

Time Sharing of Song Activity by Cicadas in Temengor Forest Reserve, Hulu Perak, and in Sabah, Malaysia

MATIJA GOGALA¹ & KLAUS RIEDE²

Abstract: During the Malaysian Nature Society's Expedition to Belum we observed that the singing of many cicada species is limited daily to a narrow time window of about 30 minutes to 2 hours. Similar observations were made by one author (K. R.) in Sabah. Many such cicada species sing only at dusk, but there are also species acoustically active only at dawn ("Morning Cicada"), or within a species-specific time window during the day (e.g. *Tosena depicta*), at noon (*Terengganua sibylla*), or even at midnight ("Midnight Cicada"). The authors discuss the connection of such behaviour with a high biodiversity in Malaysian rainforests. Unfortunately, the determination of species was possible only in some cases; for other cicadas we used preliminary mnemonic nicknames.

INTRODUCTION

In March and April 1994 one of us (M.G.) took part in the Malaysian Nature Society's Heritage and Scientific Expedition to Belum (Davison *et al.*, 1995), with the main intention of investigating acoustic biodiversity in the virgin forest with a special emphasis on cicadas. During the three weeks at Temengor Forest Reserve we observed one peculiarity in the rich acoustic texture of the Belum forest - the exact daily timing of song emissions in many cicada species and some other animals. This was especially evident during dawn and dusk. Recently, the second author (K. R.) made similar observations in Sabah, Borneo. Both authors reported this in the form of posters at the 7th International Meeting on Insect Sound and Vibration in Graz (September 22nd to 25th, 1994) and the present paper gives a comparison of results from both localities to demonstrate the common features and the differences in the song sequences in Temengor and Borneo.

MATERIAL AND METHODS

Temengor

Most acoustic recordings were made in the vicinity of the expedition base camp at Sungai Halong, Temengor Forest Reserve, between 21 March and 13 April 1994. Especially important were continuous intermittent recordings from the evening of 4 April to the morning of 5 April at the location "Tiger Hide" and at the sub camp from the afternoon of 11 April till the afternoon of 13

¹Slovene Museum of Natural History, Presernova 20, 61001 Ljubljana, Slovenia.

²Institut für Biologie I, Universität Freiburg, Albertstr. 21a, 79104 Freiburg i.Br., Germany. (Accepted for publication 15 March 1995).

April for the time schedule of singing of different animal species.

The acoustic recordings at Temengor were made using digital techniques limited to the sonic range between 20 and 20000 Hz with SONY DAT-corders TCD D3 and TCD D7 (sampling rate 48k samples per second, 16 Bit dynamic range) in connection with a TELINGA PRO III parabolic stereo microphone (parabola diameter: 57 cm).

The recordings were analyzed after a transfer to the ADAP II - Atari ST computer HDR (Hard Disk Recording) system via the digital interface. Time parameters of songs were analyzed and selected parts were then exported as SND files to the TOS operating system based computer programs. In a self written OMIKRON.BASIC program we made a final selection of the sound sequences for oscillography and conversion for import into CED Waterfall program to produce FFT sonograms (Fig. 2) on an IBM compatible PC Sunrace Hyperbook 2300.

During the recordings, the time and the ambient temperature were registered.

For the presentation of the time windows in which single species were singing during the research period in Temengor, a simple measure was used. We counted the number of recordings in which a particular cicada song was recorded (Fig. 1).

Borneo

Investigations were made at the Kinabalu Park, Sabah, Malaysia, in a lowland mixed dipterocarp forest at Poring Hot Spring (500 m asl). A canopy walkway system was available with a total length of 900 m. Observations were made from April to June 1991, March until May and August 1992, thereby covering different seasons and weather conditions.

Recordings in Sabah were made by 4 pairs of electret microphones (EM-3) installed at four stations about 30 m apart on the walkway. Microphones were fed into two 4-channel mixers and their outputs recorded by a stereo cassette recorder (SONY TCD5-PRO, frequency response: 40 - 16000 Hz +/-3dB). In addition, sound intensity, light intensity, temperature, and humidity were recorded.

For acoustical analysis, sound recordings were sampled into a computer (Tandon 486/33, Compaq) via an analog-digital converter (DT2821, Data Translation) at a sampling frequency of 30 kHz and analyzed with a signal processing software (Hypersignal Acoustic, Hyperception Inc.).

Unfortunately, in both localities, the identity of most of the species could not be determined, since the animals were singing high in the forest canopy and we did not use any radical methods (e.g. shooting) to obtain them for determination. In the case of *Pomponia merula* and *Dundubia vaginata* (Borneo), we caught the specimens and kept them in cages. In contrast to other species, they also sang under such conditions during their active period. For most of the other species we used nicknames to describe their sounds. Some songs from both localities can be ascribed with high probability to the same species. We hope to determine the unidentified species in future explorations.

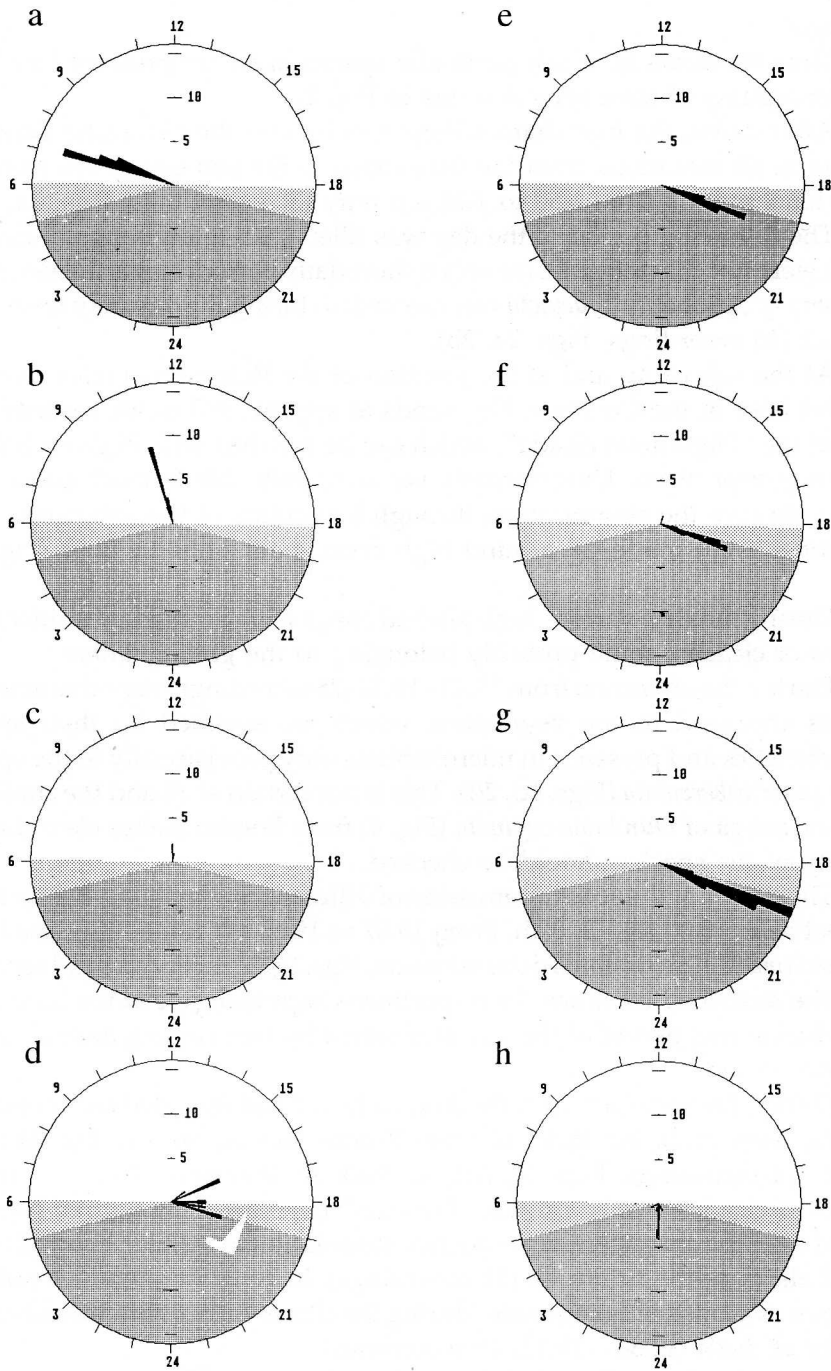


Figure 1: Occurrence of different cicada songs during the day and night in Temengor. Radius: Number of recordings per 15 minutes during the expedition period from March 21st and April the 12th, Shaded areas: night and twilight. a - "Morning Fanfare" (N=30), b - *Tosena depicta* (N=16), c - *Terengganua sibylla* (N=4), d - *Maua* sp.? (N=28), e - "Riah-riah" (N=24), f - "Pump" (N=22), g - *Pomponia merula* (N=38), h - "Midnight Cicada" (N=13).

Temengor

Time windows in which particular species sang are presented in Fig. 1 and sonograms of their typical songs in Fig. 2.

After dawn, the first characteristic species was the "Morning Fanfare", singing at all elevations from the base camp to the sub camp. We recorded these loud sounds from 6.50 to 7.36 am only (30 recordings, Figs. 1a, 2a).

The following period of the day was filled with many songs of cicadas, which were not characteristic for only a short daily period. Nevertheless, songs of *Tosena* sp., probably *T. depicta* were recorded during the day only from 10.30 to 11.23 (16 recordings, Figs. 2a, 2b).

At the sub camp and at the junction of the Ridge trails (elevation 700 m), and later in the Cameron Highlands at approx. 900 m we recorded the song of the "High noon cicada", which can be ascribed with high probability to *Terengganua sibylla*. Unfortunately we were only able to catch one female and to observe the singing male through binoculars at the sub camp. Four recordings were made, all around high noon, from 11.54 to 12.47 (Figs. 1c, 2c).

During the day, various high pitched songs were emitted by unidentified species of cicadas, some probably belonging to the genus *Purana*.

During the afternoon from 15.43 - 19.30 (28 recordings) very characteristic cicadas chorused in the vegetation, which we ascribed by their special characteristics and presence in microhabitats only provisionally to the species *Maua quadrituberculata* (Figs. 1d, 2d). This is not certain at all and the similarity with the songs of *Dundubia vaginata* (Fig. 4) from Borneo makes clear that the identity of the species should be checked.

The climax of the acoustic emission of different cicadas in the Belum forest was between 18.00 and 20.00 h. From 19.07 to 19.55 (38 recordings) we heard *Pomponiamerula* (provisional determination, Figs. 1g, 2g) every day and recorded at all the described localities. Two specimens kept in a cage at the base camp sang during this period of the day stimulated by free singing animals in the neighbourhood.

During the same period of the day, we heard and recorded another cicada species, resembling the *Riah-riah* from Borneo (see below and Fig. 4) (19.00 - 19.45, 24 recordings, Figs. 1e, 2e). At dusk another very similarly singing species of cicadas was heard, the "Fireman" (not shown in figures 1 and 2), named after the characteristic frequency modulation in quarta, resembling the sound alarm of the fire truck (11 recordings). In contrast with *Riah-riah* this species was acoustically active also during the afternoon but with the maximum activity at dusk (12.30 - 19.15, 11 recordings).

At the localities "Tigerhide" and the sub camp, a further characteristic cicada singing at dusk was the "Pump", a very loud species with a high level of frequency modulation. Their songs were recorded between 18.38 and 19.31 with one exception at 13.00 (22 recordings, Figs. 1f, 2f).

All these species are very loud but sing only during the very limited period

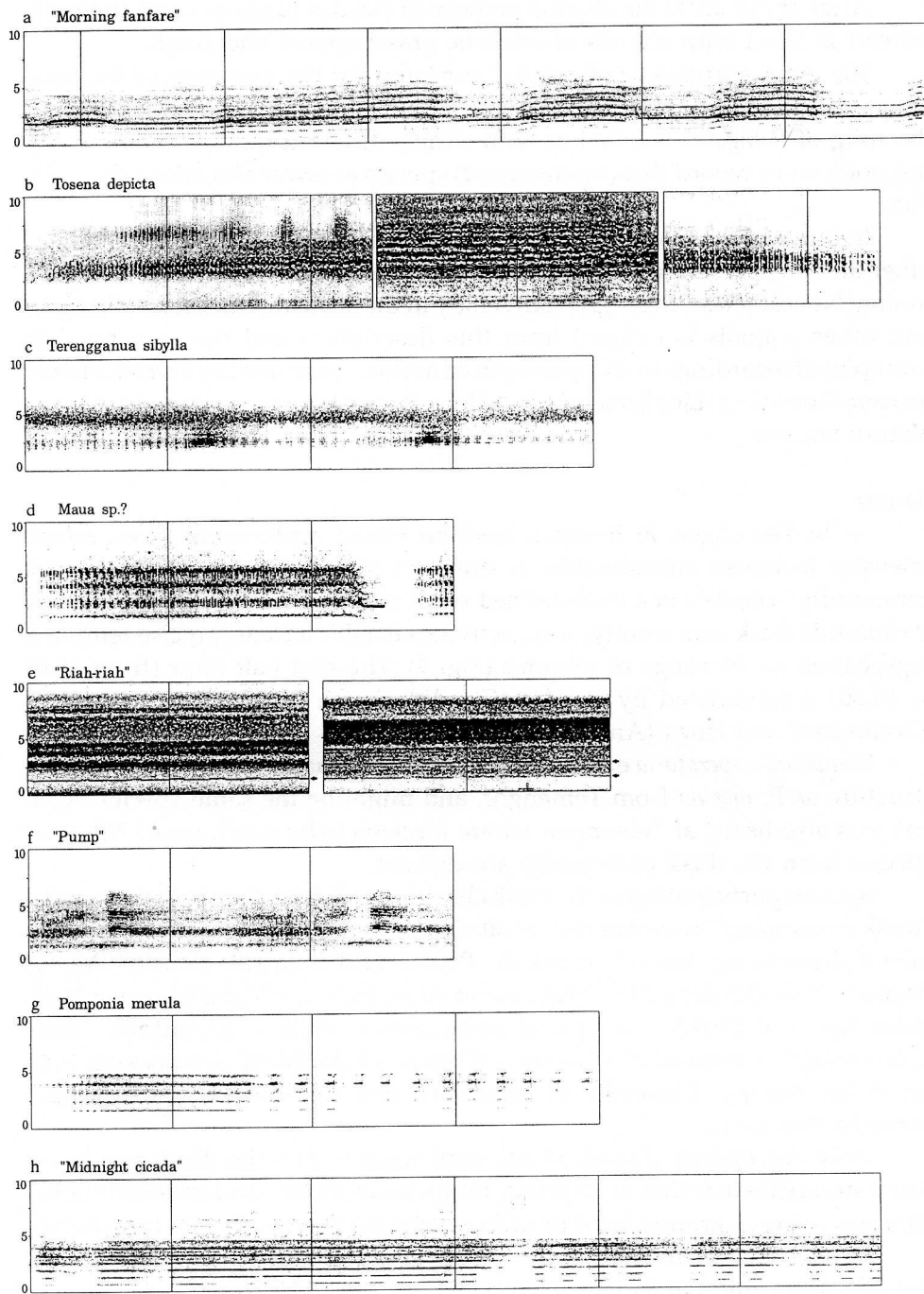


Figure 2: Typical sonograms of songs of cicada species from Belum (CED Waterfall, 512 pt, 40 dB dynamic range). Their daily acoustic activity is presented in Fig. 1. Vertical lines mark 1 second intervals. Two recordings of Riah-riah from Belum are partly covered by intense sounds of crickets, but the dominant basic frequency at 1 kHz (and the first harmonic in the second recording) (see arrows) appear in a less frequented frequency window.

of dusk.

After about 20.00 the singing activity of cicadas fades out and the night concert is filled with sounds of crickets, grasshoppers and frogs.

We were surprised only at the subcamp by the presence of the loud trumpet sound of the "Midnight Cicada" (22.10-3.49, 13 recordings), resembling the song of *Pomponia merula* but with clearly different time parameters. We did not hear or record this (unidentified) species at lower elevations (Figs. 1h, 2h).

In this presentation we do not mention many other songs of cicadas and other animals present during certain periods of the day but without typical timing. Nevertheless, the high biodiversity in the acoustic emissions of cicadas and other animals is evident from this description and the cassette with examples of recordings from Temengor, edited and produced by Prirodoslovno društvo Slovenije in Ljubljana, which will also be available through the Malaysian Nature Society.

Borneo

As in Temengor, in Bornean lowland mixed dipterocarp forest sound intensity increases considerably at dusk (cf. Riede, in press). This "dusk community" consists of a well-defined set of cicada, cricket, and frog species. Within this dusk community, song activities exhibit a clear, precise temporal segregation in the range of minutes (Fig. 3). The first half hour (from 18.00 to 18.30) is dominated by cicadas (Cicadidae), the second half by crickets (Grylloidea) and frogs (Anura).

Pomponia imperatoria exhibits a similar activity pattern and the same song structure as *P. merula* from Temengor, and might be the same species. *Riah-riah* was also heard at Temengor, where it seems to be much rarer. All other species from the dusk community are distinct.

Species participating in the dusk chorus are widely distributed: a similar "dusk community" was observed at all visited sites characterized by "lowland mixed dipterocarp forest" in Sabah, Brunei and Sarawak (Sabah: Poring; Brunei: Kuala Belalong Field Station; Sarawak: Gunung Mulu National Park, Bako National Park). The spatial organization of this ubiquitous "dusk community" is associated with certain forest strata. Most cicadas sing high up in the canopy. Especially *P. imperatoria* and *Riah-riah* change positions between two songs.

Only one species (*Dundubia vaginata*) sings within the dosel and lower forest strata (Riede & Kroker, in press). Frogs, mole crickets and crickets (mainly *Itara* spp.) sing at ground level or in forest shrubs at a height of a few metres.

Dundubia vaginata is the only species singing both at dusk and during the day, from midday to late afternoon.

The "Morning Fanfare" was frequently heard in Borneo. As in Temengor, its loud song was heard right after sunrise for about an hour. Several other Bornean species singing during the day seem to be similar to the Temengor species, but this has to be checked carefully by detailed acoustic comparisons.

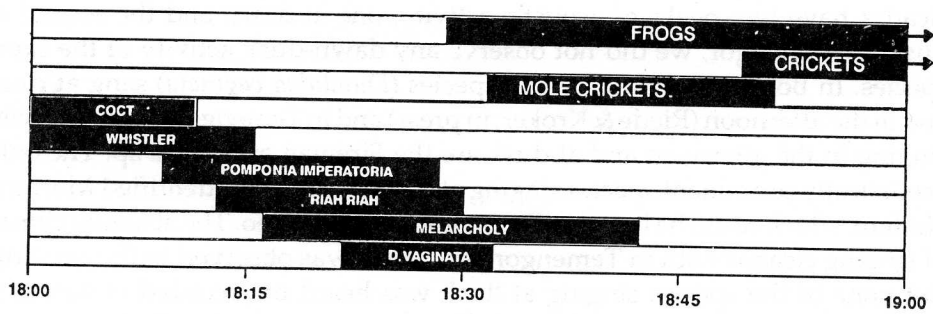


Figure 3: Temporal fine-tuning within the dusk community in Sabah. Undetermined cicada species are named mnemonically according to song characteristics. Activity patterns within the dusk community between 18.00 and 19.00 local time. Song activity marked black.

Diurnal species exhibit more sloppy temporal synchronization and longer song activities, but form spatial assemblies by species aggregations within forest patches of a few hectares in size. Accordingly, there is considerable variation of species composition depending on the recording site, and inventorying of songs is still in progress.

DISCUSSION

The time schedule of cicada songs in many tropical and subtropical habitats is so obvious that it can not be overlooked and has been already mentioned or discussed by several other authors. Young (1981) wrote about temporal selection of singing in tropical New World cicadas. The main difference from Malaysian cicadas appears to be in two characteristics, in the presence of dawn-dusk species and in the time of climax. According to Young, many Neotropical

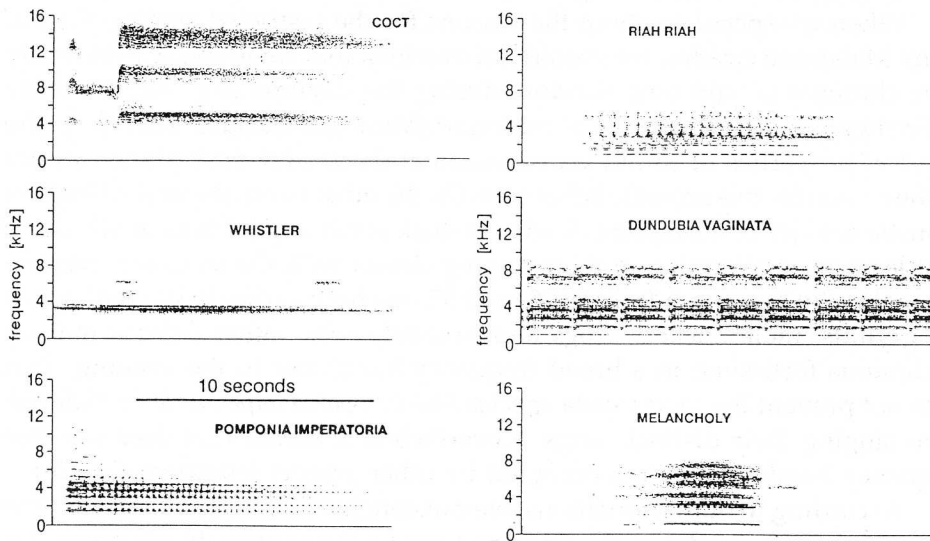


Figure 4: Sonograms of the cicada species participating in the dusk community in Sabah (Fast Fourier Transform, 512 pt, Blackman window). Scale bar of 10 s applies to all sonograms.

cicadas have two peaks of acoustic activity, one at dawn and the second at dusk. In Temengor, we did not observe any dawn-dusk activity of the same species. In Borneo, only one cicada species (*Dundubia vaginata*) sang at dusk and in the afternoon (Riede & Kroker, in press) and in Temengor the two species singing in the afternoon and at dusk are the Fireman and *Maua* sp. The only acoustically prominent species singing at dawn was the unidentified Morning Fanfare, which could be heard in Temengor and in Borneo. The absolute climax of singing cicadas both in Temengor and Sabah was observed in the evening. But none of the species singing at dusk was heard or recorded at dawn, at least during our observation times. In Temengor, we occasionally heard some evening species during the day, especially when rain or a storm was coming. This reminds us of the rooster's acoustic behaviour.

When we compare the singing times of the dusk cicadas in both regions, we cannot overlook a difference of about one hour; the species *Pomponia merula* resp. *P. imperatoria* for example sings in Temengor from 19.07 to 19.55 and in Borneo from 18.10 to 18.25. Likewise the evening concert of gryllids and mole crickets begins in Borneo at about 18.30 and in Temengor at 19.30. This corresponds quite nicely with the real time difference between the two sites due to their geographic positions. Nevertheless, it would be interesting to compare the time schedule for the same species at both localities in the same period of the year and measure at the same time the absolute light level and other physical parameters such as temperature and humidity.

The exact timing of song activity in the range of minutes suggests that a precise trigger such as fading light is used. Candidates for triggering are thresholds of total light intensity (integral over some spectral sensitivity), the velocity of light intensity change, i.e. the first derivative of the light intensity vs. time curve, or a measuring of the characteristic red shift at dusk.

When we speculate about the reasons for the restricted singing time of many Malaysian cicadas, we should not overlook that some species obviously have chosen a certain time window during the daytime (e.g. *Tosena depicta* or *Terengganua sibylla*) or even at midnight (Midnight Cicada). Therefore, the physical properties of sound transmission at dawn and dusk alone can not be the reason for this acoustic behaviour. On the other hand, the time of highest acoustic activity of Malaysian cicadas at dusk is not a quiet time at all. There is at least an overlapping of their singing climax with the so called evening organ time (in Temengor from 19.23 to 19.55, one hour earlier in Borneo), when the gryllids, mole crickets, frogs and probably some other cicadas make a continuous fortissimo in a broad frequency band later in the evening. This does not prevent the loud cicada species like *Pomponia imperatoria* or *Riah-riah* from singing their distinct songs. Nevertheless it seems that they use free frequency bands not or less occupied by other singers (compare Fig. 2e).

According to our observations, we can conclude that one reason for time sharing between cicadas in the rainforest can be the extreme biodiversity, i.e. the high number of cicada species in these habitats. In our recordings from Temengor, we can distinguish at least 33 different songs, probably belonging

to different taxa. This might also be the reason for the absence of dawn-dusk cicadas with two maxima of acoustic activity, in contrast to species from less diverse communities, as for example *Platylomia nagarasingna* from the Hat Yai region in Thailand (Gogala, in press). Another advantage of the evening climax of singing cicadas might be the reduced pressure from predators. Many birds and other potential predators are not active any more, and the nocturnal species just start their activity cycle.

The large and loud cicada species such as *Pomponia merula* do not sing continuously at one spot but rather a phrase or two at one spot, before they move in loose aggregations to nearby trees, where they sing again. Through this behaviour they are increasing the probability of attracting females and probably decreasing that of being eaten by predators. How the midnight cicada orients itself in the darkest period of the night remains enigmatic, but many animals including insects, are very successful under such circumstances.

Additional efforts are necessary to identify the species of these interesting forest singers, to investigate their behaviour, way of communication and to understand the ecological and biophysical reasons for their acoustic behaviour. And the undestroyed Temengor forest would be the right place for such investigations.

ACKNOWLEDGEMENTS

First, one of us (M.G.) would like to thank the Malaysian Nature Society, which organized the Belum expedition and made the project possible. We are specially indebted to camp managers Mr. Leong and Mr. Piee for good and smooth organization of the expedition and also to other personnel (cook, volunteers etc.) who made life so pleasant and efficient. Participation in the expedition was also supported by the Ministry of Science and Technology of the Republic of Slovenia.

Dr. Zaidi Mohd Isa helped us in catching and identifying cicadas. This author is also grateful for help to his colleagues Dr. Ignac Sivec and Miss Darja Ribaric.

K.R. thanks Sabah Parks for generous support in field investigations and the German Research Council (Theme program: Mechanism of Maintenance of Tropical Diversity).

REFERENCES

- Davison, G.W.H., Soepadmo, E. and Yap, S.K. 1995. The Malaysian Heritage and Scientific Expedition to Belum: Temengor Forest Reserve 1993-1994. *Malayan Nature Journal*, **48**: 133-146.
- Gogala, M. In press. Songs of four cicada species from Thailand. *Bioacoustics*, **6**.
- Henwood, K. & Fabrick, A. 1979. A quantitative analysis of the dawn chorus: temporal selection for communicatory optimization. *Am. Nat.* **114**: 260-274.
- Riede, K. In press. Diversity of sound-producing insects of a Bornean lowland rain forest. *Proceedings of the International Conference of Tropical Rainforest Research: Current issues*. Brunei Darussalam, 1993.
- Riede, K. & Kroker, A. In press. Songs of two common cicadas (Cicadidae) from Bornean lowland forest. *Zoologischer Anzeiger*.
- Young, A.M. 1981. Temporal selection for communicatory optimisation: the dawn- dusk chorus as an adaptation in tropical cicadas. *Am. Nat.* **117**: 826-829.