ARTICLES

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The Advertisement Call of *Ansonia latidisca*, the Bornean Rainbow Toad

Ansonia latidisca, the Bornean Rainbow Toad (Fig. 1), was, until 2011, known from three individuals from two locations in northwestern Borneo, namely, Gunung Damus in western Kalimantan, Indonesia, and Gunung Penrissen in western Sarawak, Malaysia, with the only published work being the description by Inger (1966), who classified it as a montane species. From the year of its first collection (1924), this species was not sighted until June 2011, when an expedition to the higher elevations (>1000 m elev.) of Gunung Penrissen rediscovered the species from tree trunks (ca. 2 m above ground) near forest trails (Pui et al. 2011). The species is currently listed as endangered in the IUCN Red List of Threatened Species, as the extent of its occurrence is less than 5,000 km^2, its area of occupancy is less than 500 km^2, all individuals are known from fewer than five locations, and there is continuing decline in the extent and quality of its habitat (Inger et al. 2018).

This communication presents information on the advertisement call of *A. latidisca*. Specifically, we noted note duration, note gap, repetition rate, dominant frequency, and fundamental frequency of call samples (see Cocroft and Ryan 1995).

Materials and Methods

Field observations were made at Gunung Penrissen, in western Sarawak, the range forming the natural boundary between Malaysia's Sarawak State and Indonesia's Kalimantan Barat Province. The forest type at the higher elevation of Gunung Penrissen (800–1300 m asl; 01.12°N, 110.21°E; WGS 84) is predominantly primary highland mixed dipterocarp forest, with jungle trails that permit access to the summit. Old growth trees are sparsely distributed along the trails, and there are abundant understory plants, including tree seedlings, wild gingers, aroids, rattans, climbers, ferns, and mosses. Due to high humidity levels, tree trunks are partially festooned with mosses and lichens.

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Field work was conducted from January to December 2012, over a total of 42 nights. Visual encounter surveys (Heyer et al. 1994), were conducted from 1800–2400 h. Additional surveys carried out in a wider range of habitats at different altitudes (particularly 800–1300 m, which is the known elevation range for the species) were unproductive in terms of encounters of *A. latidisca*.

Only three calling males were encountered whose complete calls could be recorded and the callers visually located. Calls were recorded using the bioacoustic techniques of Dorcas et al. (2009). Briefly, observers located calling males from transects. When a sighting was made, the recording system was set up between 1–1.5 m from the individual. The recorder was kept on until the animal ceased calling. Ambient temperature was taken at the time of recording. Recordings were made with a Marantz™ PMD670 portable solid-state digital recorder, coupled to a Sennheiser™ ME66 shotgun microphone attached to a Sennheiser™ K6P power module. The unit 66 has a super-cardioid/lobar pick-up pattern, with a frequency response in the 40–20,000 Hz (± 2.5 dB) range. The solid state recorder was set to save mono-channel audio using the PCM (Pulse Code Modulation) algorithm at the unit's maximum sample rate of 48 kHz, in the ".wav" file format. We selected the PCM algorithm for its uncompressed signal representation, avoiding distortions due to a lossy, and applied non-linear compression algorithms to the data by various MPEG algorithms. We specified the highest

Fig. 1. An adult *Ansonia latidisca*.

TABLE 1. Call distinctions in segment A and B pulse trains of the three calling individuals of *Ansonia latidisca*. Segments are from the same sequence.

Field number	SVL (mm)	T (°C)	Note		Note duration (s)		Note interval (s)
			Segment A	Segment B	Segment A	Segment B	
BH06	43.2	18.7	5	1	0.44 ± 0.15	7.8	0.88 ± 0.36
BH26	43.8	17.5	3	1	0.43 ± 0.06	10.3	0.87 ± 0.06
BH30	43.1	20.8	4	1	0.43 ± 0.25	8.2	0.85 ± 0.19

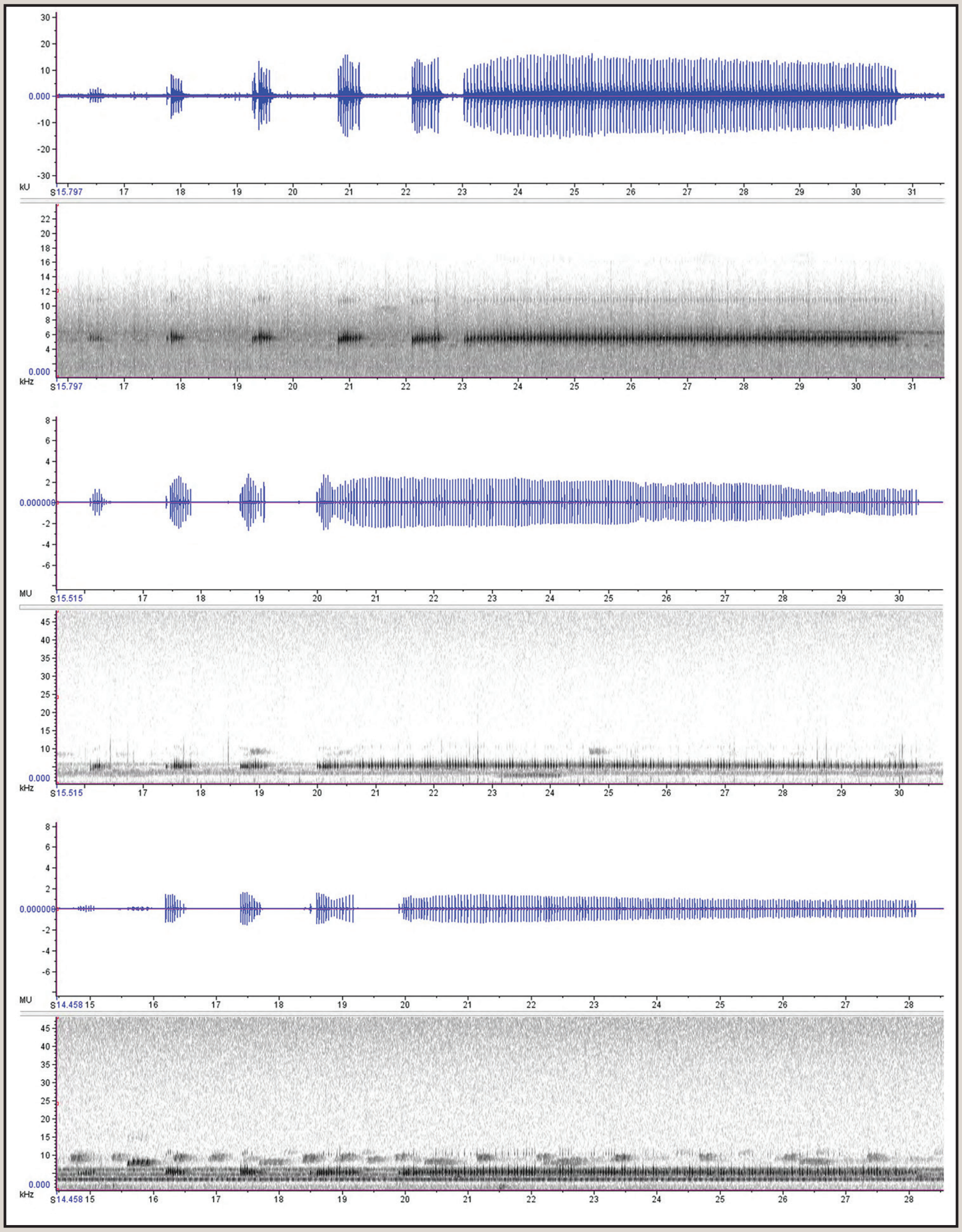

FIG. 2. Spectrogram and oscillogram of the advertisement calls of three individuals of *Ansonia latidisca,* ZRC(AUD)1.1–1.3. Recordings were made on 11 February, 26 August, and 29 September 2012.

sampling rate available to maximize our frequency capture (the maximum frequency that can be sampled is half the sampling rate). Selection of the PCM algorithm/file format automatically sets the bit rate of the recording to the maximum of 768 kbps. We set the recording level control to manual and the microphone attentuation to 0 dB.

After calling toads were tracked down visually, the recording apparatus was set up with the microphone pointing directly at calling individuals at a distance of ca. 100 cm. After fixing gain level, all headlamps and other artificial illumination sources were switched off and all movement ceased for the duration of the recording. After completion of recording, the toads were

Table 2. Comparison of selected call variables of three individual male *Ansonia latidisca*. A and B denotes type A and B pulse trains. Call parameter abbreviations are as follows: PulOn_90 (pulse time for onset to 90% [attack]); PulOn_peak (pulse time for onset to peak [rise]); Ener-0-10-Beg (energy between initial 0:10% peak amplitude); Ener-10-50-Beg (energy between initial 10:50% peak amplitude); Ener-50-90-Beg (energy between initial 50:90% peak amplitude); Ener-90-50-End (energy between final 90:50% peak amplitude); PulseOnFreq (onset pulse dominant frequency); PulseOffFreq (offset pulse dominant frequency); and PulseHalfFM (proportion of duration to reach half frequency modulation).

Field number	SVL (mm)	T (°C)	Dominant frequency (Hz)		Fundamental frequency (Hz)		Note repetition rate (notes)		Maximum frequency (Hz)		Minimum frequency (Hz)	
			A	B	A	B	A	B	A	B	A	B
BH06	43.18	18.3	5536 ± 175	5517 ± 49	2768 ± 87	2759 ± 24	5	1	5642 ± 186	5614 ± 112	5411 ± 152	5389 ± 89
BH26	43.80	17.2	5319 ± 179	5435 ± 30	2659 ± 89	2717 ± 15	3	1	5378 ± 140	5452 ± 84	4924 ± 224	5046 ± 78
BH30	43.10	21.2	5399 ± 153	5430 ± 50	2699 ± 77	2715 ± 25	4	1	5476 ± 209	5491 ± 141	4830 ± 210	4938 ± 216
Mean			5452 ± 176	5464 ± 59	2730 ± 87	2732 ± 30	4	1	5548 ± 199	5523 ± 134	5123 ± 335	5142 ± 233

Field number	PulOn90	PulOnPeak	PulseOnFreq (Hz)	PulseOffFreq (Hz)	Ener-10-50-Beg	Ener-0-10 Beg	Ener-90-50-End	Ener-50-90-Beg	PulseHalfFM	
									A	B
BH06	3.98 ± 1.39	3.98 ± 1.39	5537 ± 137	5513 ± 134	0	0.04 ± 0.02	0.03 ± 0.002	0.10 ± 0.05	0.22	0.13
BH26	1.26 ± 0.25	1.26 ± 0.25	5241 ± 188	5034 ± 107	0	0	0.03 ± 0.01	0.01 ± 0	0.05	0.24
BH30	0.85 ± 0.11	0.85 ± 0.11	5443 ± 110	5012 ± 225	0	0	0.01 ± 0	0	0.27	0.13
Mean	2.03 ± 1.7	2.03 ± 1.7	5407 ± 151	5186 ± 283	0	0	0.02 ± 0.01	0.04	0.18	0.17

captured, restrained, and cloacal temperature taken using a Blue Gizmo™ digital pocket thermometer, model BG366. The process took under 30 s. A voucher specimen was euthanized using a chlorobutanol solution, the specimen fixed in 4% formalin, preserved in 70% ethanol, and deposited in the museum of the Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Kota Samarahan. Calls were deposited in the audio collection of the Lee Kong Chian Museum of Natural History (digital audio vouchers ZRC[AUD] 1.1–1.3 [field numbers BH06, BH26, and BH30]).

Calls were analyzed using Raven Lite (vers. 1.0 for Windows) and SoundRuler (vers. 0.9.6.0) (Gridi-Papp 2011). Spectrograms and oscillograms were generated using Raven Lite (vers. 1.0 for Windows), with the recommendations of Sukumaran et al. (2006). Call characteristics are enumerated in Table 1.

Results

One call recorded from each of the three individual *Ansonia latidisca* was analyzed. These were distinct from the apparent release calls emitted when males were handled, and are considered advertisement calls. All three individuals produced a two-phase call consisting of two distinct segments. Segment A consisted of 3–5 introductory notes (5–12 pulses; mean duration 0.4 seconds each note) separated by an inter-note interval longer than the note; segment B was a long, repeated and uninterrupted note (112–155 pulses) that lasted up to 10 seconds (Table 1). Fig. 2 shows the spectrogram and oscillogram of these three individuals.

Table 2 presents data on selected call variables of the three calls. Harmonics are not evident in both segments of calls and energy of the notes is spread over the mean range 5.1–5.5 kHz. Mean dominant frequency for segment A and B are around 5.5 kHz, and the fundamental frequency is about 2.7 kHz. The maximum call frequencies for both segment A and B are 5.5 kHz and the minimum call frequencies are around 5.1 kHz.

Calls could be heard as early as 1700 h, after or during light precipitation, but most calling individuals were quiet when searched for, probably due to search-associated disturbance to the vegetation. In addition, calls were rarely heard during the dry period of 2012. The first individual was recorded on 11 February (wet season, right after the Northeast Monsoon showers) at 1810 h calling from a tree trunk, and the subsequent individuals were encountered on 26 August, at 1923 h and 29 September, at 1913 h (in the middle of the dry season) calling from a rock at a water seepage area.

Discussion

Although most calls of Bornean *Ansonia* species comprise relatively long trills composed of repeated note series (Table 3), only *A. spinulifer* has two call components that are similar to those of *A. latidisca*; a short and a long call.

Vocalization is an important component of the behavior of most anuran amphibians (Bogert 1960), and within the genus *Ansonia*, may be a series of identical repeated notes (e.g., *Ansonia hanitschi*; Malkmus et al. 2002), or a long high-pitched trill (e.g., *A. longidigita*; Malkmus et al. 2002). Several authors have demonstrated that advertisement calls can have distinctive characters for species recognition. Nonetheless, reviews by Sukumaran et al. (2006, 2010) reveal that studies of Bornean frog advertisement calls are limited and most call data

Table 3. Summary of published information on advertisement calls of Bornean *Ansonia*.

Species	Call information	Reference
A. hanitschi	Call series 6–10 sec, composed of equal notes with note repetition rate of 6 per sec; each note (duration 140–150 ms) comprises group of 3 single pulsed notes (duration 21–50 ms), repeated at intervals of 25–35 ms; frequency range 5.4 to 6.0 kHz	Malkmus et al. (2002)
A. longidigita	Long note series (0.9–10.5 sec) consisting of 4–135 notes at repetition rate 12.5–15.9 per sec, each note (duration 36–44 ms) consisting of 2–3 pulses (duration 7–33 ms); internote interval 31–36 ms; dominant frequency 3–4 kHz with harmonic at 10.8 kHz	Malkmus et al. (2002)
	Trills of 4–135 notes in 0.31–10.53 sec, 12.50–15.85 notes per sec; dominant frequency 3.4–4.0 kHz, with harmonics at 7.2–7.4 kHz; frequency modulation (FM) element in each note	Inger and Dring (1988)
A. leptopus	Short trills of 7–28 notes in 0.30–1.22 sec, 21.88–25.00 notes per sec; dominant frequency 2.9–3.4 kHz, with harmonic at 6.1 to 6.4 kHz; no sign of FM	Inger and Dring (1988)
	Five notes over 0.3 sec period (duration = 0.04 sec), each note with twin-pulse trill, first slightly shorter than second, at 0.01 sec (vs. 0.02 sec), 0.06 sec between each pulse, both pulses generally of same frequency as last three (2530 and 2650 Hz vs. 2720 Hz), interval between call ca. 2 sec	Sukumaran et al. (2010)
A. minuta	Call series of single-note harsh whistles with prominent harmonics and dominant frequency between 3.5–4.0 kHz	Inger et al. (2017)
A. platysoma	Series consists of over 100 weakly pulsed notes (duration 10–15 ms, internote interval 100–150 ms; interval between last two notes distinctly longer; note repetition rate 5–7 per sec) with frequency of 7.8 to 8.2 kHz	Malkmus et al. (2002)
A. torrentis	Elements repeated over 0.13–0.18 sec; calls composed of strong, poorly tuned note, 0.03 sec in duration, followed by 2–3 weak notes, forming series 0.06–0.09 sec in duration; dominant frequency 5–6 kHz, with energy of poorly tuned notes spread over 4.2–7.0 kHz; FM and amplitude modulation (AM) absent	Dring (1983)
A. spinulifer	Short call consists of single short note (0.01 sec), emitted 2.2 times per sec, harmonic partial; dominant frequency 2.9–3.0 kHz, less intensive frequency band sometimes at 1.8–2.0 kHz; long call sometimes follows former, 0.72–0.74 sec, consisting of 6–8 notes, irregularly emitted and variable in duration (0.01–0.06 sec), each note includes 1–4 pulses, with clear harmonics, fundamental frequency about 1.1 kHz, dominant frequency 3.9 kHz	Matsui (1982)

are abbreviated, onomatopoeic or verbally described, and about a third of frog species have undescribed calls, and lack formal descriptions using spectrograms and/or oscillograms.

In summary, the studies reported here add to the body of knowledge on the ecology of a relatively poorly known Bornean endemic amphibian species, providing new information on its acoustic ecology.

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Late-term Embryos and Hatchlings of Ouachita Map Turtles (*Graptemys ouachitensis*) Make Sounds within the Nest

The search for sound production and its potential function as acoustic communication in freshwater turtles is a new frontier in chelonian biology, following a report by Giles et al. (2009) that adult Oblong Turtles (*Chelodina colliei*) produced sounds of possible value in social communication in low-visibility environments. Research on the potential for sound production in turtle hatchlings is also progressing, although at a slower pace than for adult turtles. To our knowledge, hatchlings of only three freshwater turtle species in the South American genus *Podocnemis* (Ferrara et al. 2014a) and of several species of sea turtle (McKenna et al. 2019) are currently known to produce sounds. We provide evidence of hatchling sound production in a North American freshwater turtle, the Ouachita Map Turtle (*Graptemys ouachitensis*), from both natural nests and clutches monitored in laboratory incubators.

In 2016 and 2017 we equipped four natural nests at a nesting site along the lower Wisconsin River within 10 km of Spring Green, Wisconsin, USA (43.1777°N, 90.0679°W; WGS 84) with acoustic monitors (Song Meter 2, Wildlife Acoustics, Inc., Maynard, Massachusetts, USA) to investigate the potential for sound production by *in situ* hatchlings. The units were programmed to continually record the first 5 min of each hour from 1 August to early October, a period encompassing the expected interval of hatchling emergence (onto the surface) from nests. Recordings were made at a sampling rate of 24 kHz. At each monitored nest, microphones (model SMX-II, omni-directional, sensitivity 20 Hz–20 kHz, Wildlife Acoustics, Inc., Maynard, Massachusetts, USA) were placed within 4 cm of the undisturbed, *in situ* egg clutch, at mid-clutch depth and cabled to recorders inside 21-mm PVC pipe. Separate microphones recorded the ambient environment ca. 0.5 m above the ground surface (Fig. 1). In 2017 an additional identical acoustic monitoring station was established 2 m from an active nest in the same sand soil body as a negative control.

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Time of natural hatchling emergence from nests was studied from mid-August to early October via dedicated cameras (RECONYX™ models with either low-glow or no-glow infrared emissions, programmed to take continuous time-lapse images at 1-min intervals) suspended over each nest. Nests were excavated in early October to count hatched and unhatched eggs.

Of the three natural nests acoustically monitored in 2016, one was completely successful (7 emergent hatchlings) and two were partially successful (3 of 4, and 1 of 12 eggs hatched, respectively). In 2017 we monitored one natural nest, which failed late in incubation (5 disarticulated late-term embryos within eggshells and 2 eggs contained only sand).

Also in 2017, 10 eggs from two *G. ouachitensis* clutches collected along the Wisconsin River approximately 35 km (straight line) upstream of the study site were incubated in the lab (Thelco incubator, Model 4). The eggs were acoustically monitored with the same equipment used at the natural nest site to establish

Fig. 1. Field equipment set-up used to acoustically monitor natural *Graptemys ouachitensis* nests. The main photo shows the acoustic monitoring unit and ambient microphone within chicken wire screening to prevent disturbance by raccoons (*Procyon lotor*) and the PVC pipe shielding the cabled microphone monitoring the cage-protected nest. The inset shows the PVC pipe housing the recording microphone near its open end, close to the clutch.