Malaysian Applied Biology
https://doi.org/10.55230/mabjournal.v55i1.3523

Research Article

Vocal Signatures For Species Identification Among Eight Microhylid Frogs in Sarawak, Malaysia

Muhammad Fadzil Amram[1]*, Ramlah Zainudin[2]

1. Conservation Biology, Faculty of Tropical Forestry, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
2. Animal Resource Science and Management, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

*Corresponding author: amfadzil@ums.edu.my

ABSTRACT

The advertisement calls of frogs serve as vital communication signals, playing a significant role in species recognition and mate attraction, representing a critical aspect of their behavioural ecology. This study aims to document and analyse the advertisement calls of eight Microhylidae species in various habitats across Sarawak. Using field recordings and acoustic analysis, distinct call characteristics were identified, including frequency, note repetition rate, and pulse structure. Advertisement calls were recorded and analysed using SoundRuler Acoustic Analysis and Praat Acoustic Software. Call characteristics were subsequently compared for species differentiation. The results showed that each species exhibits distinct call characteristics, likely reflecting adaptations to habitat acoustics and conspecific interactions. Among them, *Microhyla nepenthicola* Das & Haas, 2010 demonstrated the highest rate of note repetition, the greatest number of pulsed notes per call, and the highest dominant frequency, suggesting unique acoustic adaptations within its ecological niche. These findings can contribute to the understanding of species-specific vocalisations and their potential role in mate selection, territorial defence, and environmental adaptation.

Key words: Advertisement call, dominant frequency, Microhylidae, note repetition, pulse structure

INTRODUCTION

Acoustic communication is arguably the most influential trait in the social behaviour of anuran amphibians, playing a crucial role in species recognition, territorial defence, and reproductive success. While the conditions under which animals vocalise differ among species, nearly all male frogs utilise some form of advertisement call in their vocal repertoire, which serves as a crucial precursor to successful courtship and mating (McClelland *et al*., 1996; Passos *et al*., 2017). These vocalisations are species-specific and can provide valuable insights into taxonomy, ecology, and evolutionary relationships.

Microhylidae, a family of Narrow-mouthed Frogs, is a diverse family characterized by their specialisation in consuming small prey such as insects. This family exhibits extensive variation in adult external morphology at both inter- and intraspecific levels, likely due to adaptations associated with their burrowing lifestyle (de Sá *et al*., 2012). They mostly use standing water bodies for reproduction, where some of the species have adapted to breed in small, collected water in bamboo trees, tree hole and pitcher plants. Certain genera, such as *Metaphrynella* and *Chaperina*, have developed arboreal tendencies, utilising their climbing abilities to inhabit trees (Gorin *et al*., 2021). Among the Microhylidae of Borneo, the genus *Microhyla* is particularly interesting due to its diverse ecological niches and unique reproductive strategies. Some species, such as *Microhyla nepenthicola*, have been documented utilising pitcher plants (*Nepenthes ampullaria* Jack 1835) as breeding sites, an unusual adaptation among amphibians (Das & Haas, 2010). Understanding the vocalisation patterns of these frogs is essential for assessing their behavioural ecology, species interactions, and conservation needs, particularly in the biodiverse yet increasingly threatened forests of Sarawak.

Despite the ecological significance of frog vocalisations, research on the acoustic behaviour of Malaysian frogs remains limited, particularly for Bornean Microhylidae. The study by Sukumaran *et al*. (2006) found that many microhylid species lacked detailed acoustic documentation. Several had only verbal descriptions or none at all. In contrast, several studies have documented anuran vocalisations in Peninsular Malaysia, including the descriptions of *Limnonectes macrognathus* Boulenger, 1917 and *Leptobrachium smithi* Matsui, Nabhitabhata & Panha, 1999 by Dasi & Shahriza (2022). Additionally, research on frog vocalisations in Sarawak has provided valuable insights. Early descriptions by Dring (1983a, 1983b, 1987) laid the groundwork for understanding species-specific acoustic traits among stream-dwelling and arboreal anurans. For instance, *Leptobrachella* species were shown to produce short, high-pitched calls with distinct temporal patterns, facilitating species recognition in acoustically complex montane habitats (Dring, 1983b). Similarly, *Philautus ingeri* emits a soft series of “quoink”-like notes, typically from elevated perches near streams, reflecting both phylogenetic and ecological influences on call evolution (Dring, 1987). Dring (1983a) identified three distinct frog call types for *Kalophrynus nubicola* across elevational zones in Gunung Mulu, each varying in structure and location, from brief “gek” calls at lower elevations to longer “gegger” calls mid-slope, and unrecorded

Article History
Accepted: 9 January 2026
First version online: 31 March 2026
Cite This Article:
Amram M.F. & Zainudin, R. 2026. Vocal signatures for species identification among eight microhylid frogs in Sarawak, Malaysia. Malaysian Applied Biology, 55(1): 48-58. https://doi.org/10.55230/mabjournal.v55i1.3523

"gan" calls at the summit. Building on this acoustic evidence, Fukuyama *et al*. (2021) later confirmed that these vocal variants correspond to three distinct species, underscoring the role of bioacoustics in cryptic species delimitation.

Dehling (2010) found that the calls of two *Microhyla* species in Borneo exhibit striking similarities, with the primary distinction being a lower dominant frequency. A previous study by Zainudin *et al*. (2010) on the genus *Pulchrana* (previously known as *Hylarana*) discovered significant differences in call characteristics between species, particularly in the number of pulsed notes and note repetition. The variation of the advertisement calls of Sarawak *Pulchrana* was found to be able to discriminate the species within the genus, where call note, pulse duration, call energy, call frequency and call intensity are all useful characters in discriminating the *Pulchrana* species (Marly *et al*., 2017). Amram *et al*. (2018) found that advertisement call characteristics are effective for species recognition in Sarawak Bufonids, aligning with the findings of this study. Similarly, Deka and Zainudin (2025) identified pulse duration, call energy, and call frequencies as key parameters distinguishing frog species. Their research further revealed a strong correlation between dominant frequency, pulse duration, and body size, suggesting that larger frogs tend to produce lower-frequency calls. Vocal structure also plays a significant role in shaping acoustic signals. A study by Deka *et al*. (2015) on Ranidae examined morphological variations in the vocal apparatus and found that closely related species exhibit similar vocal structures, potentially enhancing species recognition and reproductive success. Additionally, Amram *et al*. (2020) demonstrated through vocalisation playback experiments that male *Pulchrana baramica* Boettger, 1900, *Pulchrana glandulosa* Boulenger, 1882, and *Kurixalus chaseni* Smith, 1924 can recognise calls from their own species, further emphasising the role of vocal adaptations in facilitating intra-species communication.

These studies have emphasised the importance of vocalisation in species differentiation and have contributed to the broader understanding of amphibian bioacoustics in the region. These findings underline the critical role of acoustic communication in the taxonomy and ecological studies of Sarawak's frog species.

Family Microhylidae currently comprises seven genera in Borneo. Five genera, with eight species representative included in this study (Figure 1), namely, *Chaperina fusca* Mocquard, 1892 (Saffron-bellied Frog), *Kalophrynus heterochirus* Boulenger, 1900 (Variable Sticky Frog), *Kalophrynus dringi* Dring, 1983 ('Dring's Sticky Frog), *Kalophrynus subterrestris* Inger, 1966 (Burrowing Sticky Frog) - no picture taken, *Kaloula pulchra* Gray, 1831 (Banded Bullfrog), *Metaphrynella sundana* Peters, 1867 (Tree Hole Narrow-mouthed Frog), *Microhyla nepenthicola* (Matang Narrow-mouthed Frog) and *Microhyla malang* Matsui, 2011 (Borneo Narrow-mouthed Frog).

Fig. 1. Bornean frogs from Family Microhylidae: a) *Chaperina fusca*, b) *Kalophrynus heterochirus*, c) *Kalophrynus dringi*, d) *Kaloula pulchra*, e) *Metaphrynella sundana*, f) *Microhyla nepenthicola*, g) *Microhyla malang*. All pictures taken by Amram, M.F.

MATERIALS AND METHODS

Materials

Different habitats in Sarawak, Malaysian Borneo, namely, Mulu National Park, Kubah National Park, Gunung Santubong National Park, Matang Wildlife Centres, Miri (WILMAR Plantation), Bungo Range National Park, and Universiti Malaysia Sarawak (Table 1), were surveyed at night, and anuran vocalisations encountered were recorded. The data collection was conducted between 2015 and 2019.

Table 1. Location of Study Site

No.	Location	Forest Type	Coordinate
1	Gunung Mulu National Park	Primary forest	N 04° 03'02.1" E 114° 51'39.9"
2	Matang Wildlife Centres	Mixed Dipterocarp	N 01° 36'40.4" E 110° 09'49.7"
3	Kubah National Park	Mixed dipterocarp	N 01° 36'19.3" E 110° 11'30.3"
4	Santubong National Park	Primary	N 01° 73'16.3" E 110° 33'24.3"
5	Wilmar Plantation, Miri	Mixed Dipterocarp, Secondary	N 03° 16'03.4" E113° 40'02.4"
6	Universiti Malaysia Sarawak	Peat swamp & secondary forest	N 01° 46'11.4" E 110° 43'11.9"
7	Bungo Range National Park	Primary and Secondary	-

For sampling intensity, each site was sampled for one to four weeks, with two to three manpower. During sampling, the sites were surveyed, and Male frogs' vocalisations were recorded upon encounter via a TASCAM DR-40 Linear PCM Recorder. Upon recording, the frogs were identified by their morphology and matched to the description by Inger & Stuebing (2005) and Inger *et al*. (2017). Several sounds (2-3 individuals) of each male of the Bornean frogs were recorded for two to 10 min, depending on the call gaps of each species. The number of anurans recorded for this study is listed in Table 2. Sample size (*n*) is indicated as the number of sounds or notes analysed in 60 s, and means are given for the number of sounds recorded (Amram *et al*., 2018).

Table 2. Number and Species of Microhylidae Recorded

Family	Species (*n* = number of samples)	Location
Microhylidae	*Chaperina fusca* (*n*=1)	Gunung Mulu NP
	Kalophrynus heterochirus (*n*=4)	Kubah NP and Santubong NP
	Kalophrynus dringi (*n*=2)	Gunung Mulu NP
	Kalophrynus subterrestris (*n*=1)	Kubah NP
	Metaphrynella sundana (*n*=6)	Kubah NP, Gunung Mulu NP, Wilmar Plantation
	Microhyla nepenthicola(*n*=7)	Bungo Range, Kubah NP, Matang WC
	Microhyla malang (*n*=3)	Kubah NP
	Kaloula pulchra (*n*=1)	UNIMAS

The frogs' vocalisations were recorded in .wav format with a 44.1 kHz sample rate and 16bit bit size, in stereo. Audio files were trimmed using WavePad Sound Editor. The sound was analysed using SoundRuler Acoustic Analysis 0.9.6.0 2003-2007 Marcos Gridi-Papp software, and Praat software.

RESULTS

The advertisement calls of the eight species of Microhylidae exhibited distinct acoustic characteristics. However, the calls of *Chaperina fusca* were recorded for only 30 s due to equipment malfunction, and the recordings were further compromised by background noise from nearby insects. Among species recorded, genus *Microhyla* demonstrated the highest number of pulsed notes, separating them from other genera, whereas species from other genera predominantly produced single pulsed notes (Table 3). The following section presents detailed descriptions of the advertisement calls recorded for each Microhylid species, accompanied by representative acoustic oscillograms and spectrograms.

Table 3. Summary of call characteristics of 8 species of Sarawak Microhylidae

Specied	Call Characteristics		
	No. of pulsed notes	Note repetition rate/ 60 s	Dominant frequency (kHz)
Chaperina fusca call type 1	2	22	NA
Chaperina fusca call type 2	1	6	NA
Kalophrynus heterochirus	1	22	4.5-4.7
Kalophrynus dringi	1	10	2.67-2.72
Kalophrynus subterrestris	1	30	2.73
Metaphrynella sundana	1	16-18	1.6-1.8
Microhyla nepenthicola	2-14	62	5.6-6
Microhyla malang	3-9	12	2.3
Kaloula pulchra	1	16	`1.25

A. *Chaperina fusca*

Chaperina fusca (Saffron-bellied Frog) has a very soft "tic" and "squeaky" calls. Identifying this species based on its call is challenging, as the male's vocalisation is subtle and resembles insect sounds rather than a typical frog call (Mahyudin *et al*., 2019). Males call in groups, where some individuals were observed climbing trees or buttresses to call for their mates to breed. Their vocalisation consists of two distinct call types: a short, peaked "tic" note with two pulses (Figure 2, circled) and a longer, high-pitched "squeaky" note (Figure 3, circled). The "tic" call is the dominant call type, while the "squeaky" note is produced less frequently. Due to technical limitations, recordings were only taken for 30 s, during which 28 call repetitions were observed. The oscillogram and spectrogram were unclear due to interference from insect sounds, making it difficult to determine the dominant frequency.

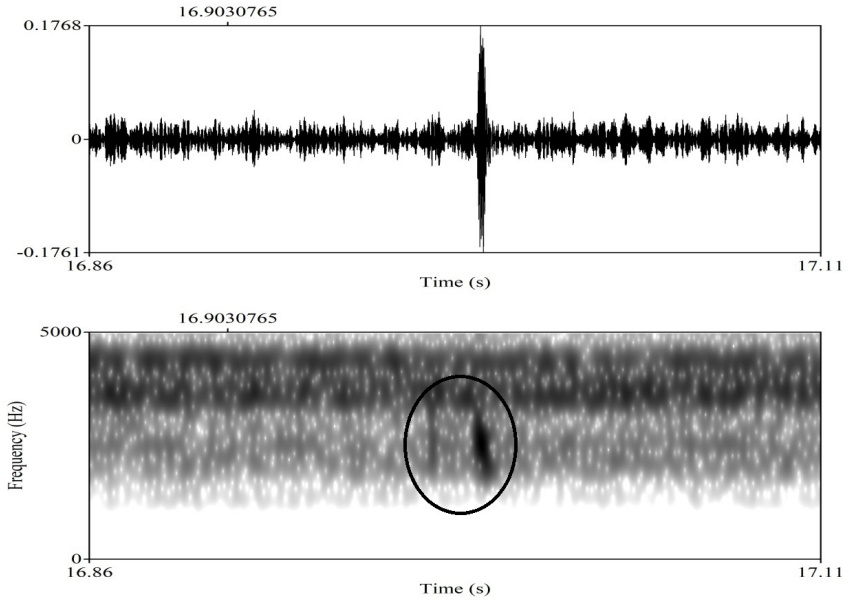

Fig. 2. Oscillogram and spectrogram of "tic" call of *Chaperina fusca*.

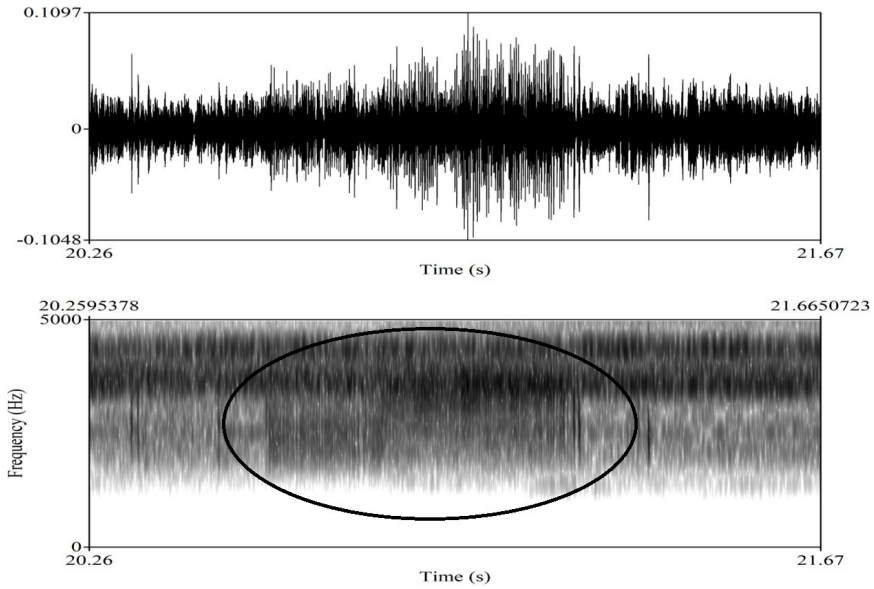

Fig. 3. Oscillogram and spectrogram of the "squeaky" call of *Chaperina fusca*.

B. *Kalophrynus heterochirus*

Kalophrynus heterochirus (Variable Sticky Frog) produced continuous repetitive high-pitched vocalisation. Its calls exhibit two distinct modes: one characterised by higher intensity with intervals between call groups, and another that is continuous but with longer intervals between notes. Each call consists of a single note (Figure 4). The higher-intensity call includes 17 to 22 notes per 60 s (Figure 5a), with intervals of 1.6 to 2.4 s between individual notes. Groups of calls are separated by intervals ranging from 20 to 27 s. In contrast, continuous calls feature approximately 21 to 22 notes per 60 s (Figure 5b), similar in note count to the high-intensity calls, but with longer intervals between notes, ranging from 2.5 to 3.3 s. The male continuously calls for more than 2 min. Based on the spectrogram, this species produced a high-pitched note, with a dominant frequency range of 4.5 to 4.7 kHz. Eight harmonics are visible, with the second as the dominant frequency.

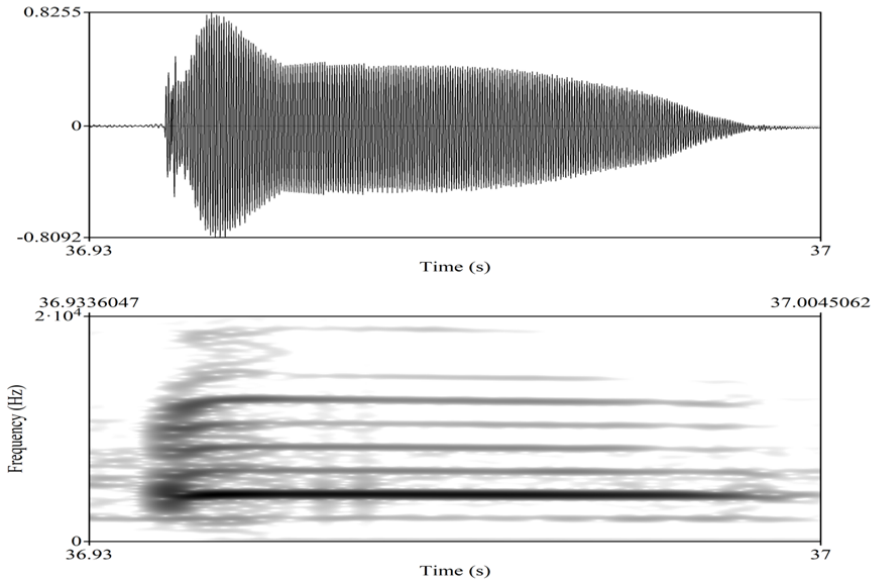

Fig. 4. Oscillogram and spectrogram of one call of *Kalophrynus heterochirus*.

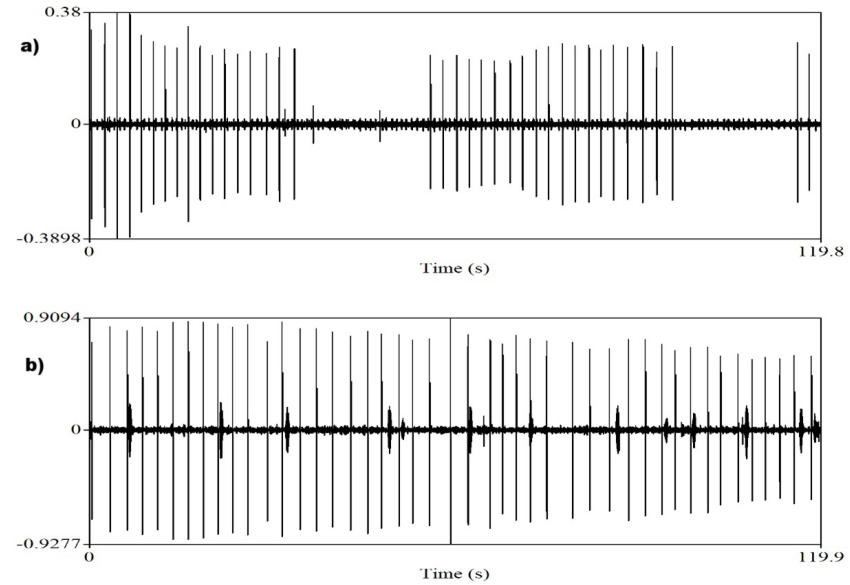

Fig. 5. Oscillogram of 2 min call of *Kalophrynus heterochirus*, where (a) is higher intensity calls, and (b) is continuous calls

C. *Kalophrynus dringi*

Kalophrynus dringi (Dring's Sticky Frog) are endemic to Gunung Mulu National Park, Sarawak. The species was separated from *Kalophrynus nubicola* by Fukuyama *et al*. 2021. It produced continuous, repetitive calls with approximately 10 notes per 60 s. Each call consists of a single note (Figure 6), with intervals between notes ranging from 5.5 to 6.8 s. This species is smaller in size compared to *K. heterochirus* but exhibits a lower dominant frequency, ranging from 2.67 to 2.72 kHz. *K. dringi* has a lower call repetition rate and frequency, which may be influenced by its habitat at higher elevations, where colder temperatures could affect vocalisation patterns.

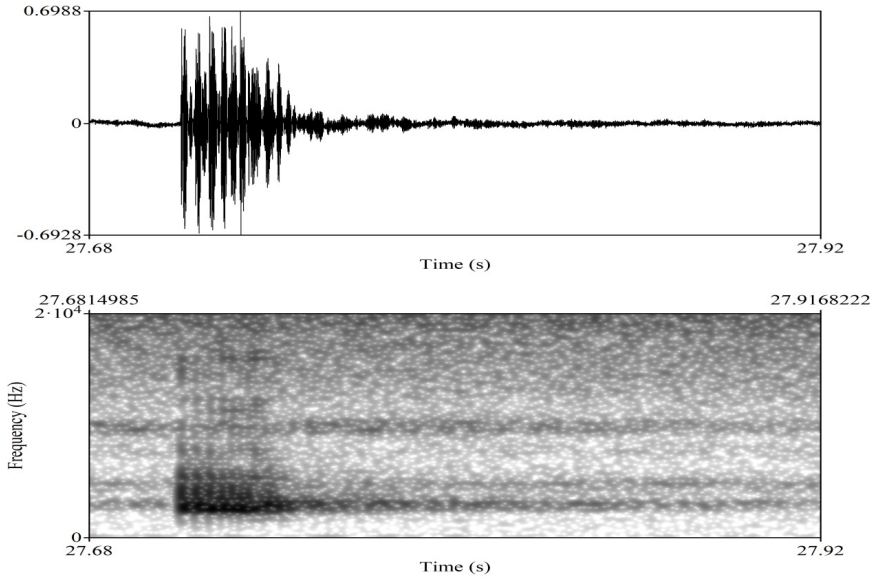

Fig. 6. Oscillogram and spectrogram of one call of *Kalophrynus dringi*

D. *Kalophrynus subterrestris*

Kalophrynus subterrestris (Burrowing Sticky Frog) is endemic to Borneo. It produced continuous, repetitive calls with approximately 30 notes per 60 s, with varying intervals ranging from 1.2 to 3 s between notes. Their calls consist of one note, with wave-like frequency modulation all the way from the beginning and ease up until the end of the note (Figure 7). Based on the spectrogram, it has a similar dominant frequency to *K. dringi*, at 2.73 kHz. 11 harmonics were visible, with the third harmonic as a dominant frequency.

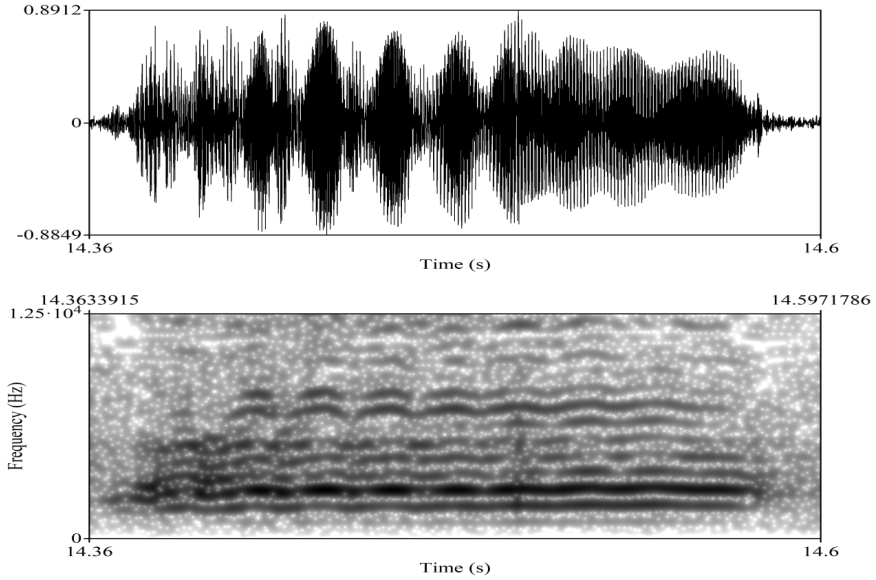

Fig. 7. Oscillogram and spectrogram of one call of *Kalophrynus subterrestris*

E. *Kaloula pulchra*

Kaloula pulchra's common name is Banded Bullfrog. They are non-indigenous species that were recently introduced to the island of Borneo. Their soft honking sound could be heard after heavy rainfall as closed as to the residential area. Their calls consist of one long note (Figure 8), with a note repetition rate of 17 to 19 per 60 s. The notes have varying intervals ranging from 2.9 to 4.5 s. The spectrogram shows the low pitch with a dominant frequency of 1.25 kHz.

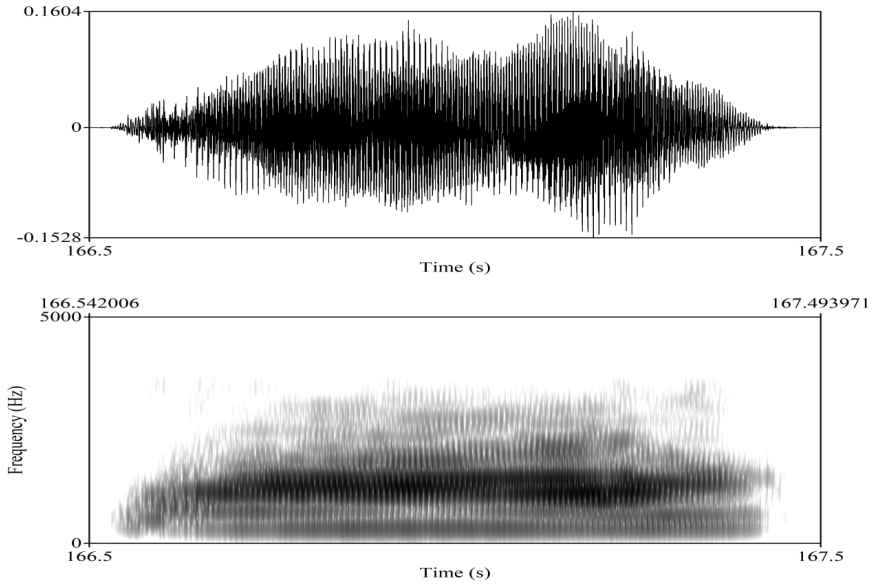

Fig. 8. Oscillogram and spectrogram of one call of *Kaloula pulchra*

F. *Metaphrynella sundana*

Metaphrynella sundana (Tree hole frog) loud "beep" sound was produced when the frog calls from inside the tree hole. The vocalisation consists of a series of continuous, repetitive high-pitched notes, with each call containing a single note (Figure 9). The note repetition rate ranges from 16 to 20 notes per 60 s, with intervals between notes varying from 2.5 to 3.9 s. The call exhibits harmonic structure, with 14 harmonics visibly present. The first harmonic serves as the dominant frequency, ranging between 1.6 and 1.8 kHz.

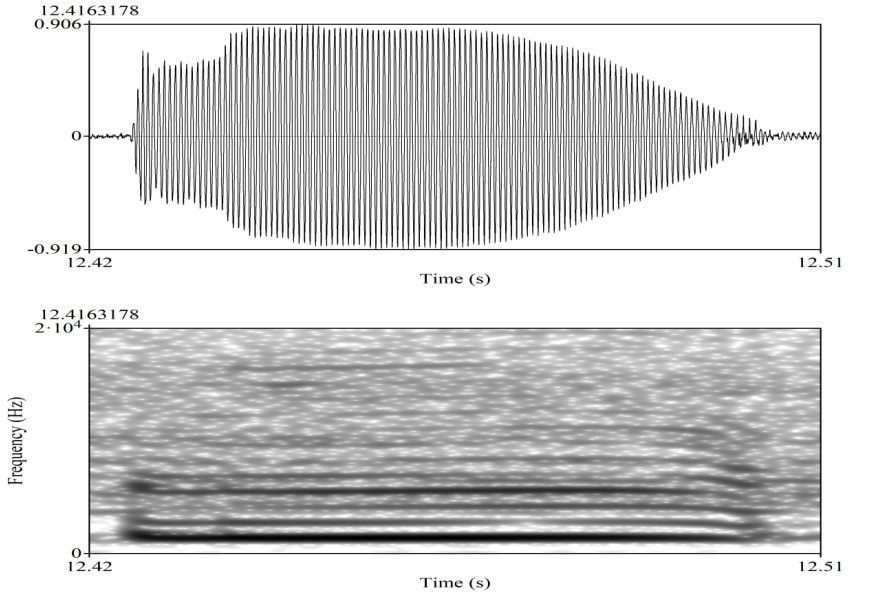

Fig. 9. Oscillogram and spectrogram of one call of *Metaphrynella sundana*

G. *Microhyla nepenthicola*

Microhyla nepenthicola (Matang Narrow-mouthed Frog)calls in a dense chorus, producing a rapid "clicking" sound with a series of continuous high-pitched notes. The calls are not continuous; following a long pause, individuals resume calling. The time between calls varies significantly, likely influenced by behavioural interactions with conspecifics. Typically, a single individual initiates a calling bout, triggering responses from others (Sukumaran *et al*., 2010). Each call consists of two to 14 notes (Figure 10), with a repetition rate of 62 calls per 60 s. The vocalisations begin with two notes (Figure 11) and gradually increase in number as more individuals join the chorus. Spectrogram analysis reveals a high-pitched call with a dominant frequency ranging from 5.6 to 6 kHz.

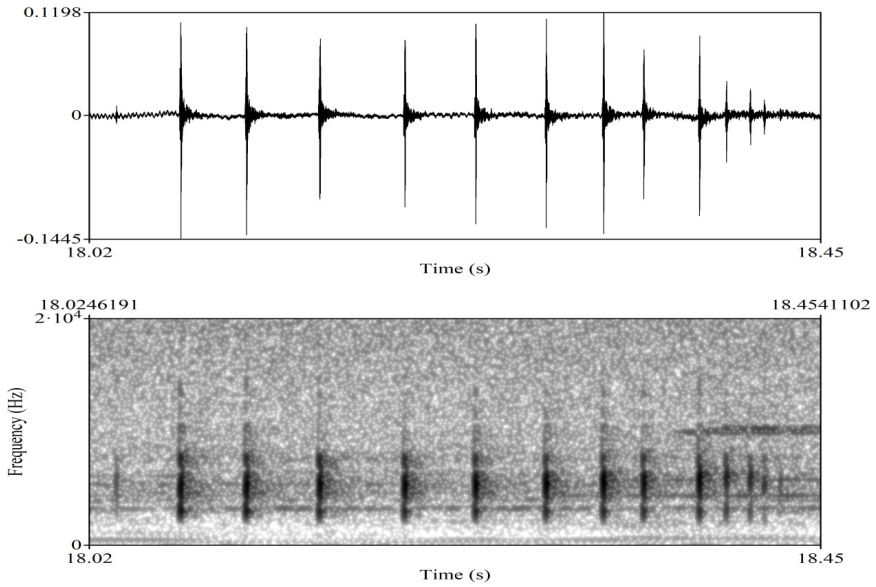

Fig. 10. Oscillogram and spectrogram of one call of *Microhyla nepenthicola*

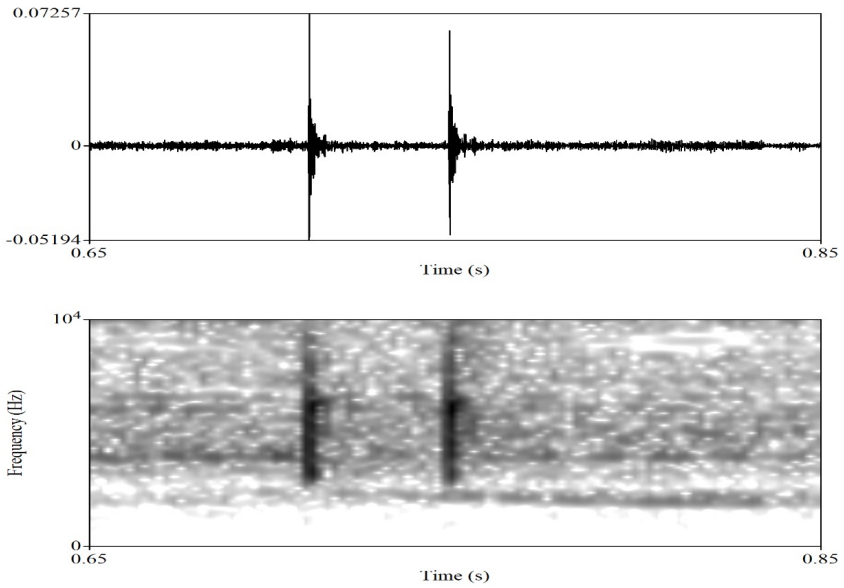

Fig. 11. Oscillogram and spectrogram of the beginning call of *Microhyla nepenthicola*

H. *Microhyla malang*

Microhyla malang, commonly known as the Borneo Narrow-mouthed Frog, produces a pleasant "crackling" sound and calls in choruses. Unlike *M. nepenthicola*, *M. malang* has fewer individuals in its chorus, making it easier to attribute calls to specific individuals. The call begins with three short notes and progresses to a sequence of up to nine notes (Figure 12). Each note consists of a single pulse, with a call repetition rate of 12 per 60 s. Although its call temporal properties are similar to those of *M. borneensis*, *M. malang* produces a lower-pitched call, with a dominant frequency of 2.3 kHz.

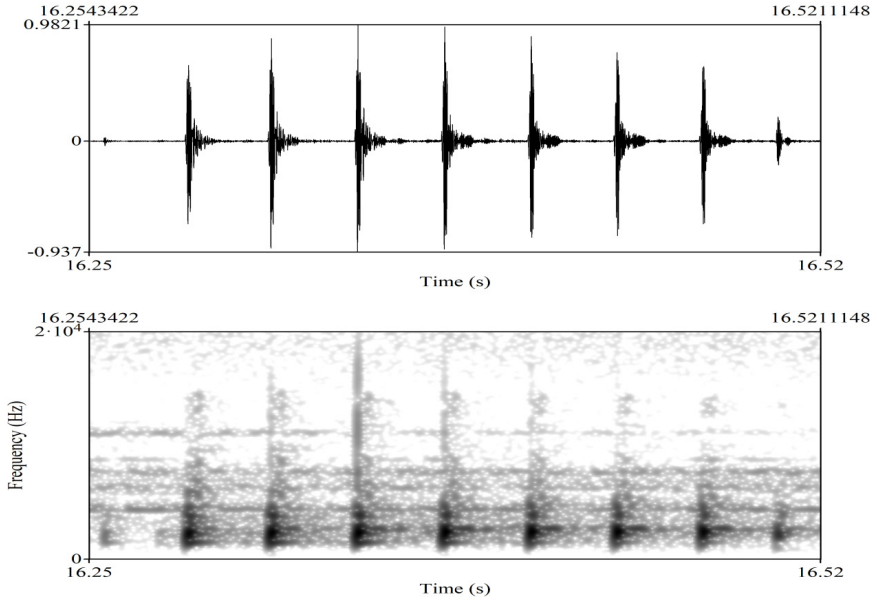

Fig. 12. Oscillogram and spectrogram of the beginning call of *Microhyla malang*

DISCUSSION

The acoustic characteristics of the eight Microhylidae species from Sarawak reveal considerable variation in call parameters, which likely play a critical role in species recognition, mate selection, and ecological adaptation.

The number of pulsed notes per call varied among the species, with *Microhyla nepenthicola* (maximum of 14 notes) and *Microhyla malang* (maximum of 9 notes) exhibiting the most complex calls. These pulsed calls with higher note counts may enhance signal detectability in noisy or dense habitats, potentially aiding mate attraction (Gerhardt & Huber, 2002). In contrast, most other species, particularly from the genus *Kalophrynus*, *K. heterochirus*, *K. subterrestris*, and *K. dringi*, produced calls with a single pulsed note, suggesting a simpler call structure that may suffice in their specific acoustic niches or result from constraints such as energy expenditure or predation risk (Ryan, 1988).

Among *Kalophrynus*, *K. subterrestris* demonstrated a higher note repetition rate (30 notes/60 s), suggesting a highly active calling strategy. Such rapid calling may be beneficial for maximising chances of detection by conspecifics during short breeding periods. In contrast, other *Kalophrynus* species, such as *K. dringi* and *K. heterochirus,* showed much lower repetition rates (10–22 notes/60 s), potentially reflecting different breeding strategies, lower competition, or energy conservation strategies (Wells, 2007).

Dominant frequency among the species ranged widely, from 1.25 kHz in *Kaloula pulchra* to 5.6–6.0 kHz in *Microhyla nepenthicola*. Generally, dominant frequency is inversely correlated with body size in anurans, where larger species produce lower-frequency calls due to their larger vocal cords and body resonators (Deka *et al*., 2015). This trend is evident in this dataset, with a larger-bodied *Kaloula pulchra* exhibiting the lowest dominant frequency, while the smaller *Microhyla nepenthicola* emitted one of the highest. *Microhyla borneensis* also has 62 notes repeated for 60 s, the highest in the Family.

Microhylidae also contain unique frogs that uses object to amplify their calls or to exploit resonance effects, as *M. sundana* does by exploiting the acoustic properties of cavities in tree trunks (Lardner & Lakim, 2003). By amplifying the calls, *M. sundana* produce calls with the largest pulse duration of all the frogs in this study. *M. sundana* emits 16–20 notes per min, with a dominant frequency of 1.6–1.8 kHz, suggesting adaptation to low-frequency sound propagation suitable for dense forest habitats (Penna & Solís, 1998).

Chaperina fusca exhibited two distinct call types differing in note structure, suggesting potential context-dependent usage or dual-function calls. Such variability might reflect different social contexts (e.g., advertisement vs. territorial calls), which merits further investigation (Toledo *et al*., 2015; Köhler *et al*., 2017).

The observed diversity in call characteristics among these species reflects evolutionary adaptations to their respective ecological niches, including habitat structure, ambient noise, and reproductive behaviour. Acoustic partitioning among sympatric species likely reduces hybridisation risk and interspecific competition (Duellman & Trueb, 1994). Continued research into microhabitat use, population density, and reproductive timing would provide deeper insights into how these call features evolved in response to ecological pressures

CONCLUSION

The comparative analysis of advertisement calls among various anuran species reveals significant interspecific differences in acoustic parameters, including pulsed note count, note repetition rate, and dominant frequency. These variations are reflective of species-specific adaptations to ecological conditions and communication requirements. High-frequency calls and rapid note repetition, as observed in *Microhyla borneensis*, likely support short-range communication in dense habitats, whereas low-frequency, slower calls such as those produced by Kaloula pulchra may facilitate long-range signalling in more open or cluttered environments.

The presence of dual call types in *Chaperina fusca* and variability across species in the *Kalophrynus* and *Microhyla* genera

emphasises the importance of acoustic signals in species recognition, mate selection, and reproductive isolation. Based on these findings, understanding these vocalisation patterns is crucial for species identification and conservation efforts, as highlighted by recent studies in anuran bioacoustics.

ACKNOWLEDGEMENTS
This study was funded by the Ministry of Higher Education (MoHE) research grant FRGS/1/2013/STWN10/UNIMAS/02/3 and F07(DPP44)/1264/2015(19). Special thanks to the Forestry Department of Sarawak for the permit given NCCD907.4.4 (Jld.12)-106; No.236/2015) to collect samples for this study.

ETHICAL STATEMENT
Not applicable.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

REFERENCES
Amram, M.F., Zainudin, R. & Abdul Wahid, H. 2018. Mating calls of selected Sarawak toads (Amphibia: Anura: Bufonidae). Sains Malaysiana, 47(1): 1-7. https://doi.org/10.17576/jsm-2018-4701-01

Amram, M.F., Zainudin, R. & Abdul Wahid, H. 2020. Notes on advertisement calls playback by three species of Sarawakian frogs. Borneo Journal of Resource Science and Technology, 10(1): 51-60. https://doi.org/10.33736/bjrst.2237.2020

Das, I. & Haas, A. 2010. New species of Microhyla from Sarawak: Old World's smallest frogs crawl out of miniature pitcher plants on Borneo (Amphibia: Anura: Microhylidae). Zootaxa, 2571: 37-52. https://doi.org/10.11646/zootaxa.2571.1.2

Dasi, O. & Shahriza, S. 2022. Advertisement calls of *Limnonectes macrognathus* (Anura: Dicroglossidae) and *Leptobrachium smithi* (Anura: Megophryidae), native frog species from Langkawi, Kedah, Peninsular Malaysia. Bioacoustics, 31(1): 81-91. https://doi.org/10.1080/09524622.2021.1886170

de Sá, R.O., Streicher, J.W., Sekonyela, R., Forlani, M.C., Loader, S.P., Greenbaum, E., Richard, S. & Haddad, C.F.B. 2012. Molecular phylogeny of microhylid frogs (Anura: Microhylidae) with emphasis on relationships among New World genera. BMC Evolutionary Biology, 12: 241. https://doi.org/10.1186/1471-2148-12-241

Dehling, J.M. 2010. Advertisement calls of two species of *Microhyla* (Anura: Microhylidae) from Borneo. Salamandra, 46(2): 114-116.

Deka, E.Q. & Zainudin, R. 2025. Advertisement call characteristics of male Sarawak frogs (Family Ranidae). Journal of Sustainability Science and Management, 20(2): 364-389. https://doi.org/10.46754/jssm.2025.02.012

Deka, E.Q., Lela, S., Wahid, H.A. & Zainudin, R. 2015. Vocal apparatus structure of the Sarawak frogs (Amphibia: Anura: Ranidae). Sains Malaysiana, 44(9): 1289-1299. https://doi.org/10.17576/jsm-2015-4409-11

Dring, J.C.M. 1983a. Some frogs from Sarawak. Amphibia-Reptilia, 4: 103-115. https://doi.org/10.1163/156853883X00021

Dring, J.C.M. 1983b. Frogs of the genus *Leptobrachella* (Pelobatidae). Amphibia-Reptilia, 4: 89-102. https://doi.org/10.1163/156853883X00012

Dring, J.C.M. 1987. Bornean treefrogs of the genus *Philautus* (Rhacophoridae). Amphibia-Reptilia, 8: 19-47. https://doi.org/10.1163/156853887X00036

Duellman, W.E. & Trueb, L. 1994. Biology of Amphibians. John Hopkins University Press, Baltimore. 610 pp. https://doi.org/10.56021/9780801847806

Fukuyama, I., Matsui, M., Eto, K., Hossman, M.Y. & Nishikawa, K. 2021. Discovery of a deeply divergent and highly endemic frog lineage from Borneo: A taxonomic revision of Kalophrynus nubicola Dring, 1983 with descriptions of two new species (Amphibia: Anura: Microhylidae). Zoologischer Anzeiger, 293: 326-343. https://doi.org/10.1016/j.jcz.2021.06.016

Gerhardt, H.C. & Huber, F. 2002. Acoustic Communication in Insects and Anurans - Common Problems and Diverse Solutions. University of Chicago Press, Chicago. 542 pp.

Gorin, V.A., Scherz, M.D., Korost, D.V. & Poyarkov, N.A. 2021. Consequences of parallel miniaturisation in Microhylinae (Anura, Microhylidae), with the description of a new genus of diminutive South East Asian frogs. Zoosystematics and Evolution, 97(1): 21-54. https://doi.org/10.3897/zse.97.57968

Inger, R.F. & Stuebing, R.B. 2005. A Field Guide to the Frogs of Borneo. 2nd Ed. Natural History Publication (Borneo) Sdn. Bhd., Kota Kinabalu. 209 pp.

Inger, R.F., Stuebing, R.B., Grafe, T.U. & Dehling, J.M. 2017. A Field Guide to the Frogs of Borneo. 3rd Ed. Natural History Publication (Borneo) Sdn. Bhd., Kota Kinabalu. 236 pp.

Köhler, J., Jansen, M., Rodríguez, A., Kok, P.J.R., Toledo, L.F., Emmrich, M., Glaw, F., Haddad, C.F.B., Rödel, M.-O. & Vences, M. 2017. The use of bioacoustics in anuran taxonomy: Theory, terminology, methods and recommendations for best practice. Zootaxa, 4251(1): 1-124. https://doi.org/10.11646/zootaxa.4251.1.1

Lardner, B. & Lakim, M.B. 2003. Animal communication: Tree-hole frogs exploit resonance effects. Nature, 420(6915): 475. https://doi.org/10.1038/420475a

Mahyudin, N.A.A.B., Munian, K., Azman, M.S., Md Fauzi, N.F.B., Ahmad Ruzman, N.H.B. & Zakaria, N.A.B. 2019. Chaperina fusca Mocquard 1892 [WWW Document]. Malaysia Biodiversity Information System (MyBIS). URL https://www.mybis.gov.my/art/170 (accessed 5.17.25).

Marly, M.A.A., Zainudin, R. & Amram, M.F. 2017. Identification keys on advertisement call characters for the genus Pulchrana (Anura: Ranidae) in Sarawak. Malaysian Applied Biology, 46(4): 15-21.

McClelland, B.E., Wilczynski, W. & Ryan, M.J. 1996. Correlations between call characteristics and morphology in male cricket frogs (*Acris crepitans*). Journal of Experimental Biology, 199: 1907-1919. https://doi.org/10.1242/jeb.199.9.1907

Passos, L.F., Garcia, G. & Young, R.J. 2017. Neglecting the call of the wild: Captive frogs like the sound of their own voice. PLoS ONE, 12(7): e0181931. https://doi.org/10.1371/journal.pone.0181931

Penna, M. & Solís, M. 1998. Frog call intensities and sound propagation in the South American temperate forest region. Behavioral Ecology and Sociobiology, 42(6): 371-381. https://doi.org/10.1007/s002650050452

Ryan, M.J. 1988. Constraints and patterns in the evolution of anuran acoustic communication. In: The Evolution of the Amphibian Auditory System. B. Fritzsch (Ed.). Wiley, New York. pp. 637-677.

Sukumaran, J., Das, I. & Haas, A. 2006. A synopsis of bioacoustic studies of anuran amphibians of Borneo. Herpetological Review, 37: 288-293.

Sukumaran, J., Das, I. & Haas, A. 2010. Descriptions of the advertisement calls of some Bornean frogs. Russian Journal of Herpetology, 17(3): 189-194.

Toledo, L.F., Martins, I.A., Bruschi, D.P., Passos, M.A., Alexandre, C. & Haddad, C.F.B. 2015. The anuran calling repertoire in the light of social context. Acta Ethologica, 18(2): 87-99. https://doi.org/10.1007/s10211-014-0194-4

Wells, K.D. 2007. The Ecology and Behavior of Amphibians. University of Chicago Press, Chicago. 1400 pp. https://doi.org/10.7208/chicago/9780226893334.001.0001

Zainudin, R., Rahman, M.A. & Md-Zain, B.M. 2010. Mating calls description of five species of frogs from the genus *Hylarana* Tschudi 1838 (Amphibia, Anura, Ranidae) from Sarawak, Malaysia. Sains Malaysiana, 39(3): 363-369.