Giraffe

Infrasound From the Giraffe

Go to Layman's version

Scientific Version

Invited to the Sept. 2001 American Zoological Association Conference, presented at the regional Acoustical.Society of America Conference 2001 **von Muggenthaler, E., Baes, C., Hill, D., Fulk, R., Lee, A., (1999) Infrasound and low frequency vocalizations from the giraffe; Helmholtz resonance in biology, Published in the proceedings of Riverbanks Consortium**

Abstract

The giraffe, a savanna ungulate, possessing limited auditory vocalizations, was found to produce infrasound. Recordings were made of 11 Giraffe (*Giraffe camelonardalis reticulata*), at the North Carolina Zoological Park in Asheboro, North Carolina and the Riverbanks Zoo and Botanical Garden in Columbia, South Carolina. A portable system (7 Hz – 22 kHz) was used to record the vocalizations. Analysis was conducted in real-time in the field using a portable trigger oscilloscope and National Instruments Polynesia. Real-time analysis consisted of Hamming FFT's and time domain displays. The signals were also analyzed in the lab using Polynesia and Momentum Data System's DSP Works. Each signal was low-pass/high pass filtered, and FFT's and spectrographs were performed. Audible signals contained frequencies from 11 Hz (75dB+/-3) to 10,500 Hz (80dB +/- 3) with dominant frequencies between 150-200 Hz. Inaudible vocalizations detectable by real-time analysis and trigger scope, measured from 14 Hz (60 dB +/-3) to 250-275 Hz (30dB +/-3) with dominant frequencies between 20-40 Hz. A behavior known as a neck throw appeared to be correlated with the signals, leading the researchers to theorize that Helmholtz resonance, ($V=c^2S/$

$(4\pi^2 Lf^2)$ was responsible for the production of the vocalizations. Additionally, the decibel levels of the inaudible signals decreased rapidly over 40 Hz, which suggests that the vocalization may be designed to be a covert form of communication. The hypothesis that giraffe, like okapi, elephant, whale, and rhinoceros produce infrasound, was supported.

I. Introduction

Within the last 12 years several large land mammals have been found to produce infrasound, including elephants, (Payne et al., 1986), rhinoceros, (von Muggenthaler et al., 1991), and okapi, (von Muggenthaler, 1992; Lindsey, Green, and Bennet, 1999). Other animals may also use infrasound, and low frequency vocalizations may be an important component of large animals' signals.

Payne et al. (1986) found that Asian elephants communicate both at sonic and infrasonic frequencies. The infrasonic signals ranged in frequency from 14 to 24 hertz with decibel ranges between 70 and 100 dB. African elephants also produce infrasound (Poole et al., 1988) in the range between 14-35 hertz with decibel levels up to 90 dB, and can perceive the calls of other elephants at distances up to 4 kilometers (Langbauer et al., 1991). Male African elephants have been shown to walk silently for more that 1.5 km toward a loudspeaker playing the female elephant's distinctive, low frequency estrous call (Langbauer et al., 1991).

The long wavelengths of infrasound mean that these low frequency signals are only reflected by very large objects. Therefore, there is little attenuation of infrasonic signals due to scattering by objects in the environment, making infrasound ideal for the long distant communication (Pye and Langbauer, 1998) of elephants.

Infrasound is useful for communicating in dense forest as well and for long-distance communication on the open savanna. Sounds above 1 kHz attenuate much more quickly in forest than would be expected by the inverse-square law (Eyring, 1946; Dneprovskaya et al., 1963). Low frequency sounds (below 100 Hz), however, show little excess attenuation in forest environments (e.g., Marten and Marler, 1977; Marten et al., 1977; Wiley and Richards, 1978). The okapi, a rainforest giraffid, produces infrasonic calls at around 14Hz that are likely used to maintain mother/infant contact (Lindsey et al., 1999). Okapi infants spend their days hidden in a nest while their mother browses in the forest.

Giraffes are found in the African savannah from the scrub and grasslands of the Sahara almost to Capetown, not including the Central African rain forest. Their range seems to be closely linked to the presence of acacias (Pellew, 1984). Giraffes inhabit large roaming areas, and those of giraffe cows can extend up to 43 square miles. Immature males tend to range even further than either the sexually mature bull or cows (Pellew, 1984). Roaming areas of individual giraffes overlap considerably, and loose congregations of several animals, particularly females, are common. These congregations, however, are often not stable and individual animals may leave the herd, and others join it. Giraffes appear to recognize each other "personally", and to be in visual contact with one another over large distances (Pellew, 1984).

The authors noticed two giraffe behaviors that are very similar to behaviors seen in okapi. Giraffes produce a behavior where the head and neck starts at about chest level, is thrown back over the body and curled upwards until the nose is straight up in the air. The behavior was termed a neck stretch. A similar behavior was also observed but involved only the head in which the chin is lowered and quickly raised so that the nose is pointing straight up into the air. This behavior was called a head throw.

The savanna habitat and wide-ranging, loose heard structure of giraffes is similar to that of African elephants. While giraffes have the advantage of height, and can see conspecifices over relatively long distances, vocal communication could also be useful for individuals to keep up with the locations and movements of other giraffes. Infrasound would be well suited to this type of communication much as it has been demonstrated to be for elephants. This and the demonstration of the use of infrasound by their closest relative, the okapi, suggests that giraffes may produce infrasonic signals.

II. Methods

A. Subjects and site

Eleven reticulated giraffe (*Giraffe camelonardalis reticulata*), two adult females, two adult males, a juvenile male and a yearling male and female, at the North Carolina Zoological Park in Asheboro North Carolina, and three adult females, one male, and one yearling were recorded at the Riverbanks Zoo and Botanical Gardens in Columbia South Carolina. The animals at both zoos were recorded inside their barns. At the North Carolina Zoological Park, the giraffe were recorded from the second floor of the enclosure, between 1 and 8 meters from the animals. At the Riverbanks Zoo, the animals were recorded from both the ground floor, and the second story at a distance of approximately 5 meters.

B. Recording protocol

Recordings were made for a total of 20 hours during daylight hours from June to November 1997 at the North Carolina Zoological Park. The three giraffe at the Riverbanks Zoo were recorded for 2 hours in January 1998, and then again for 5 hours in October 2000. Recordings were made in the barns at both facilities without the giraffe present, to determine the specific acoustical characteristics of each structure. All acoustical interference in the barns such as running water, or electrical fence generators, were marked and eliminated before the recording sessions. A Sony TCD-D8 Digital Audio Tape recorder (DAT), and several Statham Radio's LIZ microphones were used to record the signals. The Sony's frequency response at 48 kHz sampling rate tested with a Larson-Davis 2800 Precision Analyzer was +/- 3 dB from 7 Hz to 22 kHz and +/- 1 dB from 11 Hz to 20 kHz. The LIZ microphone

(1.5 Hz –22 kHz; 66.1 dB/(Hz)$^{1/2}$ @ 1P), is powered by an emitter/follower buffer and is housed in the AT8410A Audio Technica shock mount, which has an attenuation of 8 – 10 dB. An Audio Technica windscreen, with 10 – 20 dB attenuation is also used. The signals were monitored using a portable Techtronix Tekscope THS710 storage and trigger oscilloscope attached to the recorder. A portable computer running Polynesia, a real-time FFT and time domain analysis program, was also used. This equipment helped to determine when infrasound occurred, including sounds from manmade sources, such as airplanes. When manmade interference was noted, recording was halted until the signal disappeared. Records were also kept of the head throws and neck stretches that occurred during the recording session. The time readout on the DAT recorder was noted when each head throw or neck stretch occurred so that the behavior could be correlated to the presence or absence of an infrasonic vocalization. FFT's were performed when each head throw or neck stretch occurred, to determine if a signal had been produced.

1. Calibration

Calibration of the microphones is performed at Statham Radio every 6 months, using a Bruel and Kjaer 2608 measurement amplifier, a Bruel and Kjaer 4231 calibrator, an Audio Precision System 1, and an Electrovoice 1821 compression driver for measurements below 40 Hz. All Statham Radio calibration devices are certified by the manufacturers annually. Calibration of the recording system in the field to insure accurate levels during recording, analysis, and playback is performed using a Bruel and Kjaer 4226 multifunction acoustic calibrator. The 4226 generates accurate and stable signals ranging from 31.5 Hz to 16 kHz in octave steps.

C. Signal Analysis

Signals were analyzed using Momentum Data System's DSP Works, digital signal processing software, and National Instruments' Polynesia. DAT tapes were scanned and all signals marked using DSP Work's real-time spectrographic function, and Polynesia's real-time FFT and time domain functions. Signals were then isolated by Polynesia's Snapshot function. After being marked, the signals were transferred to computer hard drive. Full analysis was then run on signals that corresponded with neck stretches or head throws. Signals were analyzed by means of DSP's FFT functions. Additionally the signals were examined using Polynesia, and were lowpass filtered at 275 hertz. FFT's and spectrographs were again performed after the filtering process. Each infrasonic signal was made audible using Polynesia, and was then stored on Compact Disk as a wave file.

III. Results

The recordings contained 255 examples of vocalizations with fundamental frequencies around or below 20 hertz. There appeared to be two types of signals. Spectral analysis showed that 221 or 87% of the signals were between 14 Hz (at 60dB +/-3) to 250 Hz (at 30dB +/-

3) as shown in Fig. 1 and Fig. 2. The decibel levels of these signals decreased rapidly over 35-40 hertz and were not audible to the researchers. The second type of signal occurred 22 times or 9% of the total number of signals and were audible; 11 Hz (75dB +/- 3) to 11,200 Hz (89dB +/-3) as shown in Fig. 3 and Fig 4. Twelve signals or 4%, were removed from the results due to background interference. The lowest frequency, 11 Hz, came from a very large adult bull.Vocalizations accompanied 35 out of 37 neck stretches or 95% of the time. Vocalizations occurred 54 times out of 218 head throws, which is 25% of the time. No signals occurred without the neck stretch or head throw behavior. Vocalizations occurred more frequently in adult males and young females when giraffes were separated, although the adult females at North Carolina were unable to be recorded in the barn separated from sight of their offspring for safety reasons.

IV. Conclusions

This study has determined that giraffe emit vocalizations that are infrasonic. The mechanism for the production of infrasonic vocalizations by giraffe has not been examined. Further investigation of giraffe anatomy and how air is moved from the lungs, through the neck and out the sinuses will be necessary. One possibility is that since giraffe vocalizations have only been seen to occur during the head throw behavior, infrasound and other components of giraffe communication might result from large volumes of air being forced up the neck, and/or possibly channeled through hollow posterior sinuses.

During the study, observers noticed a "shiver" or vibration extending from the chest up the entire length of the trachea that occurred during some neck stretches that accompanied vocalizations. It is possible that this "shiver" is air movement, and could be responsible for the signal. If air is moving up the giraffe's neck is producing infrasound, the mechanism may be Helmholtz resonance, which occurs when an enclosed volume of air is coupled to the outside free air by means of an aperture. It is a system of one degree of freedom and is a very simple type of resonator system, (Kinsler and Frey, 1962.) It is suggested that future studies involve creating a database of giraffe vocalizations, so that upon natural death the dimensions of the giraffe lung and trachea and the corresponding calculations for Helmholtz resonance can be produced to see whether they correspond. A brief example is the following:

Calculations of Giraffe Neck Resonance and Helmholtz resonance:

Neck resonance Assume a neck length of 1.5 m. Then $f = c/2L = 330$ (m/s)/ 2 x 1.5 m = 108 Hz. Assume the 14 Hz component is Helmholtz resonance. Find the lung volume needed to produce the Helmholtz resonance at this frequency.

Assume Speed of sound $c = 330$ m/s

Throat diameter = 5 cm = 0.05 m. Then throat area $S = \pi \times (0.05)^2/4 = 0.002\ m^2$.

Neck length L = 1.5 m

Then $V = c^2 S/(4Lf^2) = 330^2 \times 0.002/(4\pi^2 \times 1.52 \times 14^2) = 0.0188\ m^3$ for two lungs= $0.009\ m^3$ for one lung

This is equivalent to a cube 0.2 m (20 cm) on a side, or 18 liter capacity for both lungs. An adult human is capable of exhaling 4.5 liters, and human athletes 6.5 liters. It is therefore reasonable to assume that the giraffe, weighing a ton, could have lungs capable of exhaling 3 times the amount of a human. The lungs are a flexible membrane; therefore, membrane compliance or equivalent volume would have to be taken into consideration when performing calculations.

Another topic for future research will be to establish whether the vocalizations have communicative value, as this study was not designed to study the response of one giraffe's vocalizations to another. If the giraffe are communicating, it would be very advantageous for them, being prey, to be able to communicate "covertly" using signals designed to blend in with background noise. The most common giraffe vocalizations have frequencies up to 275 Hz, which should be audible. However, the decibel level of these signals drops significantly above 40 Hz, and the audible portion of the signal is lost in ambient noise. The giraffe's signal may be designed to be audible at low frequencies, which are less directional, and inaudible at the higher, directional frequencies. This would effectively hide the location of the sender.

Future research should focus on whether the signals are associated with identifiable and stressful contexts, as this has implications for the care and welfare of captive giraffes. In the giraffe’s natural environment, the frequency levels between 10 and 20 hertz are a relatively "quiet" bandwidth, only a few other animals and natural sounds exist to inhibit their communication. This is not true in urban areas. Infrasound can travel virtually unimpeded for great distance; the signals can be interrupted or jumbled because of other sources of infrasound such as large generators, trains, freeways and other man made objects. Every effort should be made, therefore, to see that captive animals are placed as far as possible from extraneous sources of infrasound, so their vocalizations remain as intact and perceptible as possible.

This study is dedicated to the memory of Aaragorn, Maxine, Azog and Dr. Melvin Kreithen. Many thanks to Steve Wing and Dr. Zuckerwar.

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BACK NEXT

TOP

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