INFRASOUND FROM THE RHINOCEROTIDAE

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INTRODUCTION

A number of papers report studies of the auditory vocalizations of rhinoceros (e.g., Tembrock, 1963; Frame and Goddard, 1970; Spellmire, 1991). These note the existence of low frequency sounds in the animals' repertoire but none present data regarding vocalizations in the infrasonic range. This paper presents preliminary evidence that, in addition to auditory vocalizations, rhinoceroses also produce infrasounds.

METHODS AND MATERIALS

Recordings were made of rhinos during normal daily activity using a portable Bruel and Kjaer recording system and the recordings studied using a real time fast Fourier transform analysis.

Subjects

A total of 25 rhinoceroses, from four different species, were the subjects for this study. Recordings were attempted from eight female and three male Southern White rhinos (*Ceratotherium simum*) from the Virginia Zoological Park, and the Knoxville Zoo; three female and two male greater one-horned rhinos (*Rhinoceros unicornis*) at the National Zoo in Washington, D.C. and the San Diego Zoo; one male and two female Sumatran rhinoceroses (*Dicerorhinus sumatrensis*) at the Bronx and San Diego zoos, and two female and four male black rhinos (*Diceros bicornis*) at the Atlanta and San Diego zoos, and at the San Diego Wild Animal Park. Recordings of quality good enough for analysis were obtained from 16 of the animals, including representatives of all four species.

Apparatus

Recording equipment consisted of a Bruel and Kjaer tape recorder (type 7005), B&K power supply (ZG 0199), B&K preamplifier (type 2619), B&K condenser microphone (type 4133), and a B&K microphone power supply (2801). Video equipment consisted of an RCA camcorder and a Sony HI-8 video recorder.

Analyses were conducted using a Macintosh computer with real time spectrum and amplitude graphing software, and Bruel and Kjaer spectrum analyzer (type 2032).

Procedure

Recording procedures differed from session to session with the environment presented by different zoos. Generally, recording periods lasted from 20 minutes to two hours. Rhinos were recorded from distances of three feet to 30 feet, primarily while they were inside enclosures, with best results achieved when animals that were usually together in the enclosure had been brought back together after having been temporarily separated. As the animals were being recorded, the tape was marked and notes were taken about their activities during the specific recording periods. The tape counter served as a backup, so that during analysis, specific vocalizations could be easily located on the tape. The recording sessions were visually recorded by camcorder to counteract observer bias.

After each session of recording, the vocalizations on the tapes were filtered above 100 Hertz (Hz) and graphed on the Macintosh computer. The signals, that had been graphed on the computer, were run through the spectrum analyzer, using a real time fast Fourier transform (FFT) analysis. The markers on the tape, and the tape counter allowed for the same vocalizations to be graphed and analyzed repeatedly.

RESULTS AND DISCUSSION

In his review of the earlier literature on acoustical behavior of the black rhinoceros, Spellmire (1991) notes "as many as six different types of vocalization" and, from his preliminary studies, reports sex and age-specific call-behavior relationships. The sonograms he presents are all limited to auditory ranges; males having a fundamental frequency of 600 Hz with four to ten overtones and females being lower (fundamental frequency 320-340 Hz) typically with fewer than three overtones. Spellmire did not study the infrasonic range. The results presented here, we believe, provide the first evidence that rhinoceroses also call infrasonically.

Figure 1 represents typical results of the method by showing the real time spectral graph of the recording of "Rufus", an adult male white rhino at the Virginia Zoological Park in Norfolk, VA, and the associated FFT analysis. The animal was relaxed and greeting its mate, "Jesse" after a short separation. The analysis shows that the common frequencies range between 10 and 80 Hertz with spectral energies around 6, 14, 20-24, 30-38, 40-50, and 76-80 Hz. For this animal, there is an amplitude inflection at intervals of about 0.6-0.7 seconds. Another white male recorded under similar circumstances had amplitude inflections approximately every 0.2 seconds.

To discern whether the production of infrasonics is a common capability of other rhinoceroses, recordings were made of representative animals for each of the four species available in captivity. Because the animals reside in different locales the recording environments varied considerably but all subjects were females held in their common enclosures and in relaxed behavioral states.

Figure 2 presents the FFT analyses resulting from these studies. Clearly, all species produce infrasounds and all have accented ranges around 10 Hertz but few similarities in other parts of their pattern are obvious. For these recordings of these specific animals the white had spectral energies primarily between 6-16, 28-38 and 75-79 Hz, the black between 6-16, 21-28, and 32-50, the Indian had single spike accents at 18, 56 and 58, and the Sumatran had a display of spectral energies between 10 and 53 Hertz and between 76 and 96 Hz. Clearly, it is impossible, without studying many more subjects under a variety of controlled variable conditions, to determine whether the differences are species specific, individual variations, or reflect other still unmeasured external influences, behavioral tendencies and/or physiological states.

Many keepers have noted prevalent vocalizations when two or more rhinos are placed together, or in close visual proximity, particularly after temporary separation. Recordings made during these types of episodes reveal that, either coincidental with, or interspersed between, the auditory sounds, infrasounds are also being produced. A quality of interplay is not uncommon, which has characteristics of a dialogue as it alternates between the participants and displays parallelism and interruption.

Sounds below the level of human hearing are considered to be infrasonic, but it is difficult to define them accurately. The lower the pitch the greater the amplitude required for the human's detection so that heavier sound pressures are needed below 100 Hertz. Audiologists generally consider the lower limit to be between 16 and 20 Hz and even these may be detectable but only as vibrational sensations without distinct pitch. As all rhinos have part of their vocal range at or below 20 Hz, then rhinoceroses are producing infrasounds.

The expanding literature on animal communication presents examples of the use of infrasound. We make no attempt here to review this field but note that the research on elephants may be immediately relevant. Berg (1982) was the first to systematically analyze the vocalizations of African elephants. She discovered distinct patterns in the elephants' sound repertoire that could be attributed to specific behavioral contexts and some of the patterns overlapped into the infrasonic range. Payne, *et al.*, (1986) found that Asian elephants communicate both at sonic and infrasonic frequencies, the lower ranging from 14 to 24 Hz and being described as "rumbles". It was suggested that these rumbles may provide the signals for group coordinated movements when no other sounds are discernible. Poole, *et al.*, (1988) showed that African elephants also use low frequency calls, these in the range of 14-35 Hz, that are detectable at distances of several kilometers and serve for spatial coordination of family units. From a series of field studies in Africa, Payne (1989) concluded that much of the "uncanny synchronization of elephant behavior", conducted over long distances, was explainable by use of infrasound. Responses were identified over distances of up to 2.5 miles and playback of the recordings of the songs of estrous females consistently "called" males from over one mile away. She noted that elephants live in "a network of communication" based on these infrasounds.

The proximity of elephants to captive rhinos in many zoological parks complicates the recording process. Special care was taken to minimize interference from elephant infrasounds by recording rhinos inside of their building shelters. To gain some assurance that the rhino recordings were not being compromised, elephants in some of the same zoos were recorded and their patterns compared to those obtained from the rhinos. Comparison of the recording and analysis of an adult female African elephant housed in the enclosure adjacent to that of the rhino represented in Figure 1 shows that the elephant spectral graph is much more regular than the rhino and that both differences and similarities exist in different parts of the FFT analysis patterns. Both have accents below 10 Hz and others peaking at about 22 Hz. Beyond that there is a variable display of spectral energies at or exceeding 1 mV that differ between the two. The regions of similarity may constitute overlap interference and the differences may support the contention that rhinos' infrasonics are unique to them. However, absolute assurance of these statements is not easily achieved.

Important caveats govern the accuracy of data related to recording and analysis of infrasonic frequencies. Recognizing that infrasounds carry over long distances unimpeded by water or physical structures and can emanate from many sources, in addition to other animals, within the recording environment, eg. motors, pumps, automobile traffic, airplanes, trains, ship engines, wind tunnels, building resonance and especially air turbulence, make data recording within an urban setting suspect. Furthermore, during any recording session, both frequency and amplitude modification are taking place so that in a comparison of two different animals the signals may continually change their characteristic overlap or divergence, even within a short time. It must also be recognized that FFT as used here is a block transform and presents an analysis of signals received over an extended time frame. It portrays the range of frequencies and amplitudes collectively, and therefore can be used to discern the presence of infrasonics. What it cannot do is resolve time-varying spectral events. .For this, short term spectral analyses, conducted at 100-200 millisecond intervals, are needed to distinguish the time-varying aspects of this difficult class of signals. Future research from this laboratory will seek this type of spectral resolution.

Morton (1977) analyzed the auditory sounds made by a large number of birds and mammals (including rhinoceros) to hypothesize evolutionary convergence of animal sounds into specific contexts. He invoked a basic law of physics in noting a relationship between frequency and size of the vocalizing animal. "The larger the animal the lower the sound frequency it can produce" and that lower frequencies are more "harsh" because of the production of more harmonics. In this context it is not surprising therefore that rhinos, which, as a group, are the second largest of the land mammals, second to elephants, should be able to produce sound so low as to be in the infrasonic range and that their calls represent complex combinations of frequencies both sonic and infrasonic. This range gives their calls the capacity to be transmitted over long distances and for vocalizations that are highly diverse and therefore that render the animal potentially capable of having numerous sound-behavior associations. The "language" of rhinos holds promise of being both complex and sophisticated. Its interpretation will still require extensive studies of signal reception and translation, sound source, behavioral correlations, ear anatomy and auditory physiology.

CONCLUSIONS

All four captive species of rhinoceroses produce infrasounds. Typically these range between 10 and 75 Hertz. Infrasonics can be produced independently of any audible sound but they may also be components accompanying auditory vocalizations. We suggest that rhinoceroses, like elephants, may communicate at these low frequencies and that defined patterns may identify with particular behavioral events.

ACKNOWLEDGEMENT

The authors are grateful to Rhino Rescue, USA, The Eppley Foundation for Research, Inc., The Diane Baum St. Clair Fund and Old Dominion University for their support of this project, to officials of the Virginia Zoological Park, Zoo Atlanta, Bronx Zoo, San Diego Zoo and Wild Animal Park, National Zoo and Knoxville Zoo for use of their animals, and to Dr. Alan Zuckerwar for technical help and loan of the equipment.

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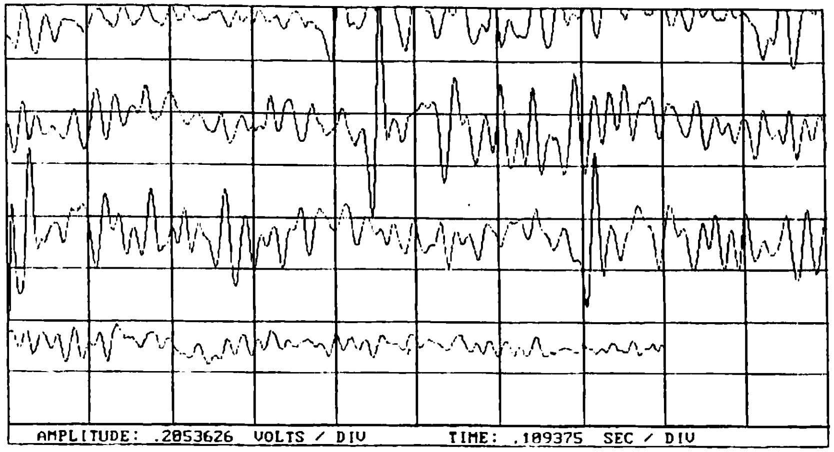
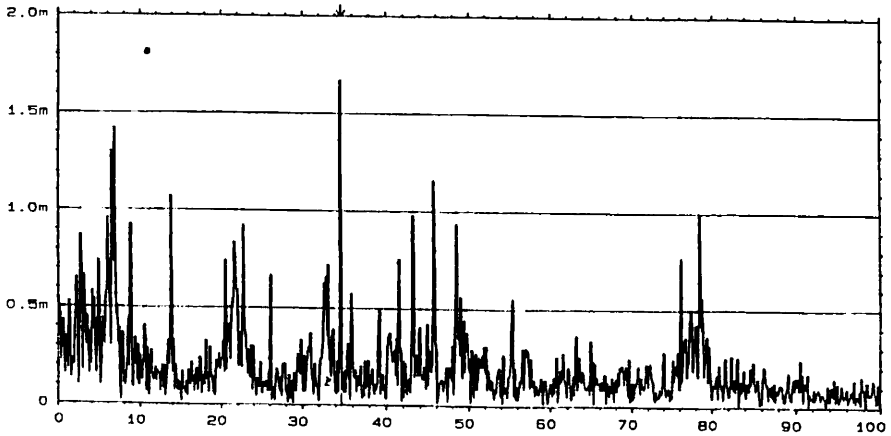
Figure 1

Infrasound Recording from a Male White Rhinoceros



A. Spectral Graph of a Four-Second Interval



B. Fourier Transform Analysis: X-Axis = Frequency (hertz);
Y-Axis = Amplitude (mV)

Figure 2

Fourier Transform Analysis of Female Rhinoceroses
of Four Different Species

A. White B. Black C. Indian D. Sumatran