Serangga 9(1–2): 63–81
ISSN 1394–5130 © 2004, Centre for Insect Systematics, UKM

BIODIVERSITY OF CICADAS IN MALAYSIA- A BIOACOUSTIC APPROACH

M. Gogala & T. Trilar *
Slovenian Academy of Sciences and Arts, Novi trg 3,
SI-1000 Ljubljana, Slovenia
* Slovenian Museum of Natural History, Presernova 20,
SI-1000 Ljubljana, Slovenia

ABSTRACT

Acoustic methods were used to investigate the biodiversity of cicadas in Peninsular Malaysia. Various approaches and methods were described how to match the species with the recorded songs in nature. As a result the song pattern and characteristics of seven cicada species were presented. Songs of four species are described for the first time (*Dundubia euterpe, Chremistica guamusangensis, Chremistica pontianaka* and *Huechys sanguinea*) and songs of three species were almost simultaneously published by M. Boulard from localities in Thailand (*Dundubia oopaga, Pomponia pendleburyi, Cryptotympana aquila*). Our data from Malaysia are in agreement with his description.

ABSTRAK

Kaedah akuastik digunakan untuk menyelidiki kepelbagaian riang-riang di Semenanjung Malaysia. Pelbagai cara dan kaedah diperihalkan bagaimana untuk memadankan spesies dengan

rakaman nyanyian dalam keadaan semulajadi. Sebagai keputusannya, corak nyanyian dan ciri-ciri ketujuh-tujuh spesies riang-riang dipersembahkan. Nyanyian empat spesies diperihalkan buat pertama kalinya (*Dundubia euterpe, Chremistica guamusangensis, Chremistica pontianaka* dan *Huechys sanguinea*) dan nyanyian dari tiga spesies telah diterbitkan pada masa yang sama oleh M. Boular dari beberapa lokaliti di Thailan(*Dundubia oopaga, Pomponia pendleburyi* dan *Cryptotympana aquila*). Data didapati dari Malaysia merupakan persetujuan dangan perihalannya.

INTRODUCTION

During the first MNS Belum expedition in 1994the senior author (M.Gogala) recorded and studied sound signals of many insect species with emphasis on cicadas. Almost at the same time a German scientist Klaus Riede studied animal sounds in Sabah. Similarity in some results namely on singing time sharing led to the common publication (Gogala & Riede, 1995). Later, authors of the present paper visited Malaysia in 1996, 1999 and the senior author also in 2002. Some results were already published (Kos & Gogala 2000, Trilar & Gogala 2002), and some data are presented on the website (http://www2.arnes.si/~ljprirodm3/asian_cicadas2.html). Nevertheless, many of our bioacoustic data on songs of cicadas are still unpublished.

In this paper, methods and some results of our acoustic investigations of cicadas in Malaysia were described. The acoustic repertoire of some other cicada species from Malaysia deserving detailed analysis will be published in separate papers elsewhere.

MATERIAL AND METHODS

The recordings of songs were made in the field using a TELINGA PRO III and PRO V parabolic microphones (parabola diameter 57 cm) connected to SONY DAT—recorders TCD—D3 and TCD—D10 (sampling rate 48 kHz, 16 Bit dynamic range).

In the labaratory, DAT recordings were transferred to the Hard Disk of a POWER MACINTOSH G3/233 or G4 computers

through an AUDIOMEDIA III sound card. Software used for viewing, editing and analyzing the song signals were DIGIDESIGN PROTOOLS 5, and CANARY 1.2. Sonagrams (spectrograms) and spectra were produced with the software Canary using the following settings: filter bandwith - 349.70 Hz, frame length 512 points, FFT size 4096 points, Hamming window, logarithmic amplitude scale, smooth display style.

Voucher specimens of cicadas were preserved in the collection of the Slovenian Museum of Natural History (PMSL) in Ljubljana and in the UKM collection, Malaysia.

In a tropical rain forests, the sounds of singing cicadas can be just listened or recorded and analysed with suitable microphones, recording devices, and computers. It is also possible to collect cicadas in the same habitats by light trapping and other classical methods. Nevertheless, it is often extremely difficult to match the collected species with the songs recorded in the same region. Cicadas often sing in dense vegetation or high in a canopy, where the access to the singing animals is very difficult. On the other hand, rain forest cicadas collected by light usually do not sing in captivity, or rarely.

To solve this problem, during our field investigations in Malaysia and Thailand, we tried the following approaches:

1. Collecting the voucher specimens of free singing and recorded animals,
2. Collecting cicadas at light sources or by other methods without simultaneous sound recordings and placing them into nets or cages to record and observe them,
    a. cicadas are sometimes but not often singing spontaneously under such conditions,
    b. cicadas begin to sing in the cage only when stimulated by sound emissions of free, conspecific animals in the neighbourhood,
    c. cicadas in cages sometimes respond to playback of various unspecific sounds with their own song especially in the case of a similar song pattern.
3. Documenting the identity of the singing animals in nature by close up video recording or photography.

Some additional methods to trigger or promote singing in captive cicadas were used by other researchers not only in the tropics, including electrostimulation of the central nervous system (Fonseca & Popov, 1994).

Probably the worst method is shooting with special amunition into the canopy where animals are singing,. This can only be effective where many cicadas of one species are singing in a chorus. Similarly, fogging can also be used but both methods do not provide clear results and are ethically questionable as well.

RESULTS

In this paper we present main characteristics of the songs of the following species, recorded and collected in Peninsular Malaysia: *Dundubia euterpe, D. oopaga, Pomponia pendleburyi, Chremistica guamusangensis, C. pontianaka, Cryptotympana aquila* and *Huechys sanguinea.* Songs of at least four of them were not previously described.

Dundubia euterpe Bloem & Duffels 1976

Cicadas of this species were collected and recorded during a joined expedition of UKM, Slovenian Museum of Natural History, Ljubljana and Museum of Amsterdam, Holland to Endau Rompin National Park, and Kuala Juram, Merapoh Taman Negara in March, 1999.

The calling song of free animals was recorded in many occasions in both localities during daytime. The proof of identity has been carried out in Endau Rompin base camp in a cage using method 2.b mentioned in Material and Methods. The voucher specimens were deposited in the collection PMSL and original recordings in the Sound Archive of the Slovenian Museum Nat. Hist.

The calling song of this species was represented in the form of oscillogram and sonagram (Fig. 1). The characteristics of the song were fast repetitive broad band clicks forming 1 or 2 short echemes (SE – 25 to 55 ms duration) followed after an interval of cca 0.2 s by a pulsed long echeme (LE) of about 2.5 s duration.

The repetition rate of whole phrases in the song is about 18 per minute. A repetition rate of pulses in the first quarter of long echeme was much higher (68 - 70 s^{-1}) than in the remaining part of LE (33 s^{-1}), where the pulsed structure of it is clearly audible. Both parts of long echem differ also in the basic structure, first part comprising doublets of pulses and second part where the basic unit is a quadruplet of clicks. The frequency range of the song was between 4 and 18 kHz with a broad peak between 8 and 15 kHz.

Dundubia oopaga (Distant 1881)

Cicadas of this species were collected and their songs recorded on Perhentian Besar Island at the end of March, 1999. The vaucher specimens were kept in collections PMSL and UKM.

The calling song pattern is represented in the Fig. 2. The first part of the song comprises 0.6 – 0.7 s long echemes with a basic frequency of 2.73 kHz and higher harmonics of which the 1st is also dominant (A, Fig. 2a,c,d). The second, longer and louder part of the song is characterized by different amplitude modulation and especially by a different frequency spectrum. The main basic and dominant frequency peaks remain the same, but become narrow banded with a lot of side bands (Fig. 2b,c,d, Section B). When the animals sing in a chorus this high pitched song pattern characterizes the forest soundscape.

Recently, the song of this species has been investigated also by Boulard from localities in Thailand (Boulard 2003a, in press). Comparison of our and his recordings showed the identity of the calling song from both localities.

Pomponia pendleburyi Boulard 2001 (*P. adusta?*)

The loud trumpeting cicada song heard usually in rainforests of Malaysia during dusk hours is familiar to many visitors of such places. The problem is, that apparently more than one species of these big insects emit similar songs. We recorded such songs during the first Belum expedition to Temengor Forest Reserve in April, 1994. We published the sonagram of it under the name *P.*

merula (Gogala & Riede 1996), what was apparently a mistake, since *P. merula* inhabits only Borneo (Duffels, personal communication) and Riede's recordings (see also Riede & Kroker 1995) belong most probably to the taxon *P. merula* and not to *P. imperatoria*. Nevertheless, the acoustic behaviour of this species from Sabah studied Riede and reported song pattern, which is not easily distinguishable from *Pomponia* sp. from Peninsular Malaysia.

In Endau Rompin (Lubuk Tapah, April 2002) we recorded *Pomponia* sp. in a cage and the specimen, deposited in PMSL is apparently identical with the newly described *P. pendleburyi* Boulard.

The song characteristics of our specimen are shown in Fig. 3. The duration of the whole song phrase lasts usually more than 20 s. During the first part, lasting about 4 s, the trumpet sound is only at the beginning slightly pulsed and reaches during this time the highest intensity. Afterward, the sound changes to a long sequence of short echemes with intensity gradually decreased. The repetition rate of SE remainsstable at around 4.5 - 6.5 s^{-1}. Such trumpetting occurs regularly during dusk, between 7.00 and 8.00 PM.

Chremistica guamusangensis Salmah & Zaidi 2002

Cicadas of this species were collected and recorded during the same expedition as mentioned above to Merapoh Taman Negara and Gua Musang in March, 1999. These cicadas appeared during our visit to Gua Musang in tremendous number and were attracted to lights in a town. They were emitting sounds during the day and at night. The field recordings were very noisy due to heavy traffic and other sounds in the town. We brought some animals to Kuala Juram, Merapoh Taman Negara and placed them into cages. During the daytime some animals spontaneously emitted a calling song, which was recorded and is represented in Figs. 4 & 5. In this and some other species of the genus *Chremistica* is characteristic a faint introductory rumbling sound, preceding the main song. Such rumbling sound slowly increases in frequency

and ends with a short flight or wing flips, or with emission of the loud calling song.

The calling song was complex and had broad frequency range. It begins with a series of short echemes of increasing intensity (rep. rate 9.3 s^{-1}) and a broad frequency band with a peak near 3.3 kHz, which abruptly changes to the narrow banded part (NBP) with a dominant frequency peak of 2.75 kHz and many side bands and higher harmonics. This NBP abruptly changes to the pulsed broad banded part of about 0.2 s duration and to the NBP of 0.15 to 0.4 s duration again many times. The song ends with about 2.5 s long NBP.

The repetition rate of this characteristic frequency modulation is 165 per minute or 2.75 s^{-1} (Figs. 4 & 5).

Chremistica pontianaka (Distant 1888)

Cicadas of this species were collected and recorded during a short visit of M. Gogala, Prof. Zaidi and his colaborators from UKM to Lubuk Tapah, Endau Rompin National Park in April, 2002. The same song pattern was recorded in other localities during the field trips also in 1994, 1996 and 1999 in other localities, like in Temengor Forest Reserve, Hulu Perak, UKM Bangi, or in Merapoh Taman Negara, Kuala Juram, wherever this common species was present.

Nevertheless, only in Lubuk Tapah, Endau Rompin (2002) we succeded to record the calling song of caged animals of this species, using method 2b in addition to record free chorusing or single animals in the forest. The voucher specimens were kept in the PMSL collection.

This species shows the same acoustic introductory behaviour described with the previous species, preceeding the emission of the calling song. In contrast to this the pattern of the calling song is very different. It comprises long lasting repetitions of the consecutive short (SE) and long echemes (LE) of a multiple frequency bands with a characteristic dominant peak at 2,85 to 2.95 kHz. A special characteristic of this song was also a vibrato evident especially in sonagrams of LE (Fig. 6). After each short echeme or two short echemes of 52 to 75 ms duration 1 or 2 even

shorter (10 - 20 ms) broad banded echemes follow preceeding the obligatory long echeme of 260 - 600 ms duration. Therefore the sound pattern has a characteristic rhythmic structure (Fig. 6). Animals singing free in the forest typically synchronize their singing in a real chorusing which can be heard during a daytime from 10 AM till around 5 PM.

Cryptotympana aquila (Walker 1850)

This is abundant species with a very wide distribution. Nevertheless, we succeeded to record its song with certainity only in 1999. We collected of this species in Gua Musang and Merapoh Taman Negara. Cicadas were kept in cages but they did not sing spontaneously. Therefore we stimulated them acoustically by playing back various unidentified songs of cicadas from Malaysia. The playback of the "fireman" song elicited singing of *C. aquila* a few times (Method 2c). An example of such song is shown in Figs. 7 & 8. The voucher specimens are in PMSL collection.

The song resembles the pattern of *Chremistica* with consecutive changes of frequency spectrum. Nevertheless, there are no narrow banded sound emissions, just changes of pulsed broad banded sound to continuous broad band signal with smaller range of frequencies (Figs 7 and 8).

Boulard (2003b, in press) recorded recently the same species free in nature on localities in Thailand and described the same song pattern.

Huechys sanguinea (de Geer 1773)

We recorded and collected cicadas of this colourful species in Endau Rompin national park during March, 1999. The voucher specimens are in the PMSL collection.

The recordings of *H. sanguinea* from this locality show regular repetition of short echemes of 55 - 65 ms duration with a repetition rate of about 10 per second, often interrupted by 3 - 5.5 s long echemes of continous buzzing (Fig. 9). The frequency band of emission is from 4.5 to 8.5 kHz with the intensity peak near 6 kHz.

DISCUSSION

In this paper we present descriptions of song patterns of four species (*Dundubia euterpe, Chremistica guamusangensis, Ch. pontianaka* and *Huechys sanguinea*) for the first time. Songs of *Dundubia oopaga, Pomponia pendleburyi, Cryptotympana aquila* from localities in Thailand were almost simultaneously described or are in press by Boulard (2001, 2003a, 2003b and personal communication). Our results on song patterns of the three cicada species from Peninsular Malaysia are in agreement with his data and confirm the identity of these taxa.

Pomponia pendleburyi is probably identical with *P. adusta,* reported in some papers from Peninsular Malaysia (e.g.: Zaidi *et al*. 2001). Boulard (2001) claims that *P. adusta* is limited to Java and is a different species. Our specimen from Endau Rompin checked by Boulard and confirmed it as *P. pendleburyi.* This species may be close or identical to *P. adusta* according to Zaidi and Duffels - personal communication . The song of it is also very similar to the song pattern published by Boulard (2001) for this species from localities in Thailand. The same or very similar song pattern has been recorded in Temengor Forest Reserve (1st Belum Expedition), in Taman Negara - Merapoh Side, in the forest around Gombak, and in Endau Rompin National Park, Malaysia.

Boulard (2001) also found that the song of *P. intermedia* does not differ substantially from the general song pattern, emitted by the *Pomponia* species mentioned above. Therefore an exact comparative study should be devoted to this group of closely related species.

The song of the *Huechys sanguinea* has been recorded in Taiwan by Lee (2003) but the oscillogram does not show any clear pattern and a description of their sound emissions in the text allows the assumption that the song of Taiwanese animals does not have the same acoustic pattern and do not belong to the same taxon. The acoustic approach often helps to discriminate morphologically similar taxa (e.g.: *Cicadetta montana* and *C. montana macedonica* from Europe - Gogala & Trilar 1999) or confirms the identity of similar cicadas from different localities (e.g. *Purana sagittata* from Gombak and Taman Negara,

Peninsular Malaysia (Trilar & Gogala 2002)). A number of species collected in certain habitats is often not much lower than a number of "acoustic species" i.e. song patterns ascribed to the cicadas, recorded in the same habitat, and during the same period of time.

However, one would expected more song patterns or "acoustic species" compared with the collected cicadas at the same locality. The is because we see in unrecognized song differences or song patterns not recognized as cicada songs, in daytime period of acoustic activity not covered by sound recordists (Gogala & Riede, 1996), in an unexpected frequency range (ultrasound, see Popov et al., 1997), or even in different channels of communication including substrate-borne signals. Anyway, the acoustic approach to biodiversity studies of cicadas can make classical field investigations of singing cicadas in the tropics much more effective.

ACKNOWLEDGEMENTS

We would like to thank to Dr. Zaidi Mohd. Isa and Mr. Ruslan Mohd. Yusop who enabled us to work at the Centre for Insect Systematics of the Universiti Kebangsaan Malaysia in Bangi and who organized excellent field work in Taman Negara.

Our special thanks go to the Endau Rompin Team of the Malaysian Nature Society: Francis Cheong, Chew Keng Lin, Sing Yun Chin, Lili Bte Tokiman, Hazman Bin Md. Zaki, Ivy Abdulla, Heah Hock Heng and V. J., for their help and excellent logistic support in 1999 and to Mohd. Adli Mansor, and other coworkers of MNS in 2002.

We are also grateful for determinations of specimens to Prof. Dr. Hans Duffels, Amsterdam, Prof. Dr. Michel Boulard, Paris and Prof. Dr. M. I. Zaidi, Bangi.

REFERENCES

Boulard, M. 2001. Éthologies sonore et larvaire de *Pomponia pendleburyi* n. sp. (précédé d'un historique taxonomique concernant les grandes *Pomponia*). *EPHE, Biol. Evol. Insectes*. 14: 79-103.

Boulard, M. 2003a. Comportement sonore et Identité acoustique de six espèces de Cigales thaïlandaises, dont l'une est nouvelle (Rhynchota, Cicadomorpha, Cicadidae). *Bulletin de la Société entomologique de France*. (in press).

Boulard, M. 2003b. Éthologie sonore et statut acoustique de quelques Cigales thaïlandaises, incluant la description de deux espèces nouvelle (Auchenorhyncha, Cicadoidea, Cicadidae). *Annales de la Société entomologique de France*. (in press).

Fonseca, P. J. & Popov, A.V. 1994: Sound radiation in a cicada: the role of different structures. *J. Comp Physiol.*175: 349-361.

Gogala, M. 1994. Songs of four cicada species from Thailand. *Bioacoustics*. 6: 101-116.

Gogala, M. & Riede, K. 1996. Time sharing of song activity by cicadas in Temengor Forest Reserve, Hulu Perak, and in Sabah, Malaysia. *Malayan Nature Journal*. 48(3-4): 297-305.

Gogala, M. & Trilar, T. 1999. The song structure of *Cicadetta montana macedonica* Schedl with remarks on songs of related singing cicadas (Hemiptera: Auchenorrhyncha: Cicadomorpha: Tibicinidae). *Reichenbachia, Schriftenreihe Taxonom. Entomol.* 33(1): 91-97.

Kos, M. & Gogala, M. 2000. The cicadas of the *Purana nebulilinea* group (Homoptera, Cicadidae) with a note on their sound. *Tijdschrift voor Entomologie.* 143: 1-25.

Lee, Y. J. 2003. *A taxonomic review of Cicadidae (Insecta: Homoptera) in Taiwan*. PhD. Dissertation, School of Agricultural Biotechnology, Seoul National University. 243 pp.

Popov, A. V., Beganovic, A. & Gogala, M. 1997. Bioacoustics of singing cicadas of the western Palaearctic: *Tettigetta brullei* (Fieber 1876) (Cicadoidea: Tibicinidae). *Acta entomologica slovenica.* 5: 89-101.

Riede, K. & Kroker, A. 1995. Bioacoustics and niche differentiation in two cicada species from Bornean lowland forest. *Zoologischer Anzeiger*. 234: 43-51.

Salmah, Y. & Zaidi, M. I. 2002. The genus *Chremistica* Stal (Homoptera: Cicadidae) from Peninsular Malaysia, with descriptions of two new species, *Chremistica guamusangensis* n. sp. and *Chremistica kecil* n. sp. *Serangga:* 7(1-2): 225-244.

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

Zaidi, M. I., Azman, S. & Ruslan, M. Y. 2001: Cicada (Homoptera: Cicadoidea) fauna of Langkawi island, Kedah. *Serangga*. 6(1): 109-122.

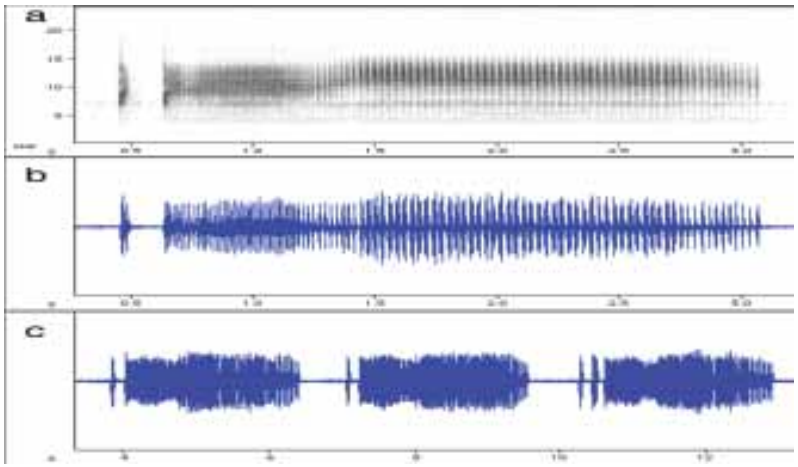

Fig. 1 Song of *Dundubia euterpe* from Endau Rompin. a, sonagram or spectrogram; b & c, oscillograms.

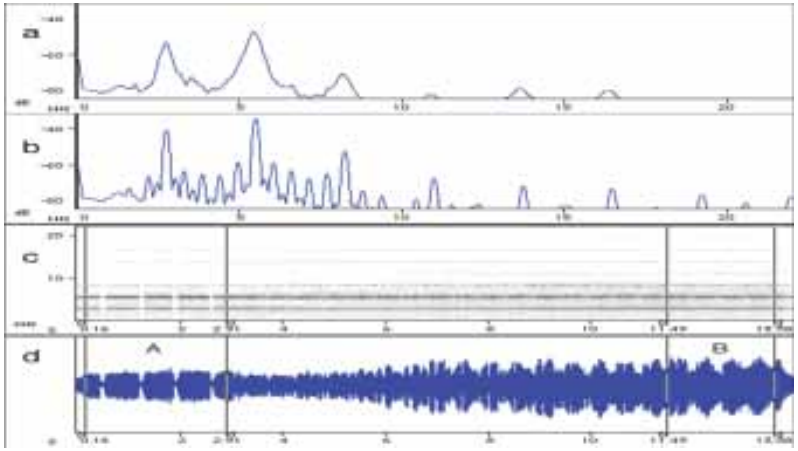

Fig. 2 Song of *Dundubia oopaga* from Perhentian Besar Island. a, spectrum of the section A; b, spectrum of the section B; c, sonagram or spectrogram; d, oscillogram. Spectrum of sound changes from broad banded peaks (a) to narrow banded peaks with side bands (b) near the 3rd second and keeps this characteristics till the end of a song.

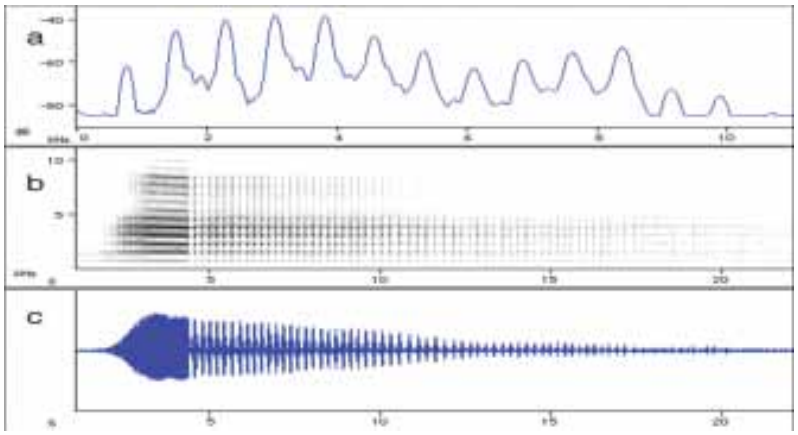

Fig. 3 Song of *Pomponia pendleburyi* from Endau Rompin, Lubuk Tapah. a, average spectrum; b, sonagram or spectrogram; c, oscillogram. This is the song of caged animal provoked by the free conspecifics in the neighbourhood.

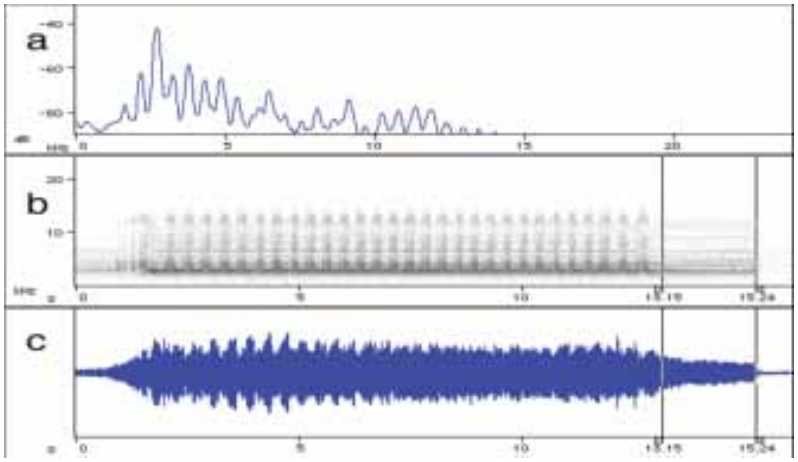

Fig. 4 Song of *Chremistica guamusangensis* from Gua Musang: a, spectrum of the "tail", marked last part of the song; b, sonagram or spectrogram; c, oscillogram. This is the spontaneous song of a caged animal.

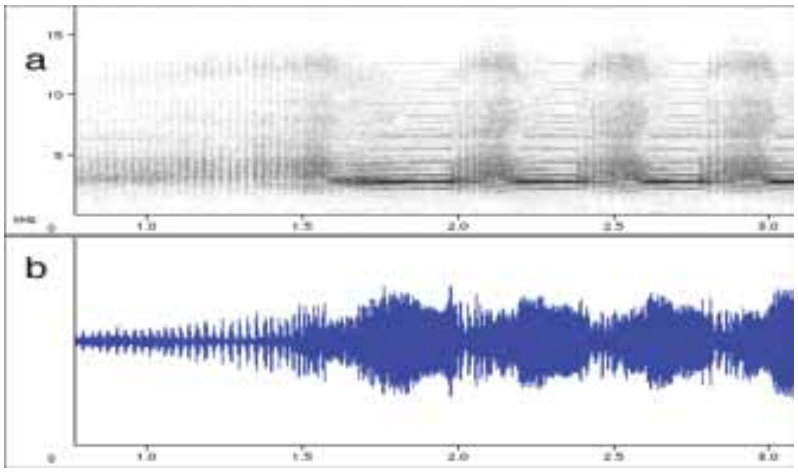

Fig. 5 Initial part of the song of *Chremistica guamusangensis* shown in Fig. 4 in a different time scale to see details of spectral and amplitude structure. A, sonagram or spectrogram; b, oscillogram. Abrupt changes of pulsed broad band parts with the narrow banded parts of the song, typical for many tropical cicadas are evident. The dominant frequency of the narrow banded parts of the song is 2.72 kHz.

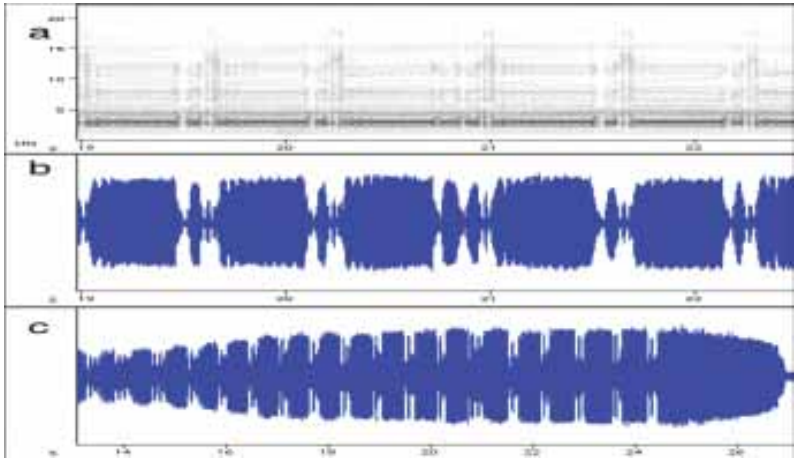

Fig. 6 Song of *Chremistica pontianaka* from Endau Rompin, Lubuk Tapah. a, sonagram or spectrogram; b & c, oscillograms. Interchange of repeated narrow banded short and long echemes show a species specific dominant frequency of 2.9 kHz with many side bands and higher harmonics. Typical for this species is a regular frequency fluctuation ("vibrato"). This pattern is enriched with even shorter broad band echemes.

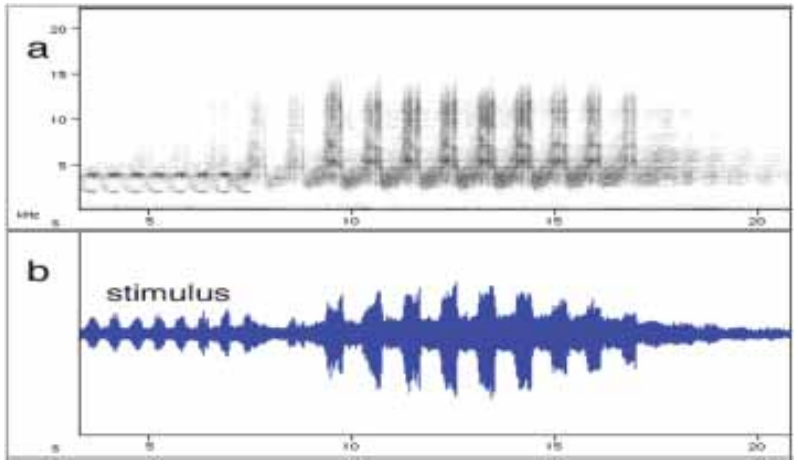

Fig. 7 Song of *Cryptotympana aquila* from Taman Negara, Merapoh. a, \sonagram or spectrogram; b, oscillogram. In the left part of the picture the frequency and intensity modulated song of an unknown cicada ("fireman") can be seen played back as a stimulus. It provoked singing of a caged *C. aquila* best seen in a right 2/3 of traces.

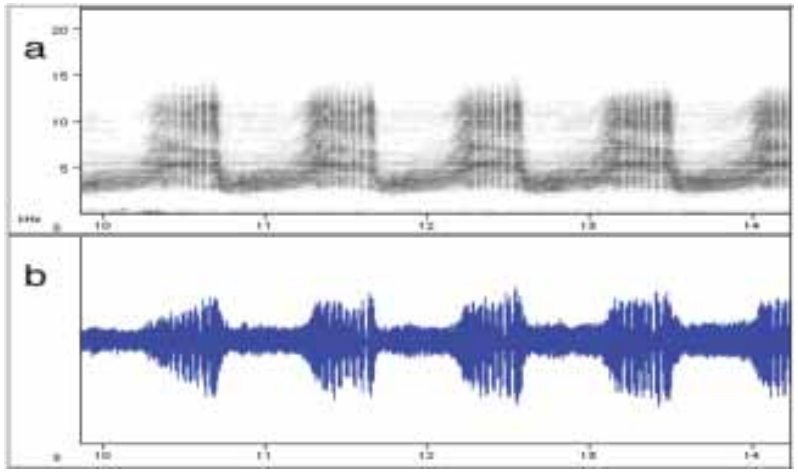

Fig. 8 Extended part of the same song of *Cryptotympana aquila*, shown in Fig. 7 to show the song structure. a, sonagram or spectrogram; b, oscillogram. Pulsed and intense broad band parts of the song are bound with lower pitched and narrower banded parts with some degree of frequency modulation ("glissando up"). There are no clear frequency peaks.

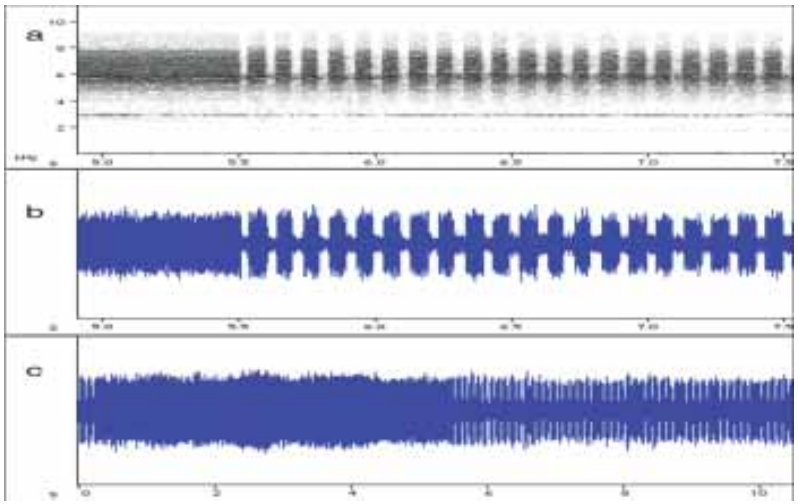

Fig. 9 Song of *Huechys sanguinea* from Endau Rompin. a, sonagram or spectrogram; b & c, oscillograms. The lower trace (c) shows a longer part of song comprising one long echeme and a sequence of many short echemes. Such longer echemes appear in a song each 10 - 15 s. In the sonagram (a) a signal at about 3 and 6 kHz belongs to the background sound of other cicadas, probably *Chremistica pontianaka.*