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Short communication

Vocal repertoire of the black rhino *Diceros bicornis* ssp. and possibilities of individual identification

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Rhinos are among the most threatened species in the world. Zoo populations form a reserve to enable re-introductions into the wild. This requires successful reproduction in captivity. Many factors have been discussed to explain the lack of breeding success, e. g. sub-optimal management of reproductive animals, physiological reasons. Knowledge of rhino communication could contribute valuable data for an understanding of their behaviour and hence lead to an optimisation of their management. LAURIE (1997) described twelve calls in the Indian rhino and OWEN-SMITH (1973) ten in the white rhino. However, there is no detailed quantitative study on the vocalisations of any of the rhino species and to our knowledge none on the vocalisations of the black rhino. This study has the aim to described the vocalisations of the black rhino, in their behavioural context in captivity. Acoustic signals have the potential to be used for vocal tagging. This has been demonstrated mainly in various avian species (SAUNDERS et al. 1988) and in a few mammalian species (SNOWDON et al. 1980; RENDALL et al. 1996). To date, re-introduced individuals have had to be monitored by costly and invasive means such as radio tagging from helicopters (BÖER et al. 1999). Moreover, immobilisation of rhinos for placing the radio collars has been discussed in terms of its negative impact on the fertility of female rhinos (ALIBHAI et al. 2001). Here, we analyse vocalisations of the black rhino for the possibility of individual identification and discuss whether monitoring of rhinos in the wild by vocal tagging is possible. Low-frequency vocalisations would be best suited for monitoring, since, owing to their physical properties, they suffer little from attenuation. MUGGENTHALER et al. (1993) reported that four rhino species (black rhino, white rhino, Indian rhino, Sumatran rhino) produce infrasound signals. We therefore used recording equipment that allowed the recording of infrasound signals.

The following zoos were visited for the present investigations: Zoo Frankfurt with 1.1 *Diceros bicornis minor*, Dvur Kralove with 4.8 *Diceros bicornis michaeli* of which 1.1 were juveniles, Zoo Berlin with 2.7 *Diceros bicornis michaeli*. Recordings were performed with a Sony DAT recorder TCD D100 and a Sennheiser microphone KE4-211-2 (modified by Sennheiser), both also sensitive to infrasound signals. Using the longplay modus in the Sony DAT-recorder extended the frequency range down to 14 Hz. Recordings were analysed using the Software Avisoft (R. SPECHT, Berlin) and Sound Analysis (TCHERNICHOVSKI et al.

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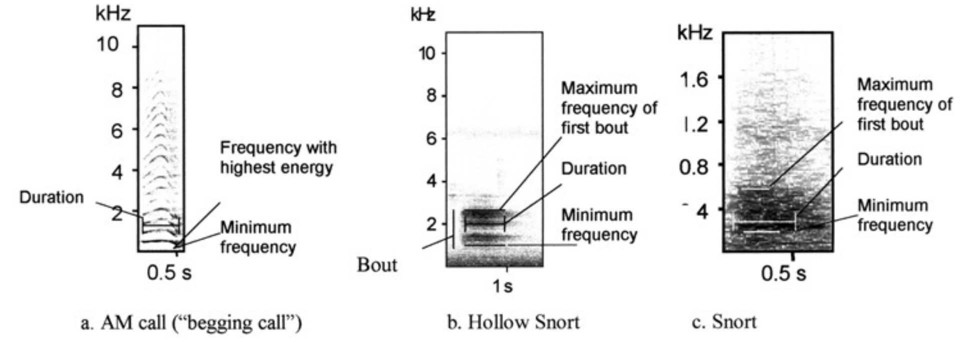

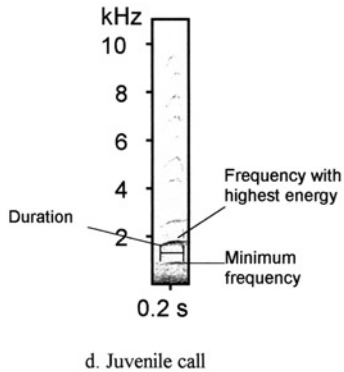

Fig. 1. Sonograms of the most frequent calls of an adult and a juvenile black rhino and the parameters measured. Frequencies are given in kHz, time in seconds (s).

2000). The following parameters were measured in all harmonic calls: duration, minimum frequency, frequency with the highest energy (Fig. 1). In modulated vocalisations the average of the fundamental was measured. The frequencies with the highest energy were measured with the help of an amplitude spectrum averaged over the total length of the call. In non-harmonic calls the following parameters were measured: duration, maximum frequency of the first bout, minimum frequency of the first bout (Fig. 1). Calls had up to 4 bouts, which were, however, not considered since most graded too rapidly into the background. When the minimum/maximum frequency of the first bout could not be clearly determined with the help of the sonagram they were measured in an amplitude spectrum as the first/last frequency above/under the background noise, which showed a clearly distinctive peak. If no frequency could be identified in the amplitude spectrum, the respective parameter was omitted, thus only frequencies that did not grade into the background noise were considered. Since some parameters could not be measured in all calls, the sample size varies between different parameters. The measurements were taken from the sonagrams computed with a sampling rate of 22 050 Hz, FFT-length 1024, frame 100%, frequency resolution 21 Hz, overlap of 87.5%, time resolution, 8 ms, and rectangular window. Only the call shown in figure 1 c is presented with a sampling rate of 4 000 Hz for better representation. For investigation of infrasound calls a sampling rate of 4 000 Hz was chosen, which resulted in a frequency resolution of 3 Hz and a time resolution of 32 ms. Infrasound was defined as calls with energy below 20 Hz. Behavioural data were recorded on a dictaphone while recording vocalisations. Each individual was recorded and observed

Table 1. Calls of adult black rhinos, their behavioural context and physical parameters. In all calls n is the number of calls analysed. The number of individuals is given with N.

Call	Begging call	Hollow snort	Snort	Aggressive Snort	Growl
Acoustic Parameters	N = 8 Mean duration: 0.36 ± 0.2 s, n = 637 Mean minimum frequency: 497.3 ± 159.5 Hz, n = 603 Mean frequency with highest energy: 1 054.11 ± 1 058.7 Hz, n = 600	N = 5 Mean duration: 0.76 ± 0.3 s, n = 28 Mean minimum frequency of first bout: 657.34 ± 346.7 Hz, n = 23 Mean frequency end of first bout: 1 108.2 ± 481.2 Hz, n = 25	N = 13 Mean duration: 0.73 ± 0.3 s, n = 100 Mean minimum frequency of first bout: 198.34 ± 149.2 Hz, n = 97 Mean frequency end of first bout : 733.53 ± 1 579.5 Hz, n = 95	N = 1 Duration: 0.33 ± 0.1 s, n = 12 Frequency end of first bout: 1 532.53 ± 106.8 Hz, n = 15	N = 1 Duration: 0.73 s, n = 1 Minimum frequency: 23 Hz
Behavioural context	Before feeding especially when hearing keepers; trying to get food from adjacent enclosure; „asking" to be petted; time approached to be let out into the outdoor enclosures.	Standing still; ears erect; no action would follow.	No obvious behaviour accompanied this vocalisation. It was given when feeding, walking, or standing still. No reaction of other rhinos could be observed following this vocalisation.	Before attacking; head held down.	Head held down; no attack followed

Table 2. Calls of juvenile Black Rhinos, their behavioural context and physical parameters. In all calls n is the number of calls analysed and N the number of individuals.

Call	Begging call, Juvenile 10 days old	Begging call, Juvenile 1 year old
Acoustic Parameters	N = 1 Mean Duration: 0.31 s, n = 11 Mean minimum frequency: 1 137 Hz, n = 12 Mean frequency with the highest energy: 1 270.9 Hz, n = 10	N = 1 Mean duration: 0.37 s, n = 66 Mean minimum frequency: 1 012.28 Hz, n = 61 No single frequency with highest energy was determinable since at least two frequencies had the same energy maximum
Behavioural Context	Before nursing, "asking" to be petted, the juvenile could follow the mother when calling or not.	Before nursing, "asking" to be petted, the juvenile could follow the mother when calling or not.

for two hours before switching to the next focus animal.

To test whether individual identification of black rhinos by vocal means is possible, an ANOVA was calculated first which yielded significant differences for all parameters listed below (P < 0,0001). To compare all parameters of all individuals at the same time a discriminant analysis was run using data obtained from the most frequent call, the begging call. The following parameters were included: duration, minimum frequency, frequency with the highest energy, pitch, frequency modulation, Wiener entropy and spectral continuity. The first three parameters are described above. The last four parameters can be calculated using the software Sound Analysis and are defined as follows (for a detailed description of the parameters and their definition, see TCHERNICHOVSKI et al. 2000):

Wiener entropy is a measure of randomness depending on the distribution of frequencies in the power spectrum. It is unitless and measured on a logarithmic scale from 0 to minus infinity. The purer a tone, the larger is its negative value. Frequency modulation is determined from the angle of the directional derivatives of frequency over time. Spectral continuity measures the continuity of frequency contours across the time window.

During a total of 308 hours of observation 5 different vocalisations could be recorded in the adult rhinos: one harmonic call and four non-harmonic calls (Fig. 1, Tab. 1). Begging call: This harmonic call is amplitude modulated. It was the only loud call that could be recorded and the most frequent vocalisation as it was given in series of continuous calls up to 1 hour. Yet, 13 adult individuals out of a total of 21 never gave this call. The two juveniles that were recorded produced a harmonic call similar to the adults (Fig. 1, Tab. 2). Snorts: These vocalisations are not harmonic. Three types of snorts differing in duration and/or frequency spectrum could be recorded:

Snort: more than 50% of all individuals observed performed snorts. It was not linked to any specific behaviour.

Hollow snort: it has a higher minimum frequency than the snort and was given when the rhino was listening attentively.

Aggressive snort: it was much shorter than the two other snorts and had the highest minimum frequency of all three snorts. It was given in aggressive situations. Growl: this vocalisation could be recorded only once. It was given in an aggressive situation, the head was held down, but no attack followed. Its minimum frequency extended almost down to the infrasound range.

There was no evidence for calls that had energy only or predominantly in the infrasound range. However, it cannot be excluded that scattered rhinos in their natural habitat may use infrasound for finding mates or other purposes. Elephants use infrasound vocalisations mainly for group co-

hesion and finding mates (POOLE et al. 1988). These are situations that do not arise in zoo environments in which only a limited range of behavioural contexts were provided in the observation period (e.g., no courtship, mating or fighting were observed).
To test if individuals can be identified by their calls, a stepwise discriminant analysis was run on the begging call data including all parameters measured (minimum frequency, frequency with the highest energy, duration, pitch, Wiener entropy, spectral continuity, frequency modulation). The begging call was the only call considered suitable, as it was the only call recorded in a large enough sample size and it is probably loud enough to allow vocal tagging. The overall discrimination rate was 61.3%, i.e. 61.3% of the tested vocalisations were correctly assigned to the corresponding individual. Table 3 shows the results for the first four discriminant functions, which explained already 97.7% of the variance. The first standardized discriminating function, which separated 63.2% of the data, includes –0.197 Continuity, –0.016 Duration, –0.27 Entropy, +0.08 Frequency Modulation, +0.71 frequency with highest energy, +0.72 minimum frequency. The relative magnitude of the coefficients in this equation determines how the independent variables are being used to discriminate among the groups. Thus, the parameters "frequency with highest energy" and "minimum frequency" contributed the most to the discrimination among individuals. A stepwise discriminant analysis showed that the remaining parameters contributed in the following order to the discrimination: frequency modulation, duration, entropy and continuity. Figure 2 shows the first two discriminant functions which allowed to assign correctly 79% of the individuals' begging calls. Some individuals had a very high identification rate (e.g. individual no. 5 with

Table 3. Discriminant functions

Discriminant Function	Eigen-value	Relative Percentage	Canonical Correlation
1	2.84	63.2	0.86
2	0.71	15.8	0.64
3	0.5	11.1	0.58
4	0.34	7.6	0.50

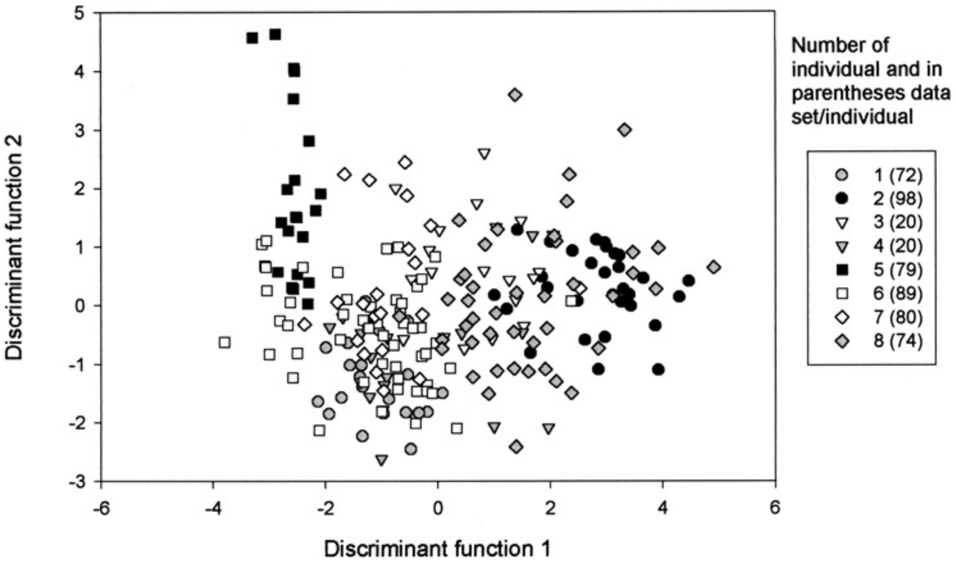

Fig. 2. Plot of discriminant functions 1 and 2 of the eight tested individuals. In parenthesis is the number of data sets included per individual.

100% correctly assigned calls). Some individuals, however, had very variable calls that could not be assigned with accuracy. For example, when omitting individual number 6 from the discriminant analysis the overall discrimination rate increased to 74.2%. Although the overall discrimination rate of 61.3% found when analysing the whole sample is significantly higher than would be expected by chance, we do not consider it high enough for general practicable use for vocal tagging. However, reintroduced rhinos or specific single individuals which are known to perform calls with a very low intra-individual variability could be monitored acoustically as it is to be expected that the begging call occurs not only in captive but also in wild rhinos. It is possible that wild rhinos use additional vocalisations – in the audible or infrasound range – some of which might prove more suitable for vocal tagging.

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