Russian Entomol. J. 15(3): 341–346 © RUSSIAN ENTOMOLOGICAL JOURNAL, 2006

Frequency modulated song of the cicada *Kalabita operculata* (Auchenorrhyncha: Cicadoidea) from Borneo

Частотно модулированная песня цикады *Kalabita operculata* (Auchenorrhyncha: Cicadoidea) с Борнео

Tomi Trilar
Т. Трилар

Slovenian Museum of Natural History, Preašernova 20, P.O. Box 290, SI-1001 Ljubljana, Slovenia. E-mail: ttrilar@pms-lj.si.
Словенский музей естественной истории, Прещернова 20, P.O. Box 290, SI-1001 Любляна, Словения.

KEY WORDS: Cicadidae, *Kalabita operculata*, bioacoustics, sound, song emission, Southeast Asia, Sabah, Borneo.

КЛЮЧЕВЫЕ СЛОВА: Cicadidae, *Kalabita operculata*, биоакустика, звук, пение, Юго-Восточная Азия, Сабах, Борнео.

ABSTRACT. The song of the cicada *Kalabita operculata* Moulton, 1923 is investigated. The sound emission analysis is based on 24 recordings of at least 16 different individuals from Mount Kinabalu (Sabah, Borneo). The typical calling song pattern with frequency modulation is described. The song starts with a continuous part of increasing intensity, which ends with loud frequency modulated sweep up. It is followed without a pause by a very loud continuous part of constant intensity, which at the end turns in a sequence of short echemes with decreasing intensity of sound and repetition rate of echemes. Duration of the song is 11.08 ± 2.61 seconds.

РЕЗЮМЕ. Изучена песня цикады *Kalabita operculata* Moulton, 1923. Анализ сигналов основан на 24 записях не менее 16 различных особей с горы Кинабалу (Сабах, Борнео). Описан типичный призывный сигнал с частотной модуляцией. Песня начинается с непрерывной части с возрастающей интенсивностью, которая заканчивается громким частотно-модулированным амплитудным всплеском. Затем без паузы следует очень громкая непрерывная часть с постоянной интенсивностью, которая в конце переходит в последовательность коротких серий с понижающейся интенсивностью звука и частотой повторения серий. Продолжительность песни составляет 11.08 ± 2.61 секунд.

Introduction

The singing cicada *Kalabita operculata* Moulton, 1923 belongs to the family Cicadidae Latreille, 1802, subfamily Cicadinae Latreille, 1802 and tribe Platypleurini Schmidt, 1918 [Moulds, 2005]. The genus *Kalabita* Moulton, 1923 is monotypic.

According to Moulton [1923] the male holotype is stored in the Natural History Museum, London and is labeled as follows: “Mt. Murud, 6.500 ft. [~ 1980 m], Sarawak, 14th November 1922, coll. Dr. E. Mjöberg”, while 3 additional males are in the Sarawak Museum.

In this paper we are describing the song characteristics of *K. operculata* from the Mount Kinabalu area, Sabah.

Material and Methods

Songs of *K. operculata* were recorded in the field using a parabolic stereo microphone TELINGA PRO V (parabola diameter 57 cm) connected to SONY DAT recorder TCD D3 (sampling rate 48 kHz, 16 Bit dynamic range). In the lab, DAT recordings were transferred to the Hard Disk of a POWER MACINTOSH G4 computer through an AUDIOMEDIA III sound card. For viewing, editing and analyzing the song signals we used PRO-TOOLS 5.0 (Digidesign, Avid Technology), and CANARY 1.2.4 (Cornell Lab of Ornithology) software. For statistical evaluation we used the EXCEL 2000 (MICROSOFT).

Altogether 24 complete songs and some fragments (only beginning or end) of at least 16 different individuals were used for analyses. The exact number of individuals recorded is almost impossible to determine when animals are chorusing in a canopy.

A single male of *K. operculata* (Fig. 1), which was first recorded and then collected, is deposited in the collection of the Slovenian Museum of Natural History (PMSL) in Ljubljana and is labeled as: “MY [Malaysia]: Borneo: Sabah: Kundassang, Mesilau Nature Resort, Mesilau Summit Trail; 16. 3. 2004; ~2400 m; leg.: T. Trilar & K. Prosenc Trilar”. All sound recordings are stored in the Sound Archive of the Slovenian Museum of Natural

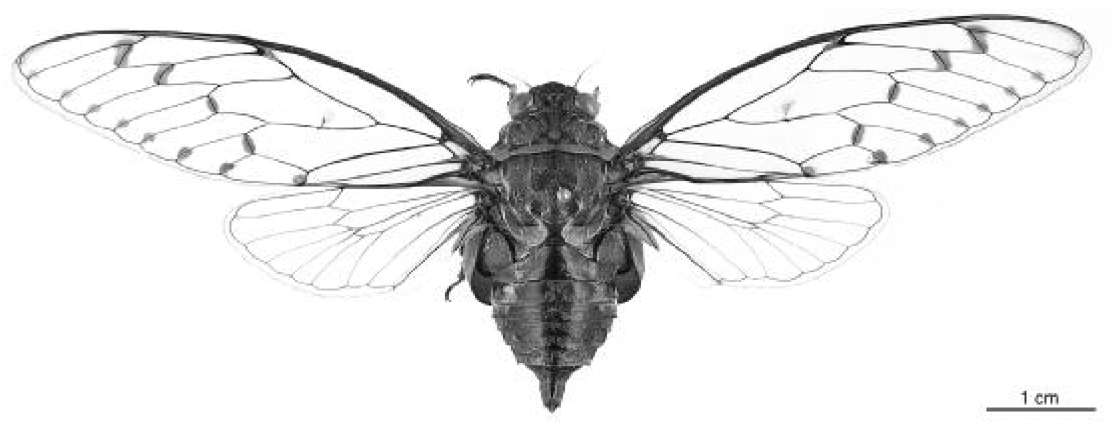

Fig. 1. *Kalabita operculata*, specimen from the PMSL collection.
Рис. 1. *Kalabita operculata*, экземпляр из коллекции PMSL.

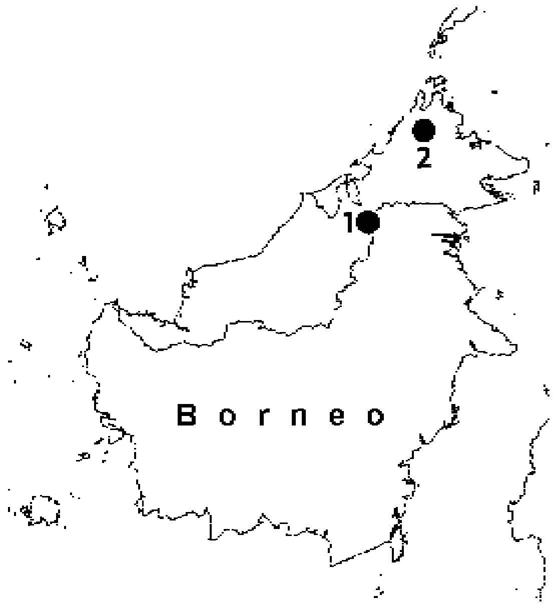

Fig. 2. Map of Borneo: 1 — type locality of *Kalabita operculata* at Mount Murud, Sarawak; 2 — our finding at Mount Kinabalu, Sabah.

Рис. 2. Карта Борнео: 1 — типовое местообитание *Kalabita operculata* на горе Муруд, Саравак; 2 — наша находка на горе Кинабалу, Сабах.

History. The samples of the song are available on the web page: *http://www2.pms-lj.si/staff/bioacoustics/asian.html*.

Results

The analysis of the sound emission of *K. operculata* is based on 24 complete songs and some fragments (only beginning or end) of at least 16 different individuals recorded on March 16th, 2003 at Pondok Bambu of the Mesilau Summit Trail in Kinabalu National Park, Sabah, Malaysia, Borneo (Fig. 2).

DESCRIPTION OF THE SONG. The broad band calling song of *K. operculata* is composed of three distinctly different parts (Fig. 3), which follow each other without a pause. Duration of the song is 11.08 ± 2.61 s (n=24, min. 7.44 s, max. 16.49 s). The songs are following each other either in many cases with the pause of different durations or occasionally with the long sequence of short echemes with changing repetition rate and intensity or rarely without a pause (i.e. the sequence of short echemes (P3) is followed without a pause with the continuous part (P1) of the next song).

The song starts with a continuous sound of increasing intensity (P1), and this part of the song ends with loud frequency modulated sweep up (Figs 3–4). It is followed without a pause by a very loud continuous part (P2) of constant intensity (Figs 3–4). After P2 follows a sequence of short echemes (P3) with decreasing intensity of sound and repetition rate of echemes (Figs 3–5).

The duration of P1 is 4.34 ± 1.55 s (n=24, min. 1.32 s, max. 7.25 s) and P2 0.97 ± 0.21 s (n=27, min. 0.67 s, max. 1.42 s). Duration of P3 is 5.91 ± 1.85 s (n=28, min. 1.99 s, max. 8.55 s) and consists of 47 ± 11 echemes (n=27, min. 32 echemes, max. 72 echemes). Repetition rate of echemes at the beginning of P3 is 8.39 ± 0.92 per second (n=26, range 7–10 echemes per second) and at the end of P3 decreases to 6.69 ± 0.84 (n=27, range 5–8 echemes per second). The duration of each of the first three echemes is 103.7 ± 12.4 ms (n=84, min. 73.2 ms, max. 135.6 ms) with 22.0 ± 4.5 ms pause inbetween (n=84, min. 12.5 ms, max. 33.7 ms) and the duration of each of the last three echemes but one is 55.1 ± 7.7 ms (n=69, min. 38.0 ms, max. 78.2 ms) with 102.0 ± 26.2 ms pause (n=69, min. 62.5 ms, max. 166.2 ms).

FREQUENCY RANGE. Spectral properties of *K. operculata* songs are very characteristic and represent an easily recognizable pattern.

The frequency spectrum of the *K. operculata* calling song has a wide range between 2.3–13 kHz (Fig. 3). In P1 (Fig. 4 — arrow c, Fig. 6 — gray line) the broad fundamental frequency band has two peaks with maximum intensity at 2.95 ± 0.11 kHz (n=24, min. 2.72 kHz,

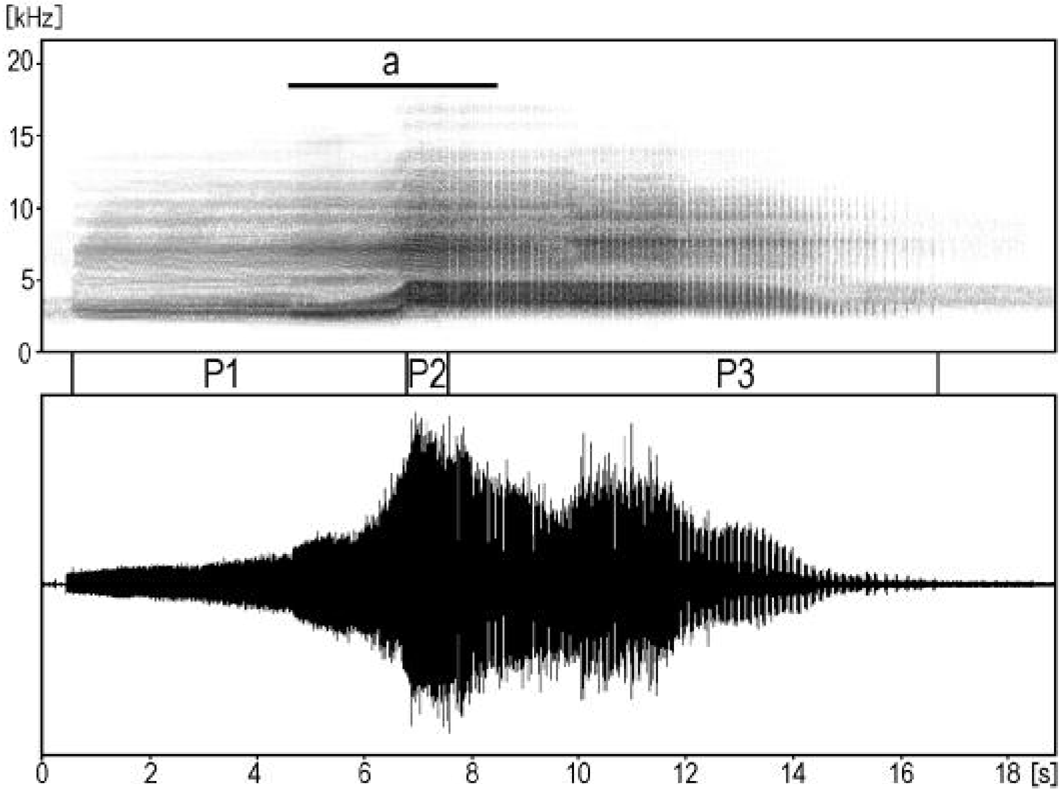

Fig. 3. Song of *Kalabita operculata* from Borneo: Spectrogram and oscillogram of a typical song. P1 — continuous part which ends with frequency modulation; P2 — very loud continuous part; P3 — sequence of short echemes; a — part enlarged in Fig. 4. Since the microphone was not calibrated, there is no scale on oscillogram Y-axis (valid also for Figs 4–5).

Рис. 3. Песня *Kalabita operculata* с Борнео: спектрограмма и осциллограмма типичного сигнала. P1 — непрерывная часть, заканчиваеющаяся частотной модуляцией; P2 — очень громкая непрерывная часть; P3 — последовательность коротких серий; a — часть, представленная в увеличенном виде на Рис. 4. Поскольку микрофон не был калиброван, на оси Y [вертикальной оси] осциллограммы масштаб отсутствует (также на Рис. 4–5).

max. 3.14 kHz) and 3.68 ± 0.22 kHz (n=24, min. 3.33 kHz, max. 4.16 kHz) and frequency range between 2.39 ± 0.10 kHz and 4.35 ± 0.26 kHz at –20 dB level from the peak frequency (Figs 3–4, 6). Besides the fundamental frequency band is prominent also broad range of harmonic frequencies, which extend between approximately 6 and 11 kHz with –10 to –20 db lower intensity compared to the fundamental frequency peaks (Figs 3–4, 6).

P1 passes into P2 via frequency modulation part (Fig. 4). In P2 (Fig. 4 — arrow d, Fig. 6 — black line) fundamental frequency band rises to 3.69 ± 0.14 kHz (n=23, min. 3.47 kHz, max. 3.94 kHz) and 4.53 ± 0.26 kHz respectively (n=23, min. 4.03 kHz, max. 5.21 kHz) (Figs 3–4, 6). The -20 dB frequency range is between 2.9 ± 0.16 kHz and 5.22 ± 0.18 kHz. Difference between fundamental frequencies of P1 and P2 is approximately two tones (Fig. 6).

The general frequency properties of P3 (Fig. 4 — arrow e) are very similar to those in P2 including the broad range of harmonic frequencies (Figs 3, 5–6). The peak frequency of first echeme is 3.63 ± 0.14 kHz (n=22, min. 3.42 kHz, max. 3.94 kHz). With decreasing intensity of sound and repetition rate of echemes in last 5 to 10 echemes are changing also spectral properties of the sound. Peak frequency descends to 3.04 ± 0.17 kHz (n=21, min. 2.67 kHz, max. 3.33 kHz) and the general spectral properties are similar to P1, but with a less prominent range of harmonic frequencies.

ECOLOGY. The field observations at Pondok Bambu of the Mesilau Summit Trail on March 15th and 16th, 2003 show that the individuals of *K. operculata* are singing in a chorus in the upper part of the tropical mountain rain forest [Kitayama, 1991] of the southern slope of Mount Kinabalu. *Kalabita operculata* was limited to an altitude from 2100 to 2500 m above see level. On March 15th, 2003 the singing activity was limited to a short time window between 10.00 and 10.30 a.m., while on March 16th, 2003 the time window was expanded from 9.15 to 11.30 a.m. The singing activity is induced by the patches of the clear sky and periods of sunny weather, that suddenly appear in the foggy clouds moving from lowland tropical rain forest towards the summit of the Mount Kinabalu.

Discussion

The species is described from Mount Murud in Sarawak where 4 males were collected [Moulton, 1923]. The finding of *K. operculata* on Mount Kinabalu is the second record for this species and the first record

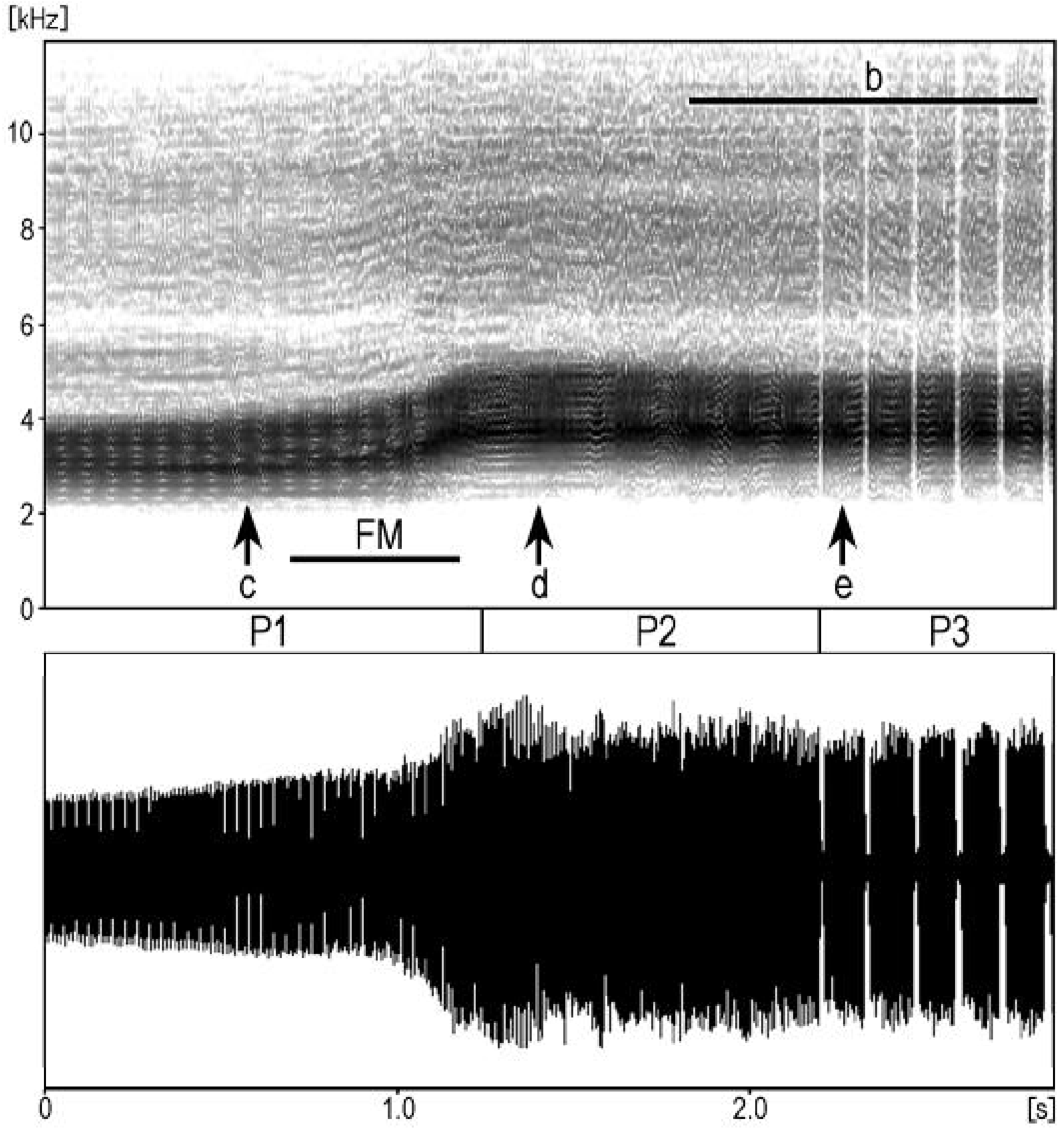

Fig. 4. Spectrogram and oscillogram of frequency modulated component of the song of *Kalabita operculata*. This part is designated in Fig. 3 as "a". P1 — continuous part which ends with frequency modulation (FM); P2 — very loud continuous part; P3 — sequence of short echemes; b — part enlarged on Fig. 5; c, d, e arrows — the position of spectral cross sections.

Рис. 4. Спектрограмма и осциллограмма частотно модулированного компонента сигнала *Kalabita operculata*. Эта часть обозначена на Рис. 3 как "a". P1 — непрерывная часть, заканчивающаяся частотной модуляцией (FM); P2 — очень громкая непрерывная часть; P3 — последовательность коротких серий; b — часть, представленная в увеличенном виде на Рис. 5; стрелки c, d, e — точки "поперечного среза" частотного спектра.

for Sabah, Malaysia (J. P. Duffels, personal communication).

The singing of many S.E. Asian singing cicada species is daily limited to a narrow time window of about 30 minutes to 2 hours [Gogala & Riede, 1995]. Many cicada species sing only at dusk, dawn or within a species-specific time window during the day or even at noon or at midnight [Gogala & Riede, 1995]. The same was observed also in *K. operculata*. It's daily singing activity was limited to the period of 9 to 11:30 a.m. On Mount Kinabalu this species is inhabiting the forest habitats (tropical mountain rain forest) on steep southern slopes, where specific, but constant daily rhythm of the weather is present. After a clear night, immediately after sunrise (at 6.15 a.m.), small clouds starts to form above the lowland tropical rain forest. The clouds are getting bigger and bigger and very soon they form the closed foggy cover (around 8 a.m.), which is traveling along the slopes towards the summit plateau of the Mount Kinabalu. Because of the movement, foggy clouds tear from time to time resulting in patches of clear sky and periods of sunny weather. If this happens in the time window between 9 and 11:30 a.m. single individuals of *K. operculata* start singing. The first singer triggers others and soon the whole chorus is singing. Singing spreads from the starting point all around the slope.

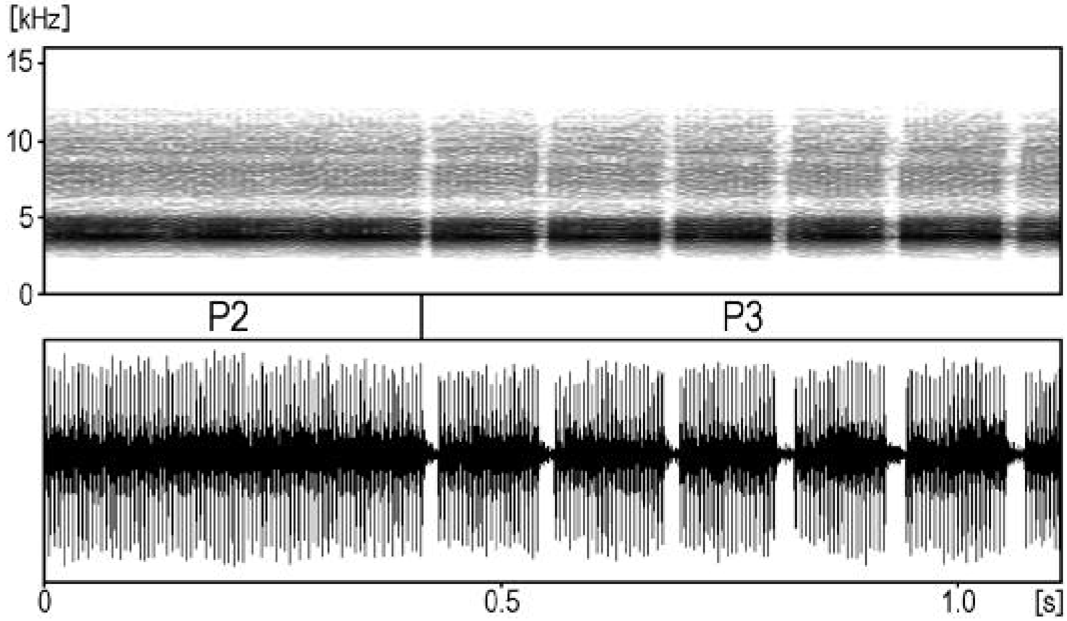

Fig. 5. Spectrogram and oscillogram of the first three echemes of P3 in the song of *Kalabita operculata*: this part is designated in Fig. 4 as "b". P2 — end of very loud continuous part; P3 — beginning of sequence of short echemes.

Рис. 5. Спектрограмма и осциллограмма первых трёх серий P3 в песне *Kalabita operculata*. Эта часть обозначена на Рис. 4 как "b". P2 — конец очень громкой непрерывной части; P3 — начало последовательности коротких серий.

After 12 a.m. the foggy clouds became to thick to break up and in the afternoon it usually starts to rain (around 2 p.m.).

In *K. operculata* we can observe quite a big variation in the duration of the song parts (P1, P2 and P3), which can be explained with high temperature differences during the periods of sunny weather and foggy cloud cover.

The special characteristic of the *K. operculata* calling song is the frequency modulation. This speciality is described also in some other species of S.E. Asian singing cicadas i.e. *Angamiana floridula* Distant, 1878 [Boulard, 2000a], *A. melanoptera* Boulard, 2005 [Boulard, 2005b], *Chremistica mussarens* Boulard, 2005 [Boulard, 2005d], *Dundubia nagarasingna* (Distant, 1881) [Gogala, 1995; Boulard, 2000a], *D. terpsichore* (Walker, 1850) [Boulard, 2001], *D. vaginata* Fabricius, 1787 [Prešern et al., 2004], *Maua albigutta* (Walker, 1856) [Gogala et al., 2004], *Meimuna nauhkae* Boulard, 2005 [Boulard, 2005a], *M. opalifera* (Walker, 1850) [Gogala, 1995], *M. tavoyana* (Distant, 1888) [Gogala, 1995], *Platylomia andamansidensis* Boulard, 2001 [Boulard, 2001], *Pl. bocki* (Distant, 1882) [Boulard, 2005a], *Purana johanae* Boulard, 2005 [Boulard, 2005a], *Pu. nebulilinea* (Walker, 1868) [Kos & Gogala, 2000], *Pu. sagittata* Schouten & Duffels, 2002 [Trilar & Gogala, 2002], *Pu.* aff. *tigrina* (Walker, 1850) [Gogala, 1995], *Tosena albata* (Distant, 1878) [Boulard, 2000b, 2005c] and *T. melanoptera* (White, 1846) [Boulard, 2000b, 2005c]. It is interesting that all these species belongs to the tribe Dundubiini Atkinson, 1886 [Moulds, 2005]. *Kalabita operculata* is the first S.E. Asian species with described song from the tribe Platypleurini Schmidt, 1918 with frequency modulation in the calling song. In some species the frequency modulated song pattern resembles some bird voices. The frequency modulated component can consist of a single sweep up (*D. terpsichore, K. operculata*, *P. bocki, T. melanoptera*, *T. albata*) or sweep down (*D. vaginata*), a long series of sweeps up (*A. floridula*, *P. nagarasingna*), a single glissando (*M. tavoyana*), a series of glissandos (*A. melanoptera*) or can be as complicated as seconds long vibrato (*C. mussarens, P. johanae*).

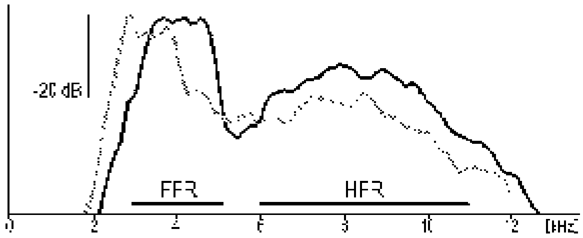

Fig. 6. Power spectrum showing frequency shift between P1 and P2 after frequency modulated sweep up. P1 — gray line (arrow c on Fig. 4); P2 — black line (arrow d on Fig. 4); FFR — fundamental frequency range; HFR — range of harmonic frequencies; −20 dB — −20 dB level from the peak frequency.

Рис. 6. Спектр громкости сигнала, показывающий изменение частоты между P1 и P2 после частотно модулированного амплитудного всплеска. P1 — серая линия (стрелка c на Рис. 4); P2 — чёрная линия (стрелка d на Рис. 4); FFR — основной частотный диапазон; HFR — диапазон высокочастотных гармоник; −20 dB — уровень −20 dB от пика частоты.

The calling song of *K. operculata* is very characteristic and represents an easily recognizable pattern, which can be used for detection of the species presence at quite a distance without collecting. Knowing and recognizing calling songs of all singing cicadas of a certain area could provide a very useful tool for mapping biodiversity richness. This can be comparable with the mapping of birds by their territorial songs in the nesting season, which is a regularly used method in ornithology.

ACKNOWLEDGEMENTS. I am grateful to Mr. Francis Liew, Sabah Parks and the staff members of Kinabalu National Park for all the help provided. Special thank goes to my wife Katarina Prosenc Trilar for her enormous effort during the fieldwork. I am thankful also to Dr. Andrej Gogala, who did the preparation of the collected specimen for the PMSL collection. I would like to thank Dr. Hans Duffels, University of Amsterdam, for the determination of the cicada, stimulating discussions, help with the literature and for reading and correcting the manuscript. Special thanks goes to Prof. Dr. Matija Gogala for all the bioacoustic advices and comments on the manuscript. The photograph of cicada was made by Jan van Arkel, digital illustrator, Institute for Biodiversity and Ecosystem dynamics, University of Amsterdam.

References

Boulard M. 2000a. Cymbalisation d'appel et cymbalisation de cour chez quatre Cigales thaïlandaises (Rhynchota, Auchenorhyncha, Cicadidae) // EPHE, Biologie et Évolution des Insectes. Vol.13. P.49–66.

Boulard M. 2000b. *Tosena albata* (Distant, 1878) bonne espèce confirmée par l' acoustique (Auchenorhyncha, Cicadidae, Tosenini) // EPHE, Biologie et Évolution des Insectes. Vol.13. P.119–126.

Boulard M. 2001. Cartes d'identité acoustique et éthologie sonore de cinq espèces de Cigales thaïlandaises, don't deux sont nouvelles (Rhynchota, Auchenorhyncha, Cicadidae) // EPHE, Biologie et Évolution des Insectes. Vol.14. P.47–71.

Boulard M. 2005a. Données statutaires et éthologiques sur des Cigales thaïlandaises, incluant la description de huit espèces nouvelles, ou mal connues (Rhynchota, Cicadoidea, Cicadidae) // EPHE, Biologie et Évolution des Insectes. Vol.15. P.5–57.

Boulard M. 2005b. Á propos de la découverte exceptionelle d'*Angamiana melanoptera* nouvelle espèce pour la tribu asienne des Polyneurini (Rhynchota, Homoptera, Cicadidae) // EPHE, Biologie et Évolution des Insectes. Vol.15. P.79–91.

Boulard M. 2005c. *Tosena albata* Distant, 1878 bonne espèce confirmée par l' acoustique (Addenda et Corrigenda) // EPHE, Biologie et Évolution des Insectes. Vol.15. P.111–123.

Boulard M. 2005d. Taxonomie et status acoustique de quatre Cigales thaïlandaises, don't deux sont nouvelles (Rhynchota, Cicadoidea, Cicadidae) // EPHE, Biologie et Évolution des Insectes. Vol.15. P.129-146.

Gogala M. 1995. Songs of four cicada species from Thailand // Bioacoustics. Vol.6. P.101–116.

Gogala M. & Riede K. 1995. Time sharing of song activity by cicadas in Temengor Forest Reserve, Hulu Perak, and in Sabah, Malaysia // Malayan Nature Journal. Vol.48. No.3–4. P.297–305.

Gogala M., Trilar T., Kozina U. & Duffels J.P. 2004. Frequency modulated song of the cicada *Maua albigutta* (Walker, 1856) (Auchenorrhyncha: Cicadoidea) from South East Asia // Scopolia. Vol.54. P.1–15.

Kitayama K. 1991. Vegetation of Mount Kinabalu Park, Sabah, Malaysia — Map of physiognomically classified vegetation // Project paper, Protected Areas and Biodiversity, Environment and Policy Institute. 44 pp. + map.

Kos M. & Gogala M. 2000. The cicadas of the *Purana nebulilinea* group (Homoptera, Cicadidae) with a note on their songs // Tijdschrift voor Entomologie. Vol.143. P.1–25.

Moulds M.S. 2005. An appraisal of the higher classification of cicadas (Hemiptera: Cicadoidea) with special reference to the Australian fauna // Records of the Australian Museum. Vol.57. No.3. P.375–446.

Moulton J.C. 1923. Cicadas of Malaysia // Journal of the Federated Malay States Museum. Vol.11. P.69–182, pls. 1–5.

Prešern J., Gogala M. & Trilar T. 2004. Comparison of *Dundubia vaginata* (Auchenorrhyncha: Cicadoidea) songs from Borneo and Peninsular Malaysia // Acta entomologica slovenica. Vol.12. No.2. P.239–248.

Trilar T. & Gogala M. 2002. Description of the song of *Purana sagittata* Schouten & Duffels (Homoptera, Cicadidae) from Peninsular Malaysia // Tijdschrift voor Entomologie. Vol.145. P.47–55.