependent structural complexity of social calls in serrate-legged small treefrogs. – Current Zoology, **70**: 253–261.

Deng, K., X. Wang, B. Zhu, L. Zhao, Y. Yang, Y. Cai, X. Sun, T. Wang & J. Cui (2023): A dataset on the call characteristics of 43 anuran species in China. – Biodiversity Science, **31**: 22344 [in Chinese with English abstract].

Ding, G. H., H. L. Hu & J. Y. Chen (2022): A Field Guide to the Amphibians of Eastern China. – China Agricultural Science and Technology Press, Beijing, China.

Dring, J. (1987): Bornean treefrogs of the genus *Philautus* (Rhacophoridae). – Amphibia-Reptilia, **8**: 19–47.

Duellman, W. E. & R. A. Pyles (1983): Acoustic resource partitioning in anuran communities. – Copeia, **1983**: 639–649.

Ellepola, G., M. R. Pie, R. Pethiyagoda, J. Hanken & M. Meegaskumbura (2022): The role of climate and islands in species diversification and reproductive-mode evolution of Old World tree frogs. – Communications Biology, **5**: 347.

Fei, L., S. Hu, C. Ye & Y. Huang (2009): Fauna Sinica Amphibia Vol. 2 Anura. – Science Press, Beijing, China.

Frost, D. R. (2024): Amphibian Species of the World: an Online Reference. Version 6.2 (accessed 14 October 2024). Electronic Database accessible at https://amphibiansoftheworld.amnh.org/index.php. – American Museum of Natural History, New York, USA.

Garg, S., R. Suyesh, S. Das, M. A. Bee & S. D. Biju (2021): An integrative approach to infer systematic relationships and define species groups in the shrub frog genus *Raorchestes*, with description of five new species from the Western Ghats, India. – PeerJ, **9**: e10791.

Goutte, S., A. Dubois & F. Legendre (2013): The importance of ambient sound level to characterise anuran habitat. – Plos One, **8**(10): e78020.

Grosjean, S., M. Delorme, A. Dubois & A. Ohler (2008): Evolution of reproduction in the Rhacophoridae (Amphibia, Anura). – Journal of Zoological Systematics and Evolutionary Research, **46**: 169–176.

Hu, S. Q., E. M. Zhao, Y. M. Jiang, L. Fei, C. Y. Ye, Q. S. Hu, Q. Y. Huang, Y. Z. Huang & W. S. Tian (1978): Amphibians and Reptiles of Tibet. – Science Press, Beijing, China.

Jiang, D., K. Jiang, J. Ren, J. Wu & J. Li (2019): Resurrection of the genus *Leptomantis*, with description of a new genus to the family Rhacophoridae (Amphibia: Anura). – Asian Herpetological Research, **10**: 1–12.

Kielgast, J. & S. Lötters (2009): Forest weaverbird nests utilized by foam-nest frogs (Rhacophoridae: *Chiromantis*) in Central Africa. – Salamandra, **45**: 170–171.

Köhler, J., M. Jansen, A. Rodríguez, P. J. R. Kok, L. F. Toledo, M. Emmrich, F. Glaw, C. F. B. Haddad, M.-O. Rödel & M. Vences (2017): The use of bioacoustics in anuran taxonomy: theory, terminology, methods and recommendations for best practice. – Zootaxa, **4251**: 1–124.

Kuramoto, M. & S. H. Joshy (2001): Advertisement call structures of frogs from Southwestern India, with some ecological and taxonomic notes. – Current Herpetology, **20**: 85–95.

Kuramoto, M. (1986): Call structures of the rhacophorid frogs from Taiwan. – Scientific Report of the Laboratory for Amphibian Biology, **8**: 45–68.

Li, J., J. Che, R. W. Murphy, H. Zhao, E. Zhao, D. Rao & Y. Zhang (2009): New insights to the molecular phylogenetics and generic assessment in the Rhacophoridae (Amphibia: Anura) based on five nuclear and three mitochondrial genes, with comments on the evolution of reproduction. – Molecular Phylogenetics and Evolution, **53**: 509–522.

Li, P., E. Zhao & B. Dong (2010): Amphibians and Reptiles of Tibet. – Science Press, Beijing, China.

Ligges, U., S. Krey, O. Mersmann & S. Schnackenberg (2013): Tuner: Analysis of music. Available online at http://r-forge.r-project.org/projects/tuner, accessed 14 Oct 2024.

Lue, K. Y., J. S. Lai & S. L. Chen (1994): A new species of *Rhacophorus* (Anura: Rhacophoridae) from Taiwan. – Herpetologica, **50**: 303–308.

Mahony, S., R. G. Kamei, R. M. Brown & K. O. Chan (2024): Unnecessary splitting of genus-level clades reduces taxonomic stability in amphibians. – Vertebrate Zoology, **74**: 249–277.

Malkmus R. & K. Riede (1996): The tree frogs of the genus *Philautus* from Mount Kinabalu. Part I: Overview and the *aurifasciatus*-group with description of a new species (*Philautus saueri* sp. n.). – Sauria, **18**: 27–37.

Matsui, M. & G. F. Wu (1994): Acoustic characteristics of treefrogs from Sichuan, China, with comments on systematic relationship of *Polypedates* and *Rhacophorus* (Anura, Rhacophoridae). – Zoological Science, **11**: 485–490.

Mo, Y. M., J. P. Jiang, F. Xie & A. Ohler (2008): A new species of *Rhacophorus* (Anura: Ranidae) from China. – Asiatic Herpetological Research, **11**: 85–92.

Mo, Y., W. Chen, X. Liao & S. Zhou (2016): A new species of the genus *Rhacophorus* (Anura: Rhacophoridae) from southern China. – Asian Herpetological Research, **7**: 139–150.

Mou, Y. P., J. P. Risch & K. Y. Lue (1983): *Rhacophorus prasinatus*, a new tree frog from Taiwan, China (Amphibia, Anura, Rhacophoridae). – Alytes, **2**: 154–162.

Muñoz, M. I. & W. Halfwerk (2022): Amplification of frog calls by reflective leaf substrates: implications for terrestrial and arboreal species. – Bioacoustics, **31**: 490–503.

Nguyen, T. T., H. T. Ninh, N. Orlov, T. Q. Nguyen & T. Ziegler (2020): A new species of the genus *Zhangixalus* (Amphibia: Rhacophoridae) from Vietnam. – Journal of Natural History, **54**: 257–273.

Poyarkov, N. A., T. V. Nguyen, E. S. Popov, P. Geissler, P. Pawangkhanant, T. Neang, C. Suwannapoom & N. L. Orlov (2021): Recent progress in taxonomic studies, biogeographic analysis, and revised checklist of amphibians in Indochina. – Russian Journal of Herpetology, **28**: 1–110.

Qian, T., Y. Shang, W. Zheng, P. Li & D. Yang (2025): Call variation and calling site preference of three sympatric *Boulenophrys* frogs. – Current Zoology, **71**: 492–503.

Rowley, J. J. L., V. Q. Dau, H. D. Hoang, T. T. Nguyen, D. T. T. Le & R. Altig (2015): The breeding biologies of three species of treefrogs with hyperextended vocal repertoires (*Gracixalus*; Anura: Rhacophoridae). – Amphibian-Reptilia, **36**: 277–285.

Siammawii, V., F. Malsawmdawngliana, L. Muansanga & H. T. Lalremsanga (2024): Observations on the breeding biology of the Upland Treefrog, *Polypedates braueri* (Vogt, 1911) from Mizoram, India. – Herpetology Notes, **17**: 25–33.

Sueur, J., T. Aubin & C. Simonis (2008): Seewave, a free modular tool for sound analysis and synthesis. – Bioacoustics, **18**: 213–226.

Sun, Z. X., T. L. Wang, B. C. Zhu & J. C. Wang (2017): Calls characteristics and temporal rhythm behavior of *Rhacophorus rhodopus* in the breeding season. – Chinese Journal of Ecology, **36**: 1672–1677.

Vassilieva, A. B., S. S. Gogoleva & N. A. Poyarkov (2016): Larval morphology and complex vocal repertoire of *Rhacophorus helenae* (Anura: Rhacophoridae), a rare flying frog from Vietnam. – Zootaxa, **4127**: 515–536.

Wang, J., J. Cui, H. Shi, S. E. Brauth & Y. Tang (2012): Effects of body size and environmental factors on the acoustic structure and temporal rhythm of calls in *Rhacophorus dennysi*. – Asian Herpetological Research, **3**: 205–212.

Wang, J., Z. C. Zeng, Z. T. Lyu, Z. Y. Liu & Y. Y. Wang (2018): Description of a new species of *Gracixalus* (Amphibia: Anura: Rhacophoridae) from Guangdong Province, southeastern China. – Zootaxa, **4420**: 251–269.

Weng, S., X. Liu, J. Li, G. Yu & J. Huang (2025): A new species of *Rhacophorus* (Anura, Rhacophoridae) from Xizang, China, with a revision of the distribution of *R. bipunctatus*. – Zoosystematics and Evolution, **101**: 437–447.

Wu, S. P., C. C. Huang, C. L. Tsai, T. E. Lin, J. J. Jhang & S. H. Wu (2016): Systematic revision of the Taiwanese genus *Kurixalus* members with a description of two new endemic species (Anura, Rhacophoridae). – ZooKeys, **557**: 121–153.

Yan, F., X. Liu, Y. Zhang & Z. Yuan (2021): Direct development of the bush frog *Raorchestes longchuanensis* (Yang & Li 1978) under laborary [sic!] conditions in Southern China. – Journal of Natural History, **55**: 125–132.

Yang, C. K. (2020): Call of female *Polypedates braueri* (Vogt, 1911) (Anura, Rhacophoridae) in Yilan, Taiwan. – Herpetology Notes, **13**: 849–850.

Zhu, B., J. Wang, L. Zhao, Q. Chen, Z. Sun, Y. Yang, S. E. Brauth, Y. Tang & J. Cui (2017): Male-male competition and female choice are differentially affected by male call acoustics in the serrate-legged small treefrog, *Kurixalus odontotarsus*. – PeerJ, **5**: e3980.

Supplementary data

The following data are available online:

Supplementary File List available on FigShare: https://doi.org/10.6084/m9.figshare.28193999.

Supplementary Video S1. Calling males of four treefrog species. Video description: Calling males of *Zhangixalus burmanus* (MT 2024008), *Rhacophorus medogensis* (XZ 2024131, marked as *Rhacophorus bipunctatus*), *Polypedates braueri* (unvouchered), and *Kurixalus naso* (MT 2024005) are shown.

Supplementary Audio S2. Chorus vocalization of *Kurixalus naso.* Audio description: This audio recording presents a chorus of *Kurixalus naso*, illustrating multiple call types, including pulsed calls not described within this study.