Chapter 4: Vocal stress associated with a translocation of a family herd of African elephant (*Loxodonta africana*) in the Kruger National Park, South Africa[3].

ABSTRACT

We examined the effect of a translocation of an African elephant family herd within the Kruger National Park (KNP) by means of vocal indicators. These animals were moved 300 km from their home range, but returned unaided to this range within 23 days. We found that translocation resulted in a change in the mean fundamental frequency of low-frequency elephant vocalizations, known as rumbles. The rumbles increased significantly in pitch compared to pre-translocation levels during the 23 days the animals spent outside their normal home range. Vocalization returned to close to pre-translocation levels by the time the animals had navigated their way back to their previous home range. Raised vocal pitch is known to be an indicator of stress in humans and other animals. These results are consistent with a physiological measure of stress, faecal glucocorticoid metabolite (FGM) levels, which were monitored during the same translocation study and have already been reported. While various measures of vocal responses to stress have been reported for humans and domestic animals, as far as we know this is the first report of prolonged monitoring of vocal stress response in free-ranging animals. Measures of behavioural responses, such as recorded vocalizations, may provide an objective non-invasive method for assessing animal stress. This could help in determining the effects that management actions can have on elephants.

4.1 INTRODUCTION

Vocal indicators of stress have been reasonably well studied in humans (Protopapas & Lieberman, 1997; Scherer *et al.*, 2001), and some work has been done with domesticated animals. Most studies have reported on crude counts of the type and number of vocalizations as indicators of stress. Scherer *et al.,* (2001)

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proposed that decoding vocal expressions across different human cultures can serve as a universal mechanism for determining the level of emotion. Vocal evidence from domesticated animals was found to be useful in assessing physiological and psychological well-being and could be utilized to improve management and welfare (Watts & Stookey, 2000).

In many non-human mammals, there also seems to be a close tie between emotional state and vocal pattern. Increases in the mean fundamental frequency of low frequency vocalizations that can be used as a measure of stress response (Boinski *et al.,* 1999; Li *et al.,* 2007; Soltis *et al.,* 2005 & 2011; Stoeger-Horwath *et al.,* 2007; Coss *et al.,* 2007; Stoeger *et al*., 2011). For example, the roar of infant African elephant (*Loxodonta africana*) , which is higher in pitch than most elephant calls, signifies primarily the caller's arousal state and therefore indicates the arousal-based physiological changes influencing acoustic features of vocalizations (Langbauer, 2000; Stoeger *et al*., 2011). Soltis *et al.,* (2005) established that structural variation in rumbles of captive female African elephants represented the individual identity and emotional state of callers. The vocal behaviour of captive animals provides useful information on their relative stress levels (Boinski, 1999), and systematic changes of vocal parameters suggest that emotion-related acoustic signals are a regular feature of vocal communication in mammals (Bastian & Schmidt, 2008).

Little work has been done on the subject of vocal stress in free-ranging wild animals (but see Poole *et al.,* 1988; Langbauer, 2000; Wood *et al.,* 2005; Soltis *et al*., 2005 & 2011). In African elephants, some parameters of rumbles can be used to determine the emotional state of the individual (Clemins *et al*., 2005; Soltis *et al*., 2005; 2009). Results from a study conducted in the Kruger National Park (KNP) which focused on rumbles recorded in family herds of elephants (Wood *et al*., 2005) found a significant association between behaviour and rumble type. They categorized rumbles according to the physical properties and showed that rumble types can be associated with specific group behaviours.

Emotion in the human voice, as in the case of elephants, is subject to individual variability, making it difficult to accurately classify arousal levels (Protopapas & Lieberman, 1997; Li *et al.,* 2007). Jitter is an evaluation of the period-to-period fluctuations in fundamental frequency whereas shimmer is a measure of the period-to-period variability of the amplitude value (Li *et al.,* 2007). Fluctuations in jitter may display as improved acoustic parameters as indicators of anxieties. Jitter and shimmer recordings in six female African elephants were found to be important features for analysis and classification of arousal level (*Li et al.,* 2007).

In environments where elephant movement is unrestricted, elephant vocalizations can provide insight into their reproduction, resource utilization, predator avoidance, coordinating movement and social interactions (Payne *et al.,* 1986; Poole *et al.,* 1988; McComb *et al.,* 2000; Garstang, 2004), all information useful to wildlife managers. Seasonal variability in quantity and quality of resources in the environment highlights the importance of elephant's capability of coordinating movements. Vocal communication further assists to uphold social bonds, cohesion in breeding herds, and in maintaining the population genetic structure in fission–fusion societies where male elephants do not form permanent associations with breeding herds (Wittemyer & Getz, 2007). Wild unrelated elephant females do not interact commonly but under circumstances of a disruption in their natural social system, interactions with other elephants do occur for short periods (Moss & Poole, 1983; Thouless, 1996). McComb *et al.* 2000 has shown that elphants can distinguish between the vocalizations of familiar and unfamiliar conspecific herds.

The information contained in vocalizations of African elephants could be of interest to managers and researchers alike, and could contribute towards the conservation of the species (Langbauer, 2000; McComb *et al.,* 2003; Wood, *et al.,* 2005). In assessing the effect of translocation on elephant's behaviour, we analyzed recordings of vocalizations as an empirical indicator of stress. In this paper we investigated the stress-related response of a breeding herd of elephants to translocation by means of evaluating vocal communication.

4.2 METHODS

4.2.1 Study Area

This study was conducted in the Kruger National Park, South Africa (Figure 1.1, Chapter 1) which covers an area of approximately 19 000km^2. Data during the pre- and post-translocation phases were collected in the southern KNP around the Lower Sabie rest camp. During the translocation phase data were collected in the northern KNP, north of the Letaba rest camp.

4.2.2 Study population and data collection

This study was part of a larger study that was designed as a controlled experiment to assist in the management of elephants (*Loxodonta africana*) and was conducted entirely within KNP over a period of 3.5 years (March 2002 to September 2005). The first breeding herd of elephants in the southern region of KNP spotted from a helicopter after take-off in a south-easterly direction towards Lower-Sabie from Skukuza was selected as our focal group.

The matriarch was fitted with a VHF radio collar and later replaced in August 2002 with a GPS satellite collar (both collars manufactured by African Wildlife Tracking, Pretoria, Gauteng, South Africa). We followed the breeding herds on foot and field crews always avoided being positioned upwind of the herd in an attempt to minimize disturbance and being detected. During each session record was kept of the estimated distance to visible elephants, the gain settings of the recorder, the date, time, and GPS coordinates, as well as of audible vocalizations from elephants or other animals. Typical recording distances while on foot ranged from 50-120m and the few occurrences when family herds were sighted close to roads, recordings from the vehicle was made at distances ranging from 20-100m. The period of vocal sampling for pre-, during, and post-translocation, was from March 2003 to August 2005. During this period a total of 47 hours of recordings over 61 appropriate condition days were made. The length of the recording sessions varied, with an average of 3 minutes per session. Most of the recordings were made between 06:00 and 11:00 and include brief periods during the capture process and the time immediately after release. Since most of the vocalizations of elephants are inaudible to humans (Payne *et al.,* 1986; Langbauer *et al.,* 1991), we did not attempt to identify the calling individual, but recorded the vocal behaviour of the group as a whole.

The focal group comprised of 11 animals on 7 October 2004 when they were captured in the Lower Sabie section. Immediately after capture, this group was loaded into a SANparks Elephant family group mass transport unit. The elephants were transported for approximately 300 km and offloaded north of the Letaba Rest Camp after four hours of travel. The age of the captured animals were categorized according to shoulder heights measured on the day of capture (Shrader *et al*., 2006). The family herd consisted of 3 adult females (≥ 28 years), 5 sub adult females (8-10 years), 1 juvenile female (2-3 years) and 2 male calves (1-2 year). They were immobilized with a combination of M99 and Azaperone (at a dosage of 3-12mg depending on the size and age of the individual). The antidote (M5050 and Naltrexone, at dosages of 12–36mg of M5050 and 25–100mg of Naltrexone according to the age of the elephant) was administered intravenously as soon as the individual was loaded into the transport crate. Capture drugs: Etorphine (M99, Novartis, Kempton Park, 1619, South Africa), Diprenorphine (M5050, Novartis, Kempton Park, 1619, South Africa), Naltrexone (Naltrexone, Kyron Laboratories, Benrose, 2011, South Africa).

The elephants then navigated their way back and re-entered their pre-translocation home range 23 days later. The post-translocation monitoring phase (October 2004 - August 2005) was defined as the day the experimental group re-entered (south of the northern most sighting of the pre-translocation phase) the pre-translocation home range.

4.2.3 Equipment

For our acoustic recordings we used a Sennheiser MKH 20-P48 condenser microphone, with a manufacturer-specified frequency response of 12 Hz – 20 kHz (at the 3 dB downpoint). We covered the microphone with a Rycote windshield (open cell foam with a fur cover) in order to reduce wind noise. The microphone was connected to a Marantz PMD670 solid state recorder, and recordings were saved as wave files. The nominal frequency response of this recorder is 20 Hz - 20 kHz, but bench tests confirmed that the response was flat down to 5 Hz. We recorded at a sample rate of 16 kHz, so the overall frequency response of the system was 12 Hz – 8 kHz, which encompasses the known range of elephant calls, from infrasonic calls to trumpets (12 Hz – 2 kHz: Berg, 1986; Langbauer, 2000). A handheld Garmin III was used for the recording of GPS coordinates.

We recorded at a sample size of 16 bits which corresponds to a dynamic range of 96 dB SPL. The signal from the microphone was split into the right and left channel of the recorder, and the gain of the channels adjusted to a difference of 20 dB, to improve the dynamic range of the system to 116 dB SPL.

4.2.4 Selection of analysis parameters

The fundamental frequency of African elephant rumbles is correlated to the level of arousal of the individual (Berg, 1983; Soltis *et al.*, 2005). These rumbles have a fundamental frequency of between 15 and 25Hz and harmonics ranging several hundred Hz (Poole *et al.,* 1988; Langbauer, 2000). Vocal parameters that may change during stress include the fundamental frequency (pitch), loudness, jitter, and the cepstral peak prominence (a measure of dysphonia or roughness) (Soltis *et al.,* 2005; 2011; Li *et al.,* 2007). However, the measurement of many of these parameters can be unreliable even in laboratory settings (Heman-Ackah & Batory, 2003). Except for fundamental frequency, the measures can also be affected by the total harmonic structure of the call, the recorded representation of which, in turn, can be affected by habitat type and distance from the sender. The habitat type and density of the vegetation can affect sound propagation and the harmonic structure of recorded animal vocalizations (Ey *et al.,* 2009). These factors however do not affect the fundamental frequency of recorded animal vocalizations. Because these last two factors, habitat type and distance, were so variable in this study, we selected the fundamental frequency (lowest frequency of a periodic waveform) of the call as the most robust parameter to measure. The fundamental frequency is also relatively easier to measure in a noisy environment compared to other parameters, such as jitter (Figure 4.1).

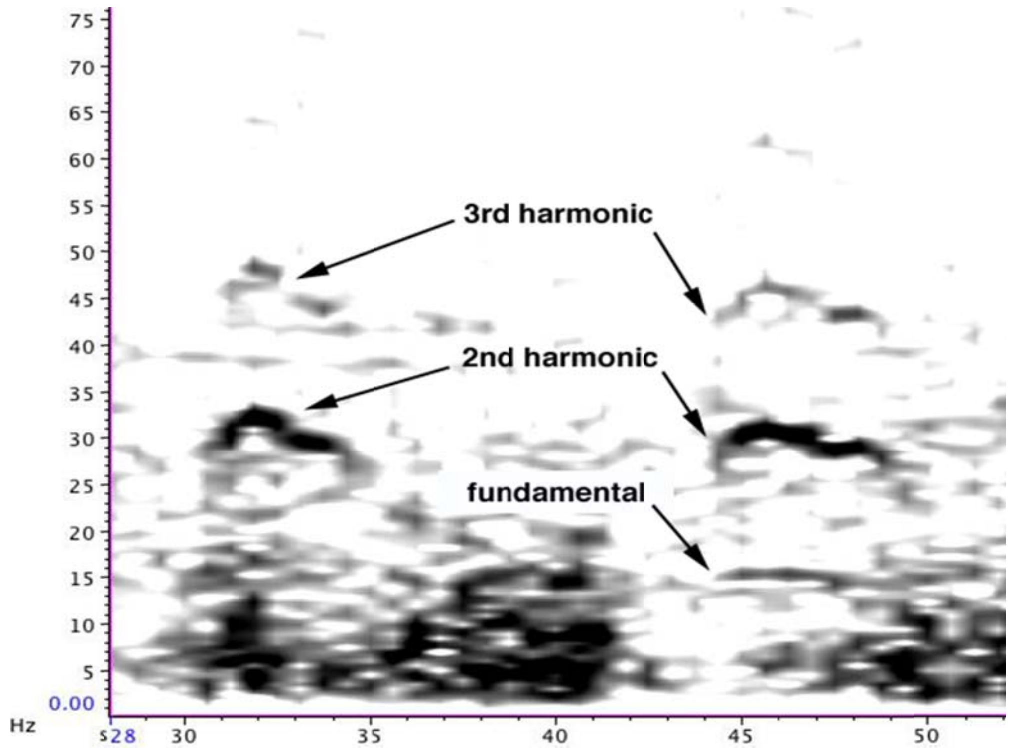

Figure 4.1. Field recording of two elephant vocalizations. Both vocalizations have fundamental frequencies of 15 Hz at the start of the call. While the fundamental frequency of the first vocalization is hidden in noise, it can be inferred from the difference in frequency (15 Hz) between the 2nd and 3rd harmonics of the call. While there was usually enough information to measure fundamental frequency, noisy field conditions made other measurements, such as jitter, unreliable.

4.2.5 Analysis protocol

The recordings were analyzed using Raven 1.3 software, developed by the Cornell Bioacoustics Research Program. We played back each file at 10 times the recorded speed, and identified elephant vocalizations by ear and by examination of a spectrogram of the entire file. Spectrograms used for measurement were calculated using Fast Fourier Transformation (FFT length 2048 samples), a Hamming window and a 50% overlap, resulting in a frequency resolution of .781 Hz. Measurements of fundamental frequencies were recorded to the nearest Hz, as measurements to tenths of Hz would have been within measurement error. We measured 306 calls pre-translocation (March 2003-October 2004), 68 calls while the elephants were in the translocated area (23 days during October 2004), and 421 calls post-translocation (October 2004-August 2005). For statistical analysis a t-test was employed to calculate a two sample, unequal variance student t-test, comparing pre-translocation to during translocation, pre-translocation to post-translocation, and during translocation to post-translocation.

Many low-frequency elephant vocalizations are frequency modulated, with their spectrogram resembling an upside-down U shape. For this reason, to insure a consistent measure, we measured the fundamental frequency averaged over the initial second of the call.

4.2.6 Determination of faecal glucocorticoid metabolite levels

Faecal samples were also collected and faecal glucocorticoid metabolite (FGM) levels examined for a parallel study (Viljoen *et al.,* 2008a, b). Due to wind conditions and safety concerns, acoustic recordings were not always taken when faecal samples of the herd were collected. Hormone values were determined according to the procedure described by Viljoen *et al.* (2008a). FGM levels of samples collected during the translocation phase were significantly higher compared to FGM concentrations of samples collected during the pre- and post-translocation phase (Viljoen *et al.,* 2008b). FGM levels returned to pre-translocation values by the time the translocated animals returned to their previous home range. FGM levels peaked during and immediately after translocation in the experimental group, while no corresponding spike was seen in the control groups indicate that factors excluding capture and translocation can be barred as causal stimuli for the observed FGM response (Viljoen *et al.,* 2008b).

4.3 RESULTS AND DISCUSSION

The mean fundamental frequency of low-frequency elephant vocalizations increased significantly above both pre-translocation ($p<0.001$, 2-tailed students t-test) and post-translocation ($p<0.001$, 2-tailed students t-test) levels during the 23 days the animals spent outside their normal home range (Table 4.1, Figure 4.2).

Table 4.1. The mean fundamental frequency of low-frequency elephant vocalizations associated with translocation of a family herd of African elephant (*Loxodonta africana*) in the Kruger National Park, South Africa.

			Fundamental Frequency	
Groups	*Count*	*Sum*	*Mean(hz)*	*Variance(hz)*
Pre translocation	306	967	14.2	1.13
Translocation	68	1124	16.5	3.66
Post-translocation	421	1038	15.3	3.36

STUDENT T-TEST

Comparision	*p value*
Pre-translocation to Translocation	1.10536E-16
Translocation to Post-translocation	2.0448E-13
Pre-translocation to Post-translocation	5.79871E-05

The mean fundamental frequency dropped after the elephants returned to their home range, but was still significantly higher than pre-translocation levels. This may be due to either residual stress response of the translocation or to excitement at being back to the pre-translocation range. These results are consistent with the physiological changes found, in terms of elevated faecal glucocorticoid metabolite levels, previously reported for the same translocation event. Stress as a physiological mechanism is not innately harmful (Moberg, 2000), but extended periods of high concentrations of glucocorticoids, as a result of prolonged periods of subjected stress, might compromise fitness (Munck *et al.,* 1984) as well as reproductive success (Liptrap, 1993) of an individual, and also permanently alter behaviour. In a transformed and fragmented South African landscape where elephant movements are restricted, remote monitoring of vocalizations can provide records of continuous tracks of the emotional changes. Utilizing this non-invasive technique of recording vocalizations, can aid in the early detection of stress and appropriate action can be taken timely, contributing towards improving the welfare of the animals.

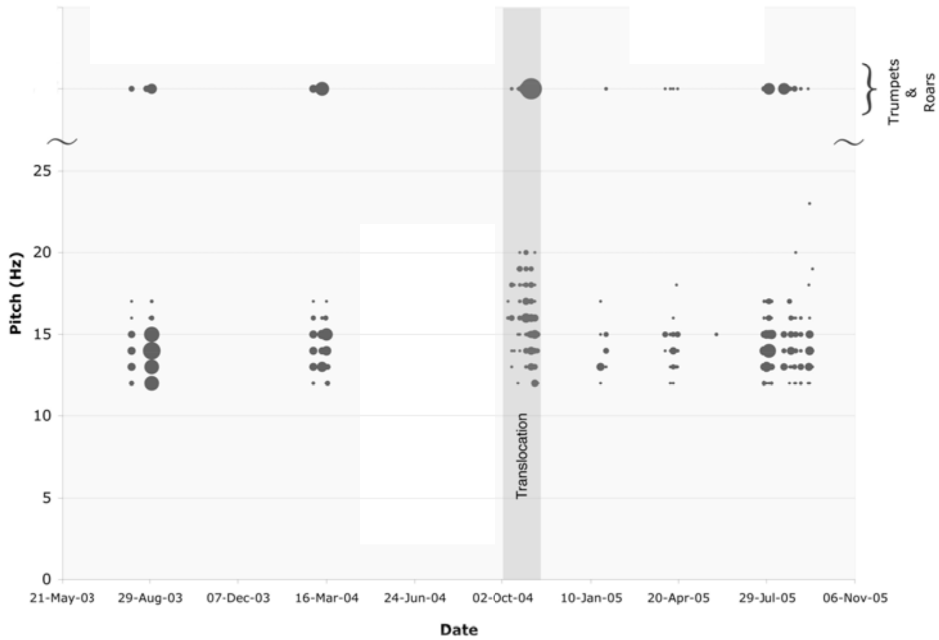

Figure 4.2. The mean fundamental frequency of low-frequency elephant vocalizations associated with a translocation of a family herd of African elephant (*Loxodonta africana*) in the Kruger National Park, South Africa. The area of each point is proportional to the number of calls at that frequency on a given day. Calls with fundamental frequencies above 30 Hz were lumped into a single category ("trumpets and roars") and not included in the analysis of low-frequency vocalizations.

Anecdotal evidence suggests that elephants know when they are in unsafe areas; e.g. crop raiding elephants are usually silent.

Elephants use the same general group of vocalization to express different things. For example, rumbles are used to continue contact with other elephants and to signal the time for the herd to move (Berg, 1983; Poole *et al.*, 1988). Family herds of elephants have demonstrated defensive behaviour by aggregating in denser groups, freezing and/or scanning the air in response to seismic playbacks of low-frequency alarm calls and low-frequency conspecific calls (Langbauer *et al.,* 1991; O'Connell-Rodwell *et al.,* 2006). The presence of lions brought about a trumpeting response (Langbauer, 2000) and elephants produced warning vocalizations and were joined in their flight by other elephants set off by the sound of troubled African honeybees (King *et al.,* 2007; 2010). Although only a few studies have been done to link elephant vocalizations with particular emotional states such as fear or a response to the presence of predators, it seems clear that specific types of elephant vocalizations serve as acoustic deterrents in certain situations. From the above discussion, it is clear that, in theory, African elephants' acoustic communication and behavioural responses can serve as a departure point in devising techniques to solve problems and as a management tool to measure the outcomes of human interventions. The practical problem with many aspects of elephant vocal communication is that deciphering the meaning of a particular call, especially when the vocalization is inaudible to humans, is often time consuming and uncertain. In contrast, measuring a physical parameter (the fundamental frequency) across all animals in a group is relatively unambiguous and uncomplicated. It is thus a much easier technique to impliment for a conservation biologist, as it does not require making fine differentiations between calls and specific meanings.

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