An acoustic analysis of lion roars. I: Data collection and spectrogram and waveform analyses

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Abstract
This paper describes the collection of lion roar data at two different locations, an outdoor setting at Antelope Park in Zimbabwe and an indoor setting at Parken Zoo in Sweden. Preliminary analyses of spectrographic and waveform data are provided.

Introduction

Felids are one of the most successful carnivore families ever to exist, and within the 35–40 different cat species that exist today several different vocalizations can be found, with different functions, ranging from the well-known purring to the most impressive sound of them all: roaring of lion (*Panthera leo*) fame. This paper focuses on the impressive lion roaring, and highlights methodological problems associated with the collection of animal vocalizations data.

Roaring: a primer

For a human observer the roaring of a lion – even more so that of a whole pride – certainly is one of the most impressive vocalizations in the animal kingdom. In its complete form lion roaring is a species-specific series of calls with a fairly regular structure of the single calls composing it and the series itself, in the latter in terms of the sequence of call types, their change of intensity in the course of the series, the temporal sequencing of the calls and their relative duration and that of the intervals between them. A typical lion roaring can last for more than a minute, usually starting off with a few low-intensity moan-like calls, then progressively increasing in intensity and duration of the calls, and in approaching the intensity climax of the series the calls become shorter again and harsher. After the climax follows a series of short harsh calls, in the beginning uttered at fairly monotonic intensity and brief intervals between the calls, then towards the end of the series gradually decreasing in intensity and with increasing interval duration (called “outro” in this paper).

Given the fact that the colloquial term ‘roar’ is commonly used for various intense animal vocalizations it is not surprising that even in the lion it has been applied to vocalizations which are definitely different from roaring as dealt with here. Early attempts at characterizing it in a more technical manner were published by e.g. Leyhausen (1950), Hemmer (1966) and Schaller (1972). More recent studies of lion roaring include Peters (1978), Peters & Hast (1994), and Pfefferle et al. (2007) .

Weissengruber et al. (2002:208) extended the definition of roaring in a general vertebrate vocalization context suggesting that lion roaring “has two distinct physiological and acoustic components:

1 a low fundamental frequency, made possible by long or heavy vocal folds, which lead to the low pitch of the roar;

2 lowered formant frequencies, made possible by an elongated vocal tract, which provide the impressive baritone timbre of roars.”

(See also Frey & Gebler, 2010).

In this paper, we studied lion roaring ‘proper’ as outlined at the start, in respect of the fine acoustic structure of its component single calls, the structural changes they undergo in the course of the roaring series and possible physiological mechanisms underlying these changes, considering the definition suggested by Weissengruber et al. (2007).

On the function of roaring

The function of lion roars has been discussed extensively in the literature, and several hypotheses have been suggested. Pfefferle et al. (2007:3952) concluded that the “primary function of roars is the advertisement and defense of territory”. In support of this hypothesis, it has been shown that lionesses can estimate the number of individuals roaring, and that they are less likely to approach foreign roars when they are outnumbered (McComb, Packer & Pusey, 1994).

Besides territorial defense, an additional function might also be coordination of hunting (Grinnell & McComb, 2001; McComb, Packer & Pusey, 1994; Schaller, 1972).

Method

The following sections describe the data collection, data processing and analysis tools.

Data collection

The data analyzed in this paper were recorded at two different locations, one outdoor and one indoor setting. Recording details are given below.

Antelope Park, Gweru, Zimbabwe

The first set of lion roar recordings was obtained at Antelope Park lion rehabilitation and release into the wild facility at Gweru, Zimbabwe, by the first and last author. Antelope Park presently holds a population of around 100 African (Zimbabwean) lions.

The recordings were made on 23 November 2010, between 0400 and 0600 hours in the morning at the main enclosure centre. This meant that at least 50 lions were within close earshot, and that most of the other 50 lions were also within hearing range, given that lion roars can be heard by humans at a distance of at least 8 kilometers (Sunquist & Sunquist, 2002:294). Estimated distance between the microphone and the lions varied from about four meters to several hundred meters, although the latter roars appeared as fairly weak signals.

The lions that were closest to the microphone were nine males, most of whom were born in 2006. Also close were seven other males with ages between seven and eight years old. Relatively close were another five males who are seven and eight years old, and also a number of females.

As it was more or less pitch-black during the recording it was impossible to know exactly what lion produced exactly what roar, or whether the roars were produced by a male or a female, although the former is more likely. Besides, there were considerable overlap between the roars of several lions (often more than a dozen at a time).

The equipment used was a Canon HG-10 HD camcorder with a clipon DM50 electret stereo condenser shotgun microphone with a 150–15,000 Hz frequency range and a sensitivity of –40 dB. The microphone was directed towards the lions that roared for the moment, and thus its position varied.

Other than slight contamination with morning bird chirping, the soundscape was relatively calm.

The recording location, with setup indications, is shown in *Plate 1*.

Parken Zoo, Eskilstuna, Sweden

Parken Zoo is a wildlife facility about an hour’s distance from Stockholm and holds a wide number of exotic animals, including several species of felids. There are presently three Asiatic (Gir) lions there: *Sarla*, a female born in 1997 (estimated 165 kilos); *Ishara*, another female born in 2007 (estimated 165 kilos); and *Kaya*, a male born in 1999 (estimated 180 kilos).

The recordings were made on 7 April 2011, between 0800 and 1000 hours in the morning. The recordings were made indoors to ensure that the lions remained in close proximity to the microphones – in their outdoor enclosure the lions would likely have walked off (far from the microphones). The cameras/microphones were set up by the first author. All three lions were at a distance from the microphones that varied between about one meter to around five meters. Since the recordings were made indoors, there were some echo effects. There was considerable contamination of the soundscape with bird chirps, emanating from a few birds perched somewhere in the enclosure.

The recordings were made with two Canon HG-10 HD camcorders. One camera used the same clipon microphone as is described above, while the other camera used an external professional high-fidelity Audiotechnica AT813 cardoid-pattern, condenser mono microphone, with a frequency range of 30–20,000 Hz and a sensitivity of –44 dB. The two cameras were placed so that, between them, they would cover as much of the enclosure as possible, with the hope of catching roaring sequences on film.

The recording location, with setup indications, is shown in *Plate 2*.

Plates 1 and 2. Recording setups at Antelope Park, Gweru, Zimbabwe (left) and Parken Zoo, Eskilstuna, Sweden (right). Left plate: Orange dots indicate approximate positions of roaring lions while the white dot indicates the most frequent position of the DM50 stereo microphone, ~250 cm above the ground. Right plate: White arrow indicates position of DM50 stereo microphone; orange arrow indicates position of AT813 mono microphone.

Plates 3 and 4. Roaring sequences caught on film at Parken Zoo, Eskilstuna, Sweden. Film captures from the two cameras lifted from the roaring sequences analyzed in this paper. Note that all film/sound files obtained at Antelope Park were recorded in complete darkness (to humans; the lions saw the authors quite well).

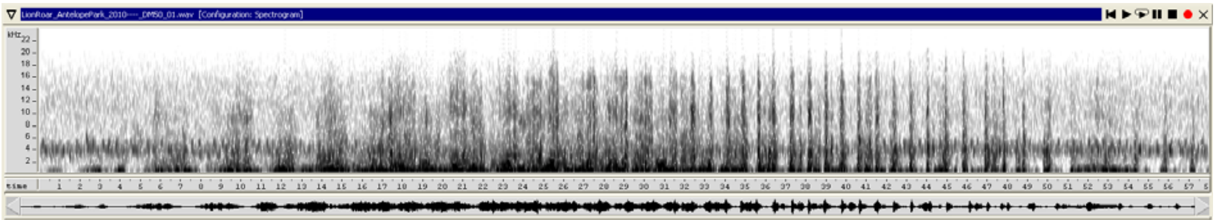

Figure 1. Spectrogram and waveform (excerpt) of multiple lions roaring sequence recorded at Antelope Park, Gweru, Zimbabwe. Canon DM50 clipon stereo microphone. Duration: 58 seconds.

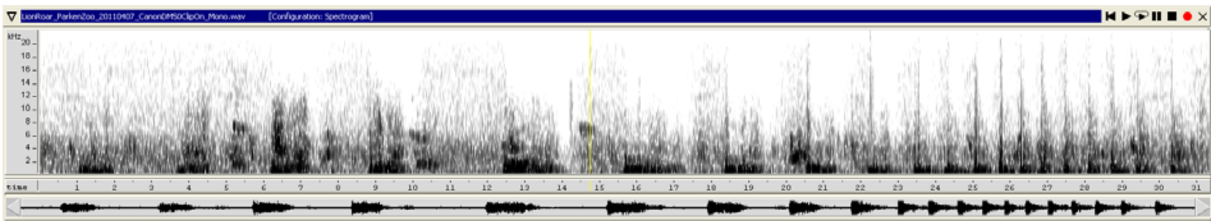

Figure 2. Spectrogram and waveform (excerpt) of lion roaring sequence recorded at Parken Zoo, Eskilstuna, Sweden. Canon DM50 clipon stereo microphone. Duration: 31 seconds.

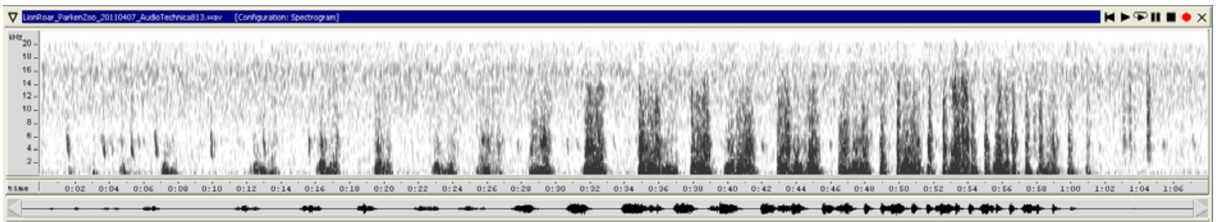

Figure 3. Spectrogram and waveform (excerpt) of lion roaring sequence recorded at Parken Zoo, Eskilstuna, Sweden. Audiotechnica AT813 external mono microphone. Duration: 67 seconds.

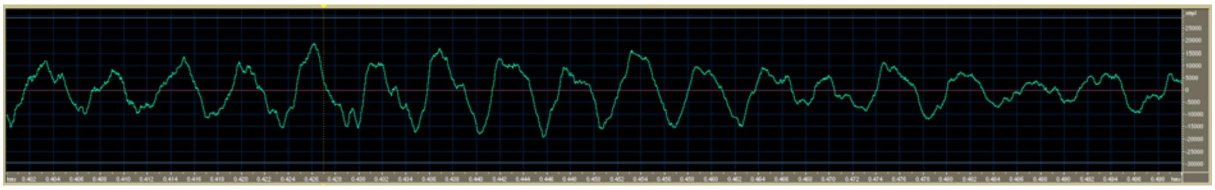

Figure 4. Waveform of lion roaring sequence ("outro" phase) recorded at Parken Zoo, Eskilstuna, Sweden. Audiotechnica AT813 external mono microphone. 18 distinct peaks – in a 100 ms sequence – give an estimated fundamental frequency of about 180 Hz.

Data post-processing

Audio tracks were extracted and converted into wav files (44.1 kHz, 16 bit, mono) with TMPGEnc 4.0 Xpress.

Analysis tools

Spectrogram and waveform analyses were carried out with WaveSurfer and Cool Edit.

Results

The film clips recorded at Parken Zoo resulted in two passages where the lions were caught on film while roaring; see *Plate 3* and *Plate 4*. This enabled comparison between acoustic and visual data (see Ananthakrishnan et al., 2011).

Spectrographic analysis

The three spectrograms shown in *Figure 1*, *Figure 2* and *Figure 3* all reveal the periodic phase characteristics of the roaring sequences. Despite the different acoustic characteristics between the microphones and the different recording setting, all three spectrograms reveal both low frequency components and a higher frequency component around 4 kHz.

Fundamental frequency analysis

A waveform passage is shown in *Figure 4*, and as is clearly seen there are 18 distinct peaks in the 100 ms long window. This gives an approximate fundamental frequency (F_0) of about 180 Hz, which is in accordance with the results reported by Pfefferle et al. (2007:3950), where mean F_0 in males was 194.55 Hz and 206.57 in females.. Naturally, further analyses are required in order to will reveal what degree of variation and range that occur in lion roars.

Discussion

The primary goal of this paper is to provide information about data collection issues associated with animal sounds, highlighting the difficulties involved when trying to obtain controlled high fidelity recordings of animal vocalizations. Future research will focus on more detailed acoustic analyses on the data obtained, and we hope to complement our data with additional high fidelity recordings of uncontaminated recordings of individual lions, in order to facilitate e.g. vocal tract estimation studies (see Ananthakrishnan et al., 2011).

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