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Short Communication

Uninterrupted vocalization during inspiration and expiration in the striped possum *Dactylopsila trivirgata* (Marsupialia, Petauridae)

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The vast majority of the calls of mammals is exclusively produced during expiration. Only for some species calls have been described, which are emitted during both phases of respiration. Regarding their structure these calls represent sequences of practically unlimited duration consisting of rhythmically organized pulses. The production mechanism of such calls differs from usual phonation as self-supporting oscillations of the vocal folds are not involved (Frazer Sissom et al 1991). The purring of some felids, including the domestic cat (*Felis catus*), the puma (*Puma concolor*) and the cheetah (*Acinonyx jubatus*), belongs to such calls (Peters 1981; Frazer Sissom et al 1991; Volodina 2000). There is some evidence that certain civets and genettes are capable of producing similar calls (Wemmer 1977). We identified a species of marsupials, the striped possum (*Dactylopsila trivirgata*) that is also capable of emitting uninterrupted (continuous) sequences of pulsed calls during both phases of respiration, i.e. during inspiration and expiration.

Recordings of the calls of male and female striped possums were made from June 1-June 9, 2000, in an enclosure of 4.5 x 1.2 x 1.8 m in the exposition ‚Nocturnal World' of Moscow Zoo (for a detailed description of the enclosures see Popov & Ilchenko 1996). Each striped possum was housed in a wooden shelter attached to the back wall of the enclosure. Recordings of the calls and corresponding behaviour were carried out while the animals were active, mostly starting after the feeding of the animals and when the light regime switched from the diurnal to the nocturnal mode.

For recording the behaviour, a camcorder Panasonic RX-10 was used. Calls were recorded on a tape recorder Reporter 5P with a dynamic microphone Tesla AMD-

411N that was attached to the wire mesh roof of the enclosure. Spectrographic analysis with a sampling rate of 11 and 22 kHz was made by means of Avisoft SASLab Pro, version 3.4e (© R. Specht). For creating a spectrogram we used a Hamming window, Fast Fourier Transformation 512 and a bandwidth of 223 Hz. In total, 168 calls were analysed.

The striped possums emitted calls during conflict interactions. The animals started to call as a consequence of the arousal provoked by appearance of their cage mate. Probably, the vocalizations represented a distant threat, as one of the partners usually left the disputed part of the enclosure and retreated to its own shelter after a mutual exchange of calls. Direct aggressive encounters were very rare and were accompanied by the same type of calls, although of much higher intensity (Ilchenko et al 2000). We could not reliably distinguish between the calls of males and females. Therefore, the description was made on a pooled sample of the calls of both sexes.

While emitting calls the striped possums opened the mouth widely and pronounced contractions of thoracic and abdominal muscles were well noticeable at the switches from inspiration to expiration. At the onset of expiration a compression of the thorax occurred that was followed by a sharp inward movement of the abdominal wall. At inspiration the indrawn abdominal wall re-expanded and was followed by a volume increase of the thorax. Frame-by-frame analysis of the video recordings, which had been made simultaneously with the acoustic recordings, allowed us to determine a correlation between the respiratory phases and sound production.

Caption of **Fig. 1**

The dynamics of the inward and outward movements of the abdominal wall of a striped possum during emission of an uninterrupted pulsed call (1), the waveform (2), and the spectrogram (3) are presented for a period of three respiratory cycles. Phases of inspiration and expiration are labelled. Top left shows the threatening posture of a striped possum during vocalization (re-drawn after Ilchenko et al 2000).

In each call the phases of inspiration and expiration could be readily distinguished. Duration of the inspiration phase was 348 ± 5.5 ms (n = 188) and that of the expiration phase was 200.7 ± 4.0 ms (n = 196). Although the duration of both phases varied strongly and broadly overlapped (inspiration: 174 – 772 ms; expiration: 86-520 ms), the expiratory phase was always shorter than the following inspiratory phase

(Wilcoxon test, T = 0, $p < 0.001$, n = 115 pairwise comparisons). In addition, a small but significant correlation was observed between coupled phases of respiration (test of parametrical correlation, r = 0.19, $p < 0.05$, n = 115). At the moment of switching from one respiratory phase to the other, sometimes a short intercalated period without pulses (lasting 10 – 25 ms) occurred. These non-pulse periods also contained acoustic energy but at a very low level (amplitude). Calls of the striped possum started with equal probability either from the expiration or from the inspiration phase (56 % and 44%, respectively, n = 50). However, the calls ended much more frequently with an expiration phase than with an inspiration phase (81% and 19%, respectively, n = 42).The duration of the pulse periods in both respiratory phases was irregular and varied between 7 and 157 ms in the inspiration phase (15.09 ± 0.35 ms on average, n = 434) and between 4 and 14 ms in the expiration phase (7.02 ± 0.09 ms on average, n = 337). The differences were significant (Mann-Whitney U-test: U = 4158.5, $p < 0.001$). Pulse periods during inspiration tended to considerably higher variation than during expiration (variation coefficients: 48.0% and 22.9%, respectively – Fig. 2). Usually, the longest pulse period in both respiratory phases occurred at the beginning and at the end of a call but not in its intermediate part.

The bulk of acoustic energy of the calls was concentrated in a narrow range between 2.0 and 3.5 kHz. The overall frequency range extended up to 6.5 kHz. Call intensity could vary considerably. Probably, a high amount of intensity modulation related to the actual level of arousal of the calling animal but was also influenced by the change of respiratory phases. In high intensity calls inspirations usually contained a higher amount of acoustic energy than expirations. In contrast, low intensity calls revealed a reverse relationship. Interestingly, a peculiar modulation of the intensity occurred in the expiration phase: at the beginning and at the end of it the acoustic energy considerably exceeded that in the middle part (Fig. 2).

Similar pulsed calls have been described in some other marsupials: the Tasmanian devil (*Sarcophilus harrisii*) and in species of the genera *Dasyuroides* and *Antechinus* (Eisenberg et al 1975). Similar calls are also produced by a small flying marsupial (*Petaurus breviceps* – our unpublished data). As in the striped possums these calls are emitted by both males and females in an aggressive context. However, to our knowledge there is no published evidence regarding the emission of these calls, apparently widespread among marsupials, during both phases of respiration.

Caption of **Fig. 2**

Waveform (1) and spectrogram (2) of the end of an inspiration phase and the following expiration phase of a pulsed call of the striped possum. Note the irregularity of the pulse period during the inspiration phase, the short intermediate phase, and the peculiar modulation of the call intensity during the expiration phase.

The pulsed calls of the striped possums share some features with the purring of felids but differ from it in others. So, in the striped possum and in the domestic cats the pulse period during expiration is shorter than during inspiration and at the switch from one respiratory phase to the next a short intermediate phase of minimal acoustic energy is observed (Frazer Sissom et al 1991). On the other hand, compared to the calls of the striped possums, felid purring is always of low intensity and exhibits only very weakly expressed amplitude modulations. In addition, the pulse period is considerably more regular (constant) in felid purring. For example, the variation coefficient of the pulse period in cheetah purring is 10.1 % (Volodina 2000), whereas in the striped possum it exceeds 22%. Felid purring exclusively occurs in a context of relaxed comfort behaviour, whereas in the striped possums it forms part of an aggressive behavioural complex (Peters 1981, 1984; Volodina 2000). Apart from that felids produce their purring without visible physical effort. In contrast, the pulse calls of striped possums are produced with easily observable, pronounced contractions of thoracic and abdominal body muscles. Therefore, felids are capable of purring for prolonged, practically unlimited time periods without becoming tired, whereas in striped possums the duration of uninterrupted calling is limited by the need for recovery after the intense physical activity that is necessary for call production.

In summary, our data confirm that a further group of mammals is capable of producing long pulsed calls during both phases of respiration. Unfortunately, at present anatomical or other relevant data (laryngoscopic, X-ray) are lacking, which would allow consideration of the production mechanism of such calls in marsupials. However, the irregularity of the pulses, which is well visible in the spectrograms, might indicate a less developed ability of controlling this type of vocalization in marsupials compared to felids.

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References