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Spectral analysis of vocalisations of the Moluccan megapode *Eulipoa wallacei* (Aves: Megapodiidae) during egg-laying activities

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Vocalisations of the Moluccan megapode *Eulipoa wallacei* during nightly egg-laying activities on the communal nesting-grounds of Tanjung Maleo near Kailolo village on Haruku Island (Moluccas, Indonesia) were tape recorded. The recorded vocalisations are associated with aggressive interactions between two or more birds. Spectral analysis of these so called ‘kek’ calls show that spectrograms consist of a harmonic pattern with increased intensity at frequencies higher than the fundamental frequency. From that phenomenon it can be concluded that the spectrogram does not give a full representation of the bird’s vocalisation, but only shows the harmonic pattern of the ‘pulse repetition frequency’ (PRF = number of pulses produced per second). It appears that the ‘kek’ call of *Eulipoa wallacei* consists of a series of pulses, of which each pulse has a fundamental frequency between 2 and 2.5 kHz and a pulse duration between 2.1 and 2.3 milliseconds. The duration of the pulse series itself (one ‘kek’) is highly variable between 40 and 210 ms and the pulse repetition rate within a ‘kek’ varies between 300 and 650 pulses/second. In general the pulse repetition pattern is rather symmetrical in time, but irregular patterns are also possible. The repetition rate of the individual ‘kek’s might reflect the state of aggression: the higher the rate the higher the state of aggression. Three types of ‘kek’ calls can be distinguished (1) short lasting kek’s (< 100 ms), produced in bursts with short interval times and a rather symmetrical spectrum; (2) long lasting kek’s (≥ 200 ms), individually produced and consisting of a rather steady frequency; (3) a mixture of both with usually a rather symmetrical frequency spectrum and a duration between 100 and 200 ms. The fact that ‘kek’ vocalisations of *Eulipoa* consist of pulse series, instead of (continuous) sinusoidal signals, is an interesting phenomenon that has not yet been described earlier in studies on avian vocalisations.

Keywords: Megapodes, Megapodiidae, *Eulipoa wallacei*, vocalisation, spectral analysis, spectrogram.

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INTRODUCTION

All species of the avian family Megapodiidae (megapodes or brush-turkeys) produce typical galliform-like sounds including ‘clucks’, ‘squawsk’, ‘gulps’ and ‘grunts’ (Jones *et al.* 1995). These are often described as contact calls. Other vocalisations, given by some species, are very loud raucous and repetitive calls

(called ‘crowning’) that may be heard over considerable distances (Jones *et al.* 1995).

The Moluccan megapode *Eulipoa wallacei* (GRAY, 1861) is also a vocal bird. Wallace (1869) described the vocalisations of this species as ‘loud wailing cries’, and De Wiljes-Hissink (1953) called it ‘noisy crowing (at the beach)’, but a recent study (Heij *et al.* 1997)

could not confirm the occurrence of 'crowing' in *Eulipoa*. The 'crowing and crying' heard by those early researchers was most likely produced by the sympatric *Megapodus forstenii* or *M. freycinet* (Heij *et al.* 1997). In fact, the only known (and tape-recorded) vocalisations of *Eulipoa* are those uttered during nightly activities at communal nesting grounds when the birds dig tunnel-shaped burrows to lay their eggs.

Jones *et al.* (1995) described tape recordings made at night at the nesting ground as "irregular, rapid series of sharp, nasal 'kèp' 'kèp' or 'kèw' 'kèw' and 'ki-ouw kouw', 'kou - kouw - kouw - kouw' or 'kuk - kuk-uk (uk)' sounds, likely to be produced during agonistic interactions over nesting burrows". Heij *et al.* (1997) stated that *Eulipoa* is a noisy bird during nightly egg-laying activities: they almost con-

stantly utter sharp 'kek-kek-kek', 'kew-kew-kew' or 'kuk-kuk-kuk' calls; the same calls are produced by (groups of) birds that reside in the forest surrounding the nesting grounds during the day. Heij *et al.* (1997) also noted a grumbling sound 'grgrgrgrgrgr' at a low frequency that was produced by birds at night at the nesting ground, but this was only audible by the human ear from a distance of less than c. 4 m. All these vocalisations are produced by females, as males of the Moluccan megapode do not visit the nesting grounds (Heij *et al.* 1997).

The 'kek' calls of *Eulipoa wallacei* are clearly associated with aggressive behaviour. While observing female birds searching for suitable spots to dig burrows and during digging activities on the relatively small nesting grounds, Heij noticed that aggression between

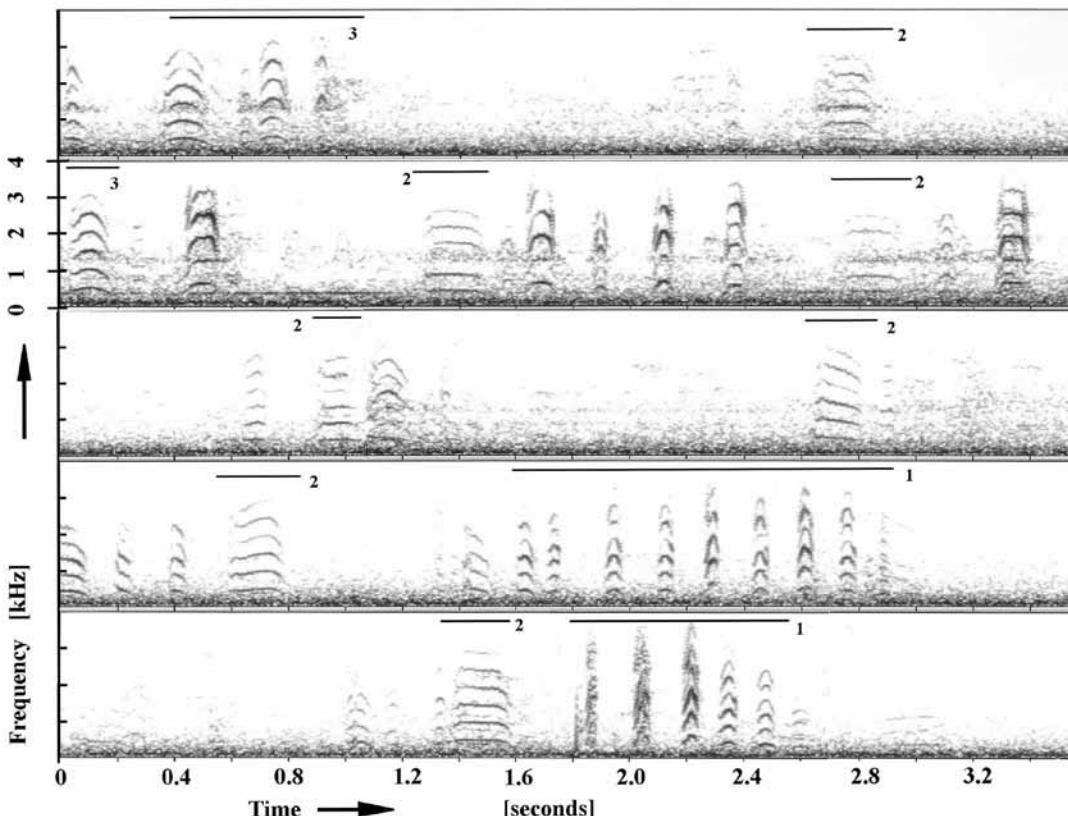


Figure 1 Spectrogram of 'kek'-vocalisations of *Eulipoa wallacei* based on recordings made in 1994 and 1995 at the Tanjung Maleo nesting grounds, Kailolo Village, Haruku Island (Moluccas, Indonesia). Five recordings of 3.55 s duration each are shown. Three types of vocalisations can be distinguished, indicated by horizontal lines **1**, **2** and **3**.

Figure 2 Another spectrogram of 'kek'-vocalisations of *Eulipoa wallacei*. For comparison the time scale (5.85 s) is equal to that of the spectrograms in Jones *et al.* (1995).

individuals increased with the numbers of digging megapodes. Females are always vocal at the nesting ground, but when the distance between two or more birds becomes less than 50 cm, birds get more aggressive and cackle at a higher repetition rate ('kek-kek-kek-kek ...etc.'). Moluccan megapodes apparently do not tolerate each other in close vicinity on the relatively small nesting grounds. Occasionally,

real fights occur: birds use their wings and feet to chase their competitors off, making even more noise (Heij *et al.* 1997).

The same 'kek' calls that were heard by Heij in daytime in the forests surrounding the nesting grounds, indicate that this type of vocalisation may also function as a contact call (see also: Heij *et al.* 1997).

With regard to the vocalisations of mega-

Figure 3 Call duration of 54 'kek's, divided into steps of 10 ms duration. Fifteen calls have a duration between 50 and 70 ms.



Figure 4 Spectrogram of four 'kek'-vocalisations of *Eulipoa wallacei*, showing a pattern of harmonics with an increased intensity between 2 and 2.5 kHz. Such a type of pattern indicates that the repetition rate of a pulsed signal is depicted and not the fundamental frequency of the vocalisation itself. The figure also shows the time/amplitude display of the four calls (two other 'kek's at the end are hardly visible). Especially from the smaller calls it can be concluded that this type of vocalisation in fact consists of a 'burst' of pulses - see the time detail (arrow). The duration of each 'kek' is approximately 55 ms.

podes, Jones *et al.* (1995) give spectrograms of 13 species, all presented in a standard format together with an oscillogram showing the corresponding sound intensity (time/amplitude display). These 13 spectrograms form the only known comparable and quantifiable data on

megapode vocalisations.

Here we present the first sonograms of the calls of *Eulipoa wallacei* and a spectral analysis of the vocalisations produced during egg-laying activities.

METHODS AND MATERIAL

During field observations of the nightly egg-laying behaviour of the Moluccan megapode on the communal nesting ground Tandjung Maleo near Kailolo village on the island of Haruku, Moluccas, Indonesia, the first author tape recorded the vocalisations produced by the megapodes. See Heij (1995, 2001) and Heij *et al.* (1997) for a detailed outline of the study area and the biology of the species.

These recordings were made in 1994 and 1995 with a National mini-cassette recorder RQ-350 or a Sanyo cassette recorder M2541 Z, fitted with a Sony Electric Condenser Microphone ECM-PB IC with parabolic reflector. Spectral analyses of the recordings were carried out by the second author in the laboratory of TNO TPD (Delft, The Netherlands), using computerised narrow-band systems, with Fast Fourier Transform (FFT) software such as Cool Edit Pro (Syntrillium Software Corp.) and Avisoft-SASLab Light (R. Specht, Germany). Understanding spectrograms is rather difficult but after consulting Slater & Seller (2000), the theory and practice becomes much clearer, even for the field-ornithologist.

In this study 54 'kek' vocalisations were analysed by determining the duration and frequency content.

RESULTS

Figure 1 shows a spectrogram of a series of 'kek'-calls of *Eulipoa wallacei*, in which five recordings of 3.55 s duration are depicted. The vertical axis (of each recording) has a linear range of 0-4 kHz. The figure gives an impression of the variety in 'kek'-calls. Roughly the following three call types can be distinguished: (1) short lasting 'kek's, produced in bursts with short interval times and a rather symmetrical spectrum - duration less than 100 ms; (2) long lasting 'kek's, individually produced and consisting of a rather steady frequency - duration around 200 ms or more; (3) a mixture of both with usually a rather symmetrical frequency spectrum and a duration between 100 and 200 ms. In Figure 1 these call types are indicated by horizontal lines accompanied by 1, 2 or 3.

Figure 2 also shows a spectrogram and the corresponding time/amplitude display of a series of 'kek'-vocalisations. For comparison, the time scale in this figure is equal to the time scale used in Jones *et al.* (1995), namely 5.85 s. Again, the large variety in spectra is striking.

The duration of each of the 54 'kek's' appeared to be between 41 and 210 ms. Figure 3 gives a review of the call duration occurrence, divided into steps of 10 ms.

Figure 4 depicts a spectrogram with four 'kek'-calls and the corresponding time/amplitude display, including a time detail of a part of the third 'kek'. The first two calls are very loud, followed by two weaker calls with decaying amplitudes. This decreasing sound intensity will be due to the directivity of the bird's voice; the bird turned its head away from the microphone location during recording. Duration of each 'kek' is between 50 and 60 ms. The time/amplitude detail (duration

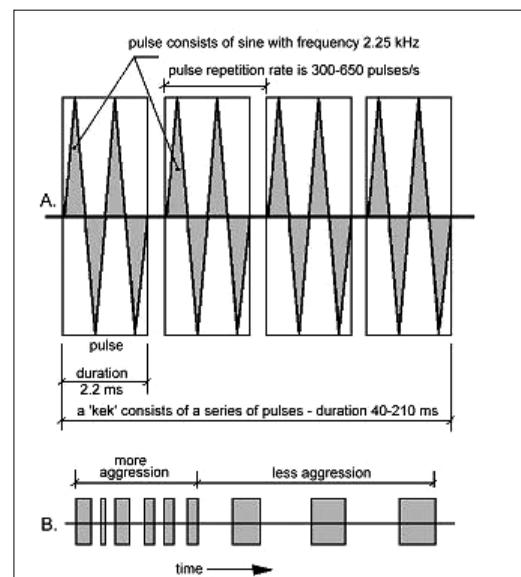


Figure 5. Schematic explanation of a 'kek'-call structure. (A) Structure of one 'kek': duration of one 'kek' is between 40 and 210 ms; a 'kek' consists of a number of pulses, repeated at a rate of 300-650 pulses/s; each pulse consists of a sine wave with a frequency between 2 and 2.5 kHz. (B) Structure of a series of 'kek's: the repetition rate of individual 'kek's, referring to the bird's behaviour, might represent the state of aggression; the higher the repetition rate, the higher the aggression and the shorter the duration of the 'kek'.

0.03 s) shows an interesting phenomenon: a repeating pattern of quite identical pulses, almost touching each other. Duration of each pulse is approximately 2.3 ms with a pulse frequency of roughly 2.3 kHz. Furthermore it appears that the spectrogram shows a pattern of harmonic frequencies in which the frequency components in the range between 2 and 2.5 kHz are highlighted (have a higher intensity than that of the lower frequencies). Such a phenomenon is only possible when the call consists of a series of pulses (instead of what might have been expected, a continuous sine wave). The time detail of Figure 4 shows these pulses.

CONCLUSIONS AND DISCUSSION

From the fact that *Eulipoa* spectrograms show a harmonic pattern with an increased intensity at frequencies higher than the fundamental frequency, it can be concluded that these spectrograms do not give a full representation of the bird's vocalisation, but only show the harmonic pattern of the 'pulse repetition frequency' (PRF = number of pulses produced per second). Consequently, 'kek'-calls, produced by *Eulipoa*, consist of pulses with a pulse frequency of around 2.25 kHz and a pulse duration of around 2.2 ms. During a 'kek', these pulses are repeated at a varying repetition rate and it is this PRF pattern that can be seen in the spectrogram. Figure 5 explains the structure of the 'kek's. PRF harmonics between 2 and 2.5 kHz are highlighted in the spectrogram because in that range these harmonics coincide with the fundamental pulse frequency. Such a phenomenon also occurs in dolphin vocalisations and is explained in Verboom & Kastelein (1995).

Usually kek's are repeated a number of

times. In Figure 1 this number varies between one, for the long-duration calls (2) till nine for the short calls (1). It is rather obvious that, when the repetition rate of individual 'kek's becomes higher, the duration of each 'kek' becomes shorter, because the bird has a certain amount of energy available for the production of a call series. The variation in calls is large, but seems to be without any obvious correlation to, for instance, duration. Most PRF patterns are rather 'symmetrical'; they start and end at roughly the same frequency and show a maximum frequency somewhere in between. Start and end PRFs are roughly between 300 and 600 Hz, maximum PRFs are between 350 and 650 Hz. As an example Figure 6 depicts the spectrum of five calls (taken at random) varying in duration from 50 - 200 ms; Table 1 gives frequency information of these calls.

In summary, it can be concluded that the 'kek'-call of *Eulipoa* consists of a series of pulses with a pulse frequency between 2-2.5 kHz and a pulse duration of 2.1-2.3 ms each. The duration of the pulse series is highly variable between 40-210 ms and the pulse repetition rate in each 'kek' varies between 300-650 pulses/s. Also the time interval between pulse series varies and might express the bird's state of aggression. In general the pulse repetition pattern is rather symmetrical in time, but irregular patterns are also possible.

An interesting conclusion from the spectral analysis is that the 'kek' vocalisations of *Eulipoa* consist of pulse series, instead of (continuous) sinusoidal signals. This means that their sound generating principle is identical to that of for instance harbour porpoise *Phocoena phocoena* and white-beaked dolphin *Lagenorhynchus albirostris*, although the actual mechanism that produces the sound

Table 1 Frequencies and duration of five 'kek' calls of *Eulipoa wallacei*.

	call 1	call 2	call 3	call 4	call 5
call duration	50 ms	80 ms	200 ms	120 ms	140 ms
starting frequency	310 Hz	600 Hz	400 Hz	530 Hz	420 Hz
centre/highest frequency	410 Hz	650 Hz	358 Hz	635 Hz	515 Hz
end frequency	340 Hz	600 Hz	320 Hz	560 Hz	350 Hz

Figure 6 Example of the Pulse Repetition Frequency (PRT) of five 'kek' calls, taken at random.

- the sound generator - must be very different. Whether all vocalisations of *Eulipoa* have a pulsed origin has not been investigated. To the best of our knowledge, this 'pulse phenomenon' has not yet been described in studies on avian vocalisations.

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