Bioacoustics of *Hylarana celebensis* (Peters, 1872) (Anura: Ranidae) From Sulawesi
[Bioakustik Kodok *Hylarana celebensis* (Peters, 1872) (Anura: Ranidae) Asal Sulawesi]

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ABSTRACT

Hylarana celebensis (Peters, 1872) is an endemic frog to Sulawesi, the species being a member of family Ranidae. The presence of the frog in its habitat is easily detected from its advertisement call; males usually call in a chorus, they call to each other in a large group. Bioacoustic of calls of a typical individual male of *H. celebensis* have not been described in detail, although it is very easy to find this species in freshwater swamps, permanent ponds, or slow-flowing waters in the lowland areas. The purpose of the bioacoustic analysis on *H. celebensis*'s calls that were recorded at Bahodopi area is to build a reference collection to be compared with *H. celebensis*'s bioacoustics from other regions in Sulawesi. Because of the wide distribution of this frog in Sulawesi; genetic structure of *H. celebensis* population may also follow the genetic structure of *Ingerophrynus celebensis*population. Calls of *H. celebensis* have two types of calls, i.e. pure tone and pulse; however, pure tones have three variation, namely pure tone type 1, pure tone type 2 and pure tone type 3; however pulsed call has only one type.

Keywords: Anura**,** *Hylarana celebensis*, bioacoustics, Sulawesi.

ABSTRAK

Hylarana celebensis (Peters, 1872) adalah kodok endemik Sulawesi, yang mana jenis ini adalah anggota dari suku Ranidae. Keberadaan kodok *H. celebensis* di habitatnya sangat mudah terdeteksi melalui suara panggilannya; jantan biasanya bersuara dalam kelompok yang ramai, mereka bersahut-sahutan satu sama lain dalam kelompok besar. Bioakustik suara panggilan individu jantan *H. celebensis* yang khas belum diinformasikan secara detail, meskipun sangat mudah untuk menemukan jenis kodok ini di rawa air tawar, kolam permanen atau perairan berarus lambat di daerah dataran rendah Sulawesi. Tujuan dari analisis bioakoustik kodok *H. celebensis* yang direkam di wilayah Bahodopi adalah sebagai acuan dalam pengungkapan bioakoustik kodok *H. celebensis* dari wilayah lain di Sulawesi, karena distribusi kodok ini meluas ada di Sulawesi, kemungkinan besar struktur genetik dari populasi *H. celebensis* juga mengikuti struktur genetik populasi kodok *Ingerophrynus celebensis*. Suara panggilan dari jantan *H. celebensis* memiliki dua tipe gelombang suara, yaitu nada murni (*pure tone*) dan nada pulsa (*pulse*). Nada murni memiliki tiga variasi, yaitu nada murni tipe 1, nada murni tipe 2 dan nada murni tipe 3, sedangkan gelombang suara nada pulsa hanya memiliki satu tipe.

Kata Kunci: Anura**,** *Hylarana celebensis,* bioakustik, Sulawesi

INTRODUCTION

Hylarana celebensis (Peters, 1872) is a frog species endemic to Sulawesi, and is a member of the family Ranidae. Adult male and female of *H. celebensis* have slim body, which is the length of the body (SVL) of both sex are not much different; the average SVL of adult males that were collected from Bahodopi area, Central Sulawesi (Figure 1) was 42.5 mm (number of individuals 16), while the average SVL of adult females was 48.6 mm (number of individuals 5).

According to Iskandar & Mumpuni (2004), the distribution of *H. celebensis* in Sulawesi covers an area of low-lying west coast of Central Sulawesi, lowland areas west and east coasts of North Sulawesi and Gorontalo to Sorowako region in South Sulawesi. The vertical distribution of this frog covers lowlands below 700 m elevation above sea level (asl). With more additional locations that have been surveyed in Sulawesi, information on distribution of *H. celebensis* has become more widespread; the frog was not just found in the region of Central Sulawesi

Figure 1. Adult male of *Hylarana celebensis* from Bahodopi area, Central Sulawesi.

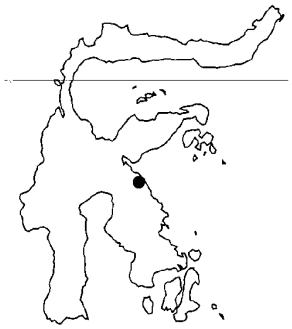

Figure 2. Bahodopi area (black circle) which is located at east coast of Central Sulawesi Province.

and North Sulawesi, but also found in the east coast of Central Sulawesi (including Bahodopi area) and in the lowland area of Southeast Sulawesi. Wanger *et al.* (2011) found *H. celebensis* in Lore Lindu National Park area; Gillespie *et al*. (2005) also found the frog on Buton Island and other islands around the island.

The presence of *H. celebensis* in its natural habitat is easily detected from its advertisement call; males usually call in a chorus, they respond to the advertisement call in a large male group. Bioacoustics of calls that a typical of adult male of *H. celebensis* have not been described in detail, although it is very easy to find this frog in its natural habitats such as freshwater swamps, permanent ponds or slow flowing waters in low land areas, which are typically found in Bahodopi area in Central Sulawesi Province (Figure 2). The main objective to describe bioacoustics of *H. celebensis* that was originated from Bahodopi area use as a basic reference in comparison with bioacoustics of *H. celebensis* from the other regions in Sulawesi; because the frog has wide distribution in Sulawesi, and most likely the population genetic structure of *H. celebensis* may also follow genetic structure of the population *Ingerophrynus celebensis,* as revealed by Evans *et al*. (2008). Possible relationships between bioacoustics of *I. celebensis* and genetics have not been proven. However that the genetic structure of the population does affect the pattern of bioacoustics was proven in *Duttaphrynus melanostictus* (Wei *et al.* 2012) and also for *Polypedates leucomystax* (Sheridan *et al.* 2010).

METHODOLOGY

Calls of four adult males *H. celebensis* were recorded in the Bahodopi area (S 02048'37.4 "; E 122004'58.5"; 258 m asl), Central Sulawesi. Date of recording on 9-10 April, 2013 by using a Sony PCM-M10 recorder using a sampling frequency of 94 kilohertz (kHz) and a bit rate of 24 bits, with the air temperature of 27.4° C. In the lab, recorded calls were first normalized and then converted to 48000 Hz (= Hertz) and 16 bits by using Adobe Audition software version 3.0 to ensure highest possible recording quality for frequencies up to 24 kHz. Adobe Audition 3.0 software was also used to describe the oscillogram and audiospectrogram of each call type of *H. celebensis*. Visualization process of sound waves in the form of oscillograms, audiospectrograms and the dominant frequency were taken by using FFT (Fast Fourier Transformation; 1024 points) at using a Hanning window. The terms were used in the description of the calls followed to Pettitt *et al.* (2012). Ratio of Coefficient Variant (CV) was calculated to determine the "static" and "dynamic" of vocalizations (Gerhardt 1991); CV calculations followed Krebs (1989).

RESULTS

Calls of *H. celebensis* have two types, i.e. pure tone and pulses (Figure 3 and 4); calls of two males were recorded for the type of pure tone and also two males for the type of pulse. Pure tone calls have three variations, namely pure tone type 1, pure tone type 2 and pure tone type 3 (Figure 3); these three types of pure tone were released randomly in five minutes long recording and the tones are frequency modulated in various ways (see Figure 3); however pulsed call has only one type (Figure 4). Three types of pure tones were released by the males in irregular tempo, while the pulses were released with a relatively in regular tempo; therefore

pulse rate and call rate of pulsed call type can be calculated by following Pettitt *et al.* (2012). Both types of sound waves are described in detail below:

I. Pure Tone Calls

I.1. Pure tone type 1

Visualization results of the audio spectrogram show the amplitude of this type is modulated with harmonic number is between 1-2; first harmonic (or fundamental frequency) is strong whereas the second harmonic is weak (Figure 3). The average value of the first harmonic is 1563.66 ± 248.61 Hz (CV = 15.90%), with a frequency range is between 937-2015 Hz; while the average value of the second harmonic is 2777.95 ± 521.11 Hz, with a frequency range is between 1593-4078 Hz (see Table 1). Up to 5 harmonics may be present in the signal. The frequency range of the first and second harmonic is very wide (> 1000 Hz), this value indicates that the filtering of the vocal apparatus seems to be rather broad, most signal energy was between 937 Hz and 2015 Hz. The average duration of the pure tone type 1 is 40.71 ± 11.06 ms (CV = 27.17%), with a range of durations between 23-91 ms. The duration of the pure tone type 1 is shorter than the duration of the two other types of pure tones (see Table 1).

I.2. Pure tone type 2

Results obtained from the audio spectrogram show that frequency of this type is an ascending modulation at an early stage and then descending modulation at the end; the number of harmonics is between 2-3, with the second harmonic being strong while the two others are weak (Figure 3). The average value of the fundamental frequency (or first harmonic) is 1366.32 ± 248.25 Hz (CV = 18.17%), with a frequency range is between 483 -1734 Hz; the average value of the second harmonic is 2139.74 ± 384.67 Hz, with a frequency range is between 1593 to 2695 Hz; while the average value of the second harmonic is 2904.58 ± 401.92 Hz, with a frequency range is between 1828-3304 Hz (see Table 1). The frequency range of the fundamental frequency and the first harmonic and the second is very wide (> 1000 Hz), this value also indicates that the filtering of the vocal apparatus seems to be rather broad, most signal energy was between 483 Hz and 1734 Hz . The average duration of the pure tone type 2 is 80.63 ± 30.35 ms (CV = 37.64%), with a range duration is between 37-151 ms.

I.3. Pure tone type 3

Visualization results of audiospectrogram show that frequency of this type is slightly modulated and has 4-7 harmonics, which is the first and the second harmonic are strong (Figure 3). The average value of the fundamental frequency is 1120.67 ± 196.98 Hz (CV = 17.58%), with a frequency range is between 937-1453 Hz; the average value of the first harmonic is 1839.50 ± 216.56 Hz, with a frequency range is between 1453 to 2015 Hz (see Table 1); while the average value of the second harmonic is 2640.17 ± 213.18 Hz, with a frequency range is between 2390 to 2953 Hz (see Table 1). Frequency range of the fundamental frequency and the first harmonic and the second is not wide (approximately 500 Hz), this value indicates that the filtering of the vocal apparatus seems to be not broad, most signal energy was between 1453 Hz and 2015 Hz. The average duration of the pure tone type 3 is 104.17 ± 34.08 ms (CV =

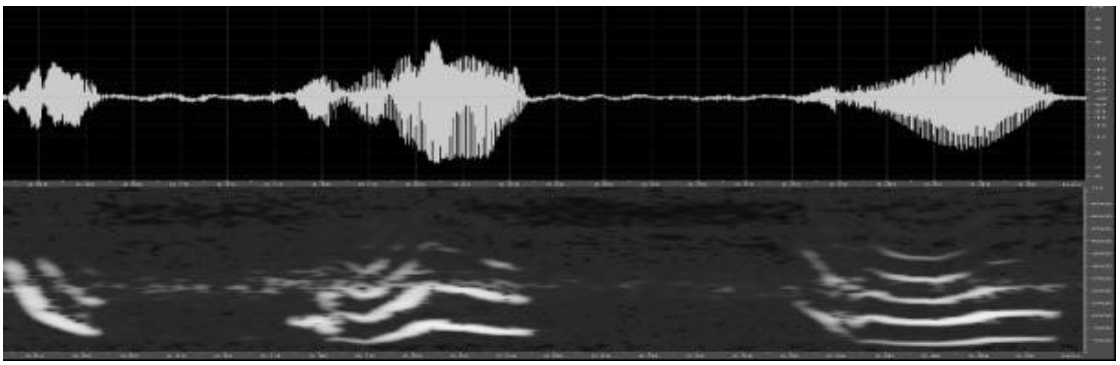

Figure 3. Oscillogram and audiospectrogram of pure tone calls of *Hylarana celebensis*. From left to right: pure tone type 1, pure tone type 2 and pure tone type 3.

32.71%), with a range duration is between 62-157 ms. The duration of a pure tone type 3 is the longest compared to the other two types of pure tones (see Table 1).

Three types of pure tone calls have irregular tempo. This character indicates that the pure tone calls are not spontaneous or clicking vocalizations, the calls can be controlled by the males. The average of fundamental frequency decreases successively from pure tone type 1 to pure tone type 3, but the number of harmonics and duration of the pure tone increases from pure tone type 1 to pure tone type 3 (see Table 1). Two males released three types of pure tone might be caused by pulse background noise in which a large group of male *H. celebensis* were calling in chorus, because the two males were about one meter outside the swamp habitat. This phenomenon occurs on *Hylarana* (= *Rana*) *taipehensis* that live near airports in Thailand, in which individual males will release calls of different frequencies in a noisy environment due to human activity (Sun & Narins 2005); however pure tone variations that were released by *H. celebensis* was natural, because there was no anthropogenic noise (resulting from human activities) in the environment around *H. celebensis* habitat during calls recording. Visualization of the three types of pure tone looks similar to visualization of pure tones that were released by *H. taipehensis* (Sun & Narins 2005). Pure tone type 1, type 2 and type 3 of *H. celebensis* are similar to pure tone type (g), type (e) and type (f) of *H. taipehensis* (see Figure 3 and Figure 6), however both frogs species have different fundamental frequencies; fundamental frequency of *H. celebensis* lower than the fundamental frequency of *H. taipehensis.*

The three types of pure tones of *H. celebensis* are dynamic calls; it is indicated by the CV values more than 12% at the fundamental frequency; as well as the duration of each type of pure tones. These CV results indicate that the intensity and duration of pure tones calls can be controlled by male of *H. celebensis*. This phenomenon also belongs to *Hylarana chalconota* (Marquez & Eekhout 2006) and *Phrynoidis aspera* (Kurniati 2013).

II. Pulsed Calls

There is only one type of pulsed call of *H. celebensis* (Figure 4a). The call type is a regular call that is often advertised in chorus by males *H. celebensis*. The pulse type of *H. celebensis* has two sets of pulses, which is one call consists of 3-5 pulses and a pulse is also composed of many sub-pulses (> 10 sub-pulses) (see Figure 4b). As a result of this rapid and varying amplitude modulation the spectrogram shows merely 'noise' (Figure 4) in which no harmonic structure can be discerned. To the ear such sounds appear scratch-like, whereas pure tone sounds as described above have a pleasant sound quality to the human ear.

The average number of pulses in every call is 4 ± 0.31, with a range of pulse is between 3-5. The average duration for the pulse is 131.87 ± 10.57 ms (CV = 8.01%), with a range duration is between 100-164 ms; while the average duration of a call is 788.23 ± 70.09 ms (CV = 8.89%), with a range call duration is between 548-963 ms (see Table 1). The average duration between pulses is 210.17 ± 16.77 ms (CV = 7.98%), with a range duration between pulse is 182-250 ms; pulse rate that were taken from the average duration is 4.76/sec. The average duration between call is 9699.05 ± 2034.10 ms (CV = 20.97%), while the range of durations is between call is 7358-16390 ms; call rate that was taken from the average duration is 0.10/sec.

Audio spectrogram visualization of pulse shows that there was no dominant frequency, but it is a span with a wide spectrum (Figure 4a). Average frequency of the lower spectrum is 1636.08 ± 151.72 Hz (CV=9.27%), with a range frequency is between 1125 to 1968 Hz, while the average frequency of the upper spectrum is 3326.15 ± 322, 01 Hz (CV=9.68%), with a range frequency is between 2906-4500 Hz; average width spectrum of the pulses is 1690.21 ± 384.62 Hz (CV=22.75%), with a range frequency is between 1032 to 2860 Hz (Table 1).

DISCUSSION

The pulsed call type is a common call which is released regularly by male *H. celebensis* ; this call is usually used as a

reciprocal call among males in a large group in its natural habitat, include grassy swamp, permanent pool and slow-moving stream. Pulsed calls type have relatively regular tempo that is shown by the value of CV<12%, the duration one pulse (CV=8.01%), the duration between pulse (CV=7.98%) and the duration of one call (CV=8.89%). CV value is more than 12% in the duration between calls (CV= 20.97%) indicates that there is an irregularity tempo on calls; this condition is common in frog's bioacoustics, because the releasing time of the call on frog depends on many environmental factors (Goutte *et al.* 2013).

Visualization results of *H. celebensis'* pulsed call shows that there is no dominant frequency on the audio spectrogram; therefore the analysis was carried out in another way by looking lower frequency and upper frequency of the spectrum. The width of the spectrum is the reduction result of the upper frequency to the lower frequencies (Figure 5). Lower and upper frequencies of the pulse are static with CV<12%, but the width of the spectrum is dynamic (CV = 22.75%).

The pulse type call of *H. celebensis* is similar with the pulse type call of *H. nicobariensis* as described by Jehle and Arak (1998) and Malkmus *et al.* (2002); the difference between the two calls type is the number of pulses per call; call of *H. celebensis* consists of 3-5 pulses, while in *H. nicobariensis* consists of 6-10 pulses; the duration of the pulse on *H. celebensis* is between 100-164 ms, whereas on *H. nicobariensis* is between 50-60 ms; the average pulse rate on *H. celebensis* is

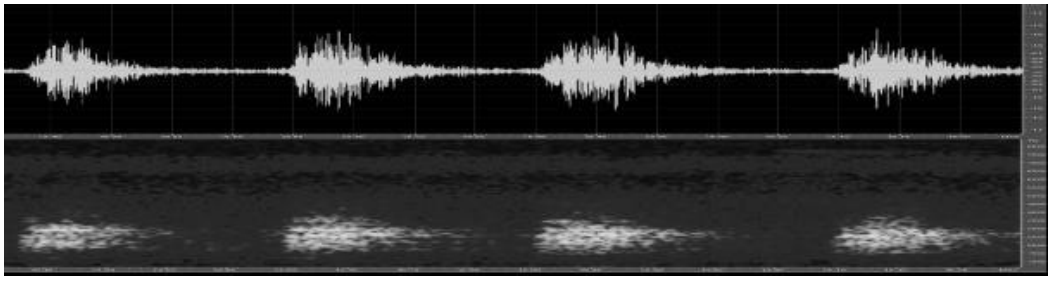

Figure 4a. Oscillogram and audiospectrogram of pulsed calls of *Hylarana celebensis*.

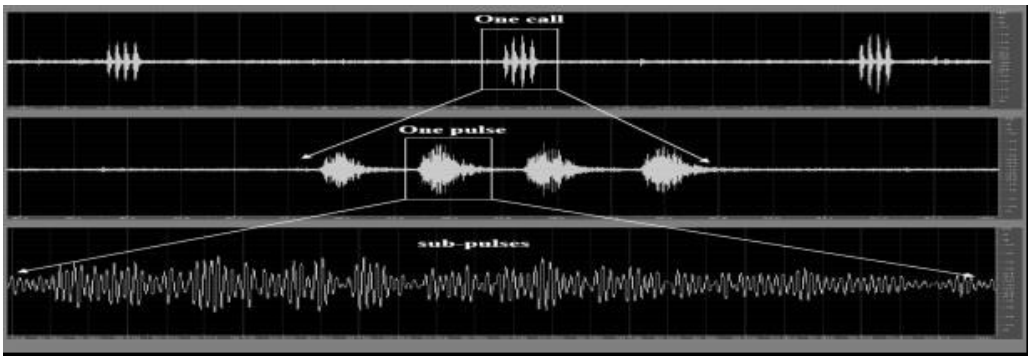

Figure 4b. Enlarged oscillogram to show the sub-pulses of pulsed call of *Hylarana celebensis.*

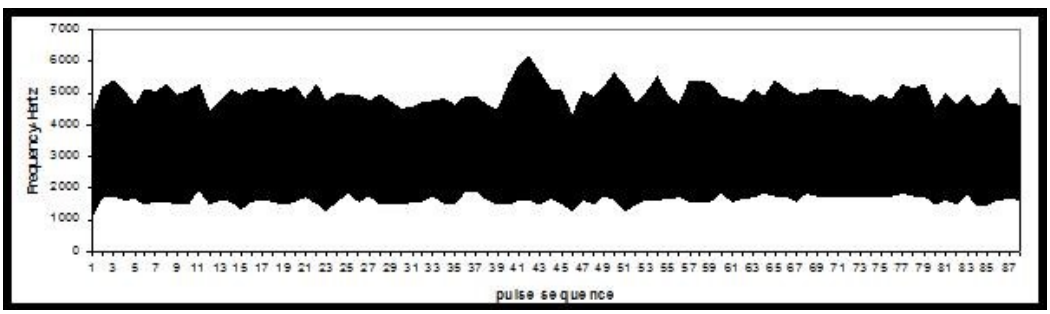

Figure 5. Wide spectrum (black color) of pulsed calls of *Hylarana celebensis*.

Table 1. The average value, standard deviation (SD), minimum and maximum values [(x ± SD) (minimum-maximum)] of the frequency and duration of four types of calls of *Hylarana celebensis*. n = total number of the analyzed calls.

Call characters	Call type			
	Pure tone type 1 (n=78)	**Pure tone type 2** (n=18)	**Pure tone type 3** (n=6)	**Pulse type** (n=87)
Fundamental frequency-Hz	1563,66±248,61 (937-2015)	1366,32±248,25 (483-1734)	1120,67±196,98 (937-1453)	-
Harmonic 1-Hz	2777,95±521,11 (1593-4078)	2139,74±384,67 (1593-2695)	1839,50±216,56 (1453-2015)	-
Harmonic 2-Hz	-	2904,58±401,92 (1828-3304)	2640,17±213,18 (2390-2953)	-
Duration of one pure tone-ms	40,71±11,06 (23-91)	80,63±30,35 (37-151)	104,17±34,08 (62-157)	-
Number of pulse/call	-	-	-	4±0,31 (3-5)
Lower frequency-Hertz	-	-	-	1636,08±151,72 (1125-1968)
Upper Frequency-Hz	-	-	-	3326,15±322,01 (2906-4500)
Width of spectrum-Hz	-	-	-	1690,21±384,62 (1032-2860)
Duration of one pulse-ms	-	-	-	131,87±10,57 (100-164)
Duration between pulses-ms	-	-	-	210,17±16,77 (182-250)
Duration of one call-ms	-	-	-	788,23±70,09 (548-963)
Duration between calls-ms	-	-	-	9699,05±2034,10 (7358-16390)

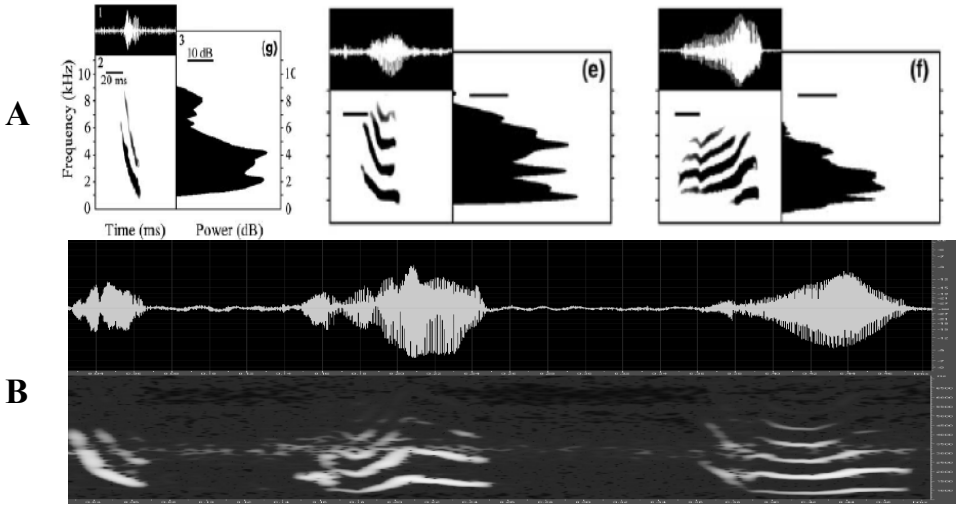

Figure 6. Oscillogram, audiospectrogram and intensity (power) of *Hylarana taipehensis* (A) from Thailand that looks similar to the three types of pure tone calls of *Hylarana celebensis* (B) from Sulawesi (image source of A: Sun & Narins 2005). (g) a pure tone that similar to pure tone type 1; (e) a pure tone similar to the pure tone type 2; (f) a pure tone similar to pure tone type 3.

4.76/sec, whereas 7.00/sec on *H. nicobariensis*; duration between pulses on *H. celebensis* is 182 -250 ms, whereas in *H. nicobariensis* is 70-80 ms. The lowest pulse frequency and the highest pulse frequency on *H. celebensis* is between 1124-4500 Hz (see Table 1), whereas on *H. nicobariensis* is between 1000-4000 Hz (Malkmus *et al.* 2002).

CONCLUSIONS

The bioacoustics of *H. celebensis* has two types of calls, i.e. pure tone and pulse. Pure tone calls consists of three types: (a) pure tone type 1; (b) pure tone type 2; and (c) pure tone type 3. Pure tone type 1 is a modulated call which has 1 -2 harmonics and the fundamental frequency range is between 937-2015 Hz. Pure tone type 2 is a modulated call which has 2-3 harmonics and the fundamental frequency range is between 483-1734 Hz. Pure tone type 3 is a slightly modulated call which has 4-7 harmonics and the fundamental frequency range is between 937-1453 Hz. The pulse type call has only one type, which has no dominant frequency on its audiospectrogram, but it is a ban with a wide spectrum which range of the spectrum is between 1032-2860 Hz.

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