STRESS IN THE AFRICAN ELEPHANT ON MABULA GAME RESERVE, SOUTH AFRICA

by

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ABSTRACT

The current study contributes to the science of biology in that it describes different methods of measuring stress in animals and distinguishes between different types of stress that animals are exposed to. The main aim of this type of research is to obtain as much information as possible on what more specifically elephants require from their environment in order to create a more suitable habitat under conditions that vary considerably from the environment in which the elephant evolved in. Two types of possible stress for elephants on small reserves were investigated: social stress and stress caused by direct human disturbances (for example tourists on game drive vehicles in fenced reserves without wilderness areas). The study group of elephants which were introduced to the study reserve ten years earlier as a group of unrelated juveniles from culling operations differed significantly according to social role play and behaviour from normal elephant societies as described by literature. None of the adult elephants from the study group initiated change of activity more than the other adult elephants on the reserve and although one of the female cows was dominant over all the other adult female cows she was dominated by the twenty-year-old bull on the reserve. The twenty-year-old bull was with the cowherd for most of the time and was aggressive towards other cowherd members when present. All the stress parameters used to monitor the influence of direct human disturbances also changed significantly in the presence and absence of game drive vehicles in the elephant's environment. The group of elephants moved more and clustered together more, individual elephants showed more behaviours associated with stress and vocalized more and adult female elephants secreted more from their temporal glands in the presence of game drive vehicles compared to periods when game drive vehicles were absent. Stress hormone metabolite levels in the dung of elephant differed significantly among individuals being highest for the twenty-year-old bull on the reserve. One section area on the reserve with the highest load of human activity also produced the highest levels of stress for elephants when group mobility, group spacing and faecal stress hormone metabolite levels were used as stress parameters. Social stress for the study group of elephants may have enhanced stress response of elephants towards direct human disturbances. Small fenced reserves hosting elephants should monitor and control game drive vehicle activity around elephants and should consider expanding their property in order to first of all provide wilderness areas to where animals can escape to when stressed by direct human disturbances and secondly to be able to introduce older female and male elephants to control and lead young animals if not present. Implementation of stress monitoring programs as part of the elephant management plan of a reserve may reduce and possibly prevent any future incidences of aggression from elephants towards humans and other species.

PREFACE

The fieldwork described in this thesis was carried out on Mabula Game Reserve, Limpopo province through the School of Life & Environmental Sciences, University of Natal, Durban, from January 2002 to March 2003, under the supervision of Professor Rob Slotow and co-supervision of Mr Bruce Page.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

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Chapter 1
GENERAL INTRODUCTION

The relationship of man and elephant goes as far back as the stone age (10 000 B.C.) when man was the hunter and elephant the hunted. Since the first elephants were tamed around 2000 B.C. the interactions between humans and elephants changed over time to benefit man in various other fields. While the ancient Romans prosecuted elephants for entertainment in amphitheatres, Asians worshipped and incorporated elephants into their religion, culture, mythology and as an every day work force. In the old world elephants not only served as sources of strength in the lines of battle but also as psychological instruments that caused confusion and fear for the enemy. African elephants (*Loxodonta africana)* were first tamed and used in war by the Nubians of Kush south of Egypt during the fifth century B.C. and later also in war by Hanniball during the second century B.C. when he crossed the Alps to attack the Romans (Meredith 2001; Saller 1999).

During the late nineteenth century elephants like, Jumbo, were being exploited in circuses and zoos followed by a massive slaughter of elephants for their ivory during the early twentieth century (Skinner & Smithers 1990; Saller 1999). In 1977 the African elephant were placed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and in 1990 shifted to Appendix I, which stated an international ban in all cross-border trade of ivory and other elephant products (World Wildlife Fund 1997). Today the once wide distribution of the African elephant throughout South Africa is limited to fenced parks, reserves and zoos. In 1998 an estimated 11 905 elephants were left in confined and fenced areas in South Africa covering a total range area of 25 847 km² of the total 1 219 912 km² of the country (Barnes *et al.* 1999). The change in distribution of elephants up until recent years was mainly due to the increasing human population growth of Africa. Competition and conflict between man and elephant for space have lead to the decline of elephant numbers outside conservation areas. It is possible to confine adult elephants to certain areas with the use of electrified fences powered by solar energy, but because of their destructive feeding habits elephant numbers in confined areas need to be controlled in order to prevent veld degradation and destruction (Ebedes *et al.* 1991).

Elephants are highly adaptable animals and occur from desert areas to forests. The only described habitat requirements for elephants are some shade in which to shelter during the hottest hours of the day, a supply of water, preferably fresh, and adequate food (Bothma 1996).

Despite their destructive feeding habits, elephants play a vital role in most ecosystems by:

(1) enhancing biodiversity when creating for example gaps in closed-canopy forests that ensure the establishment of more light-dependent grasses and herbs as a readily available food source for herbivores.
(2) dispersal and germination of forest fruit tree seeds in elephant dung.
(3) dispersal and germination of seeds of *Acacia* species for establishment of savanna woodlands in elephant dung.
(4) the provision of mineral cycling and the formation of seasonal waterholes for other game species. This phenomenon occurs when elephants utilize abandoned termite mounds for minerals like sodium and potassium. The broken-up soil provides mineral licks for other game and the increased game load on the area forms depressions that can hold water in the next rainy season (World Wildlife Fund 1997).

Currently the main objectives in keeping elephants for most fenced parks and reserves throughout South Africa are conservation of the species and ecotourism. Although tourism is a thriving enterprise it revolves mainly around financial goals and too often disregards the ecosystem and its components. Because of their size and power elephants can be a threat to species like rhinoceros and to human life when encountered for various reasons, for example because of previous negative encounters, a disrupted social structure which might have lead to increased stress and ignorance of signs of stress, aggression and irritation from elephants by tourists due to lack of knowledge of elephant behaviour (*"KwaZulu-Natal's valuable flagship species, the black and white rhino, are being violently killed by delinquent young elephants."* (Gowans 2000), *"A man was trampled to death by an elephant at the weekend after he and a game ranger tried to chase a herd onto a road for tourists to see..."*(anon 2003)).

Although the behaviour and social organization of the African elephant has been studied thoroughly under conditions of minimal human interference the impact of tourism and overall human presence and activity in small reserves on elephant life has often been neglected. What differentiates small reserves from institutions like zoos and circuses is the lack of control by game managers over the animals. Elephants on small reserves are still wild and move around at free will, which benefits the image desired to be portrayed by the game ranch owner to tourists. For the purpose of the study a small reserve is defined as a fenced area that is not large enough (according to Bothma's (1996) twenty-five elephants on a 10 000 ha reserve with an annual average rainfall of 500 mm recommendation) to host an entire population of elephant with complete social structure (families with matriarchs, bond groups, clans and bull areas) or which does not have a wilderness area away from roads and tourist activity to where animals can escape to. For the successful rehabilitation of elephants, intensive management on small reserves is becoming more and more important. Management can only be effective once resources are properly identified and objectives are clear. The aim of this study is to identify what elements other than their physical needs, elephants require in a fenced area where ecotourism is the main focus. Such reserves have a constant high density of human activity, which may negatively influence the well-being of elephants. Circumstances where elephants do not live under a state of well-being may cause added stress for elephants which in turn may lead to aggression of elephants towards humans and other species or may even jeopardise the elephants health together with a possible increase in veterinary costs and a decrease in elephant population size due to mortality.

According to Stephan (1992) a state of well-being for any animal means a physical and mental harmony of the individual within itself and with its environment. It includes freedom from pain, suffering (produced by influences which are detrimental to the nature of the individual, to its instincts and to its existence) and harm (a change of the physical and mental state for the worse often accompanied by disturbance of physiological functions). "*The meeting of requirements and the satisfaction of needs are an important basis to this respect.*" (Stephan 1992). Stress only becomes a threat to well-being when, because of its frequency or its magnitude the stressor results in a change in the animal's biological function to such an extent that the animal enters a prepathological state with an increasing vulnerability to pathology (Figure 1.1). Any external stimulus that challenges homeostasis can be viewed as a stressor (Moberg 1983). Wingfield and Ramenofsky (1999) defines stress as a situation elicited by one or more stressors in which physiological function is compromised or in which the ability to meet energetic requirements is challenged and further classifies a human disturbance as an unpredictable event to wildlife and thus a viable disturbance factor or stressor. Humans are perceived as predators by other animals like elephants through years of evolution and possibly as predictable disturbance factors in the environment. For example, a person on foot may be perceived as a hunter and elephants might move away in response to the threat. Human technology has evolved outside the elephant's environment and thus might qualify as an unpredictable disturbance factor. For example, people in a vehicle is a circumstance that elephants will not have evolved a response to and any response might be driven by the experience of that individual elephant. For the purpose of the current study the possible stressors present in the elephant's environment are divided as follows:

(1) Direct disturbances or external stressors
    (a) Natural environmental disturbances: Ambient temperature, drought, thunderstorms, diseases and fires

(b) Inter-species interactions: Predators and competition for food and space with other species like rhinoceros

(c) Human disturbances: Low flying helicopters doing game counts, darting operations for collar fittings, injuries and contraception on the elephant, tourists on game drive vehicles, building noises and general human activity around residential areas

(2) Indirect disturbances or internal stressors

(a) Intra-species interactions: Competition for dominance, births and deaths among elephants in the same group

(b) Human induced stress: Fences that limit natural migration, contact with other groups of elephants and elephant numbers within a confined area and which cause disrupted social structure (for example absence of older experienced animals like a matriarch due to re-introduction of only juvenile elephants on a reserve)

The changes in biological function that occur when an animal attempts to maintain homeostasis constitute the animal's stress response (Moberg 1983) (Figure 1.1). All animals are exposed to external and internal strains to which it is forced to react and an ability to respond to these strains is necessary for the animal's survival (Westermarck 1992). According to Wingfield and Ramenofsky (1999) there is a highly predictable component to environmental conditions that allows organisms to modify their morphology, physiology and behaviour accordingly and thus reduce the potential for stress. These responses in predictable variable environments are expressed by organisms in a series of life-history-stages (expression of several phenotypic stages such as non-breeding, breeding, migration and molt by a single phenotype) that maximizes fitness throughout the organisms lifetime. Unpredictable changes in the environment or disturbance factors can trigger either very rapid responses (e.g. flight-or-fight reactions) which triggers immediate avoidance behaviour and self-defence, or facultative behavioural and physiological responses which causes the organism to abandon the current life-history-stage and adopt an emergency response. This reaction appears to be mediated by increases in glucocorticosteroid secretion. (Wingfield & Ramenofsky 1999).

Corticotropin-releasing hormone is a polypeptide and is synthesized by the neurosecretory cells of the hypothalamus. As a response to stress the release of corticotropin-releasing hormone from the hypothalamus is activated via a neuroendocrine reflex (Frandson 1992). Corticotropin-releasing hormone is the substance responsible for adrenocorticotropic hormone to be released from the adenohypophysis of the pituitary gland. The primary effects of adrenocorticotropic hormone are hypertrophy and hyperplasia of adrenal cortical tissue, as well as increased production of adrenal cortical steroid hormones (glucocorticoids).

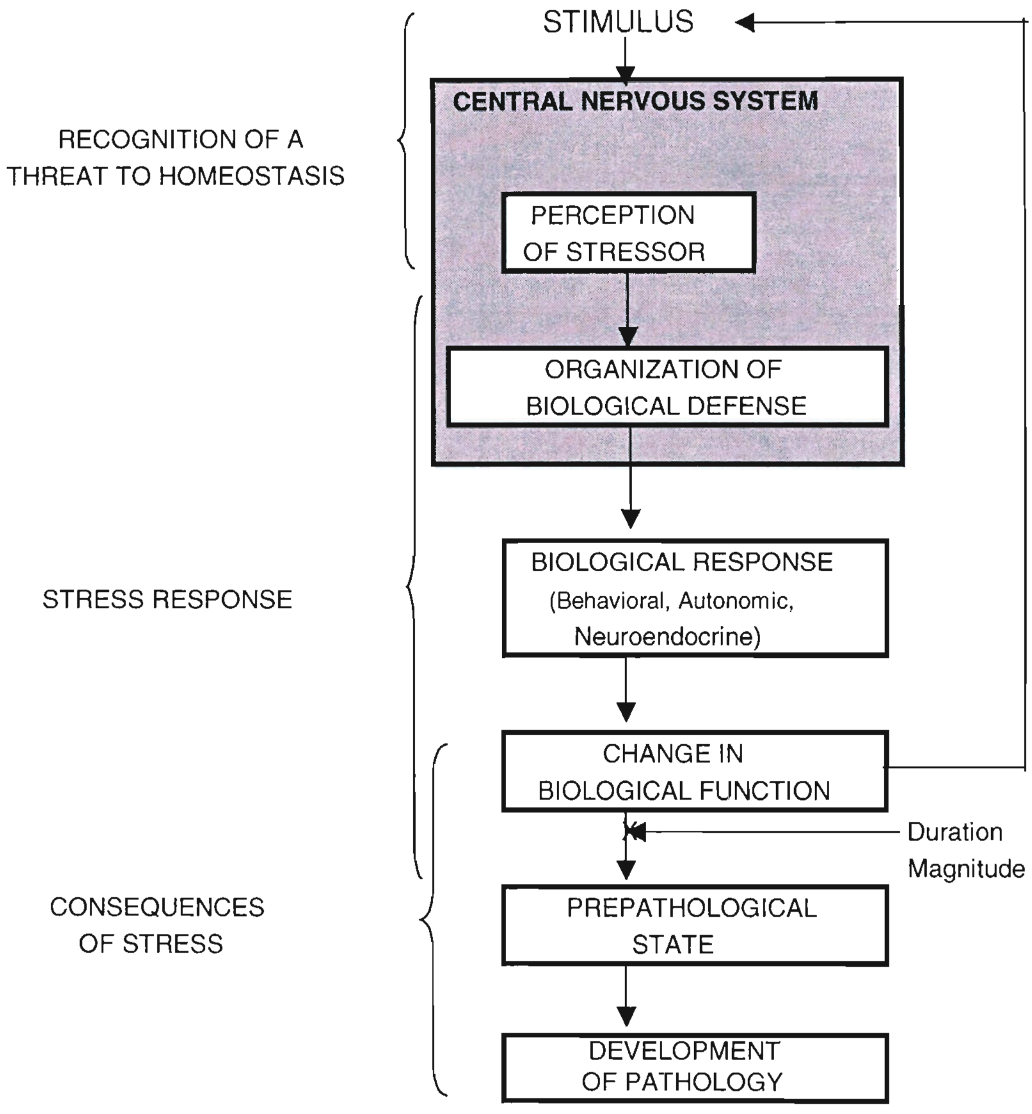

Figure 1.1: Model for response of animals to stressful events (Moberg 1983)

These hormones stimulate conversion of protein to carbohydrates for energy (Frandson 1992). Although the release of glucocorticoids are natural and an evolved mechanism of adaptation to changes in the environment for survival, constant stimulation or triggering of this mechanism over the longterm may be detrimental. Chronic high levels of circulating glucocorticosteroid (days to weeks) can inhibit gonadotropin secretion resulting in suppression of growth hormone secretion (plus insulin-like growth factors) to inhibit growth, involution of gonads and delay of puberty onset, decreased arachidonic acid formation which disrupts cell processes and neuron death in the hippocampus, metabolic exhaustion from breakdown of skeletal muscle and suppression of T-lymphocytes activity resulting in an increase in susceptibility to disease (Wingfield & Ramenofsky 1999). It is not efficient and often too late to use signs of sickness, no reproduction and no growth as measurements for stress. Therefore the likely end points of stress that constitutes an animal's response to a stressful situation such as behavioural, autonomic and neuroendocrine responses should rather be used for measurement of stress (Moberg 1983).

The current study focuses on first identifying the emergency responses of the African elephant, what disturbance factors causes the elephant to change its behaviour for the period a disturbance factor is present and more specifically the presence of human disturbances on small reserves as possible disturbance factors. The study contributes to the science of biology in that it describes different methods of measuring stress in animals and distinguishes between different types of stress that animals are exposed to. The benefits of this type of research for wildlife management on small reserves includes first of all a better understanding of elephant behaviour which enables individuals coming into regular contact with elephants to identify signs of stress or irritation at an early stage before aggression and possible injury towards tourists are evoked. Secondly regular monitoring of elephant behaviour and vocalization will assist in the identification of disturbance factors along with the elimination or reduction of such factors on small reserves by managers which will ensure higher quantity and better quality sightings of elephant for tourists and optimum mental and physical health of elephants.

The main objectives of the study are to:

(1) describe methods of measuring stress in the African elephant
(2) distinguish between social stress and stress caused by direct human disturbance in the African elephant
(3) monitor stress caused by direct human disturbances in the African elephant
(4) monitor stress caused by disrupted social structure in the African elephant

(5) develop management strategies to reduce the presence of factors causing stress in the African elephant

Because the above set goals covers a broad spectrum of factors the project are divided for more detailed description of specific stress parameters into the following sections:

(1) Disrupted social structure as a possible cause of stress for the African elephant (comparing the elephants of Mabula Game Reserve which were originally translocated to the reserve as a group of juvenile elephants from culling operations without any adults with elephant under circumstances of minimal human interference with complete social structures as described by literature)

(2) Behavioural response to direct human disturbances as indicator of stress in the African elephant (measuring vocalizations, bull aggression, signs of stress behaviour, group mobility, group spacing and general daily activity patterns as parameters for stress during periods when game drive vehicles are present in the area of the elephant compared to periods when game drive vehicles are absent)

(3) Physiological response as indicator of stress in the African elephant (measuring temporal gland secretion and fecal stress hormone metabolite levels as parameters for stress during periods when disturbances are present in the elephants environment compared to periods when disturbances are absent)

Chapter 2
GENERAL METHODS

The study area, Mabula Game Reserve, is a 10 000 ha reserve with big five status that is primarily orientated towards tourism. Currently the reserve hosts a group of ten elephants (one adult male, four adult females and five calves) that stay together most of the time, except for the adult male that leaves the group for short periods from time to time.

GEOGRAPHICAL LOCATION AND SIZE

Mabula Game Reserve is situated in the southern foothills of the Waterberg mountain range of the Limpopo Province, South Africa (24°42' to 24°50', 27°50' to 27°58'; De Bruin 1995). The vegetation is classified as sourish mixed bushveld (Acocks 1988) within the savanna biome (Low & Rebelo 1996). The reserve is divided into two separately fenced sections by the Renosterhoekspruit provincial road, i.e. Madjuma Lion Reserve of approximately 1500 ha and the Mabula Game Reserve of approximately 8500 ha in size. The elephants only occur on the Mabula Game Reserve section.

TOPOGRAPHY

According to Bredenkamp and van Rooyen (1990) Mabula Game Reserve can be divided into mountain veld, plains (mostly in the southern section where the area is flat to undulated with rocky outcrops) and drainage contours that forms streams flowing in a northern or southern direction as a result of a mountain range that traverses the study area in the north. The height above sea level of the reserve is between 1140 m and 1432 m. Most of the drainage lines have a continuous water flow during the wet season, which is the main reason for most of the earth dams being constructed in the drainage lines (De Bruin 1995).

GEOLOGY

The two main rock formation types of Mabula Game Reserve are granite and quartzite, although granophire, shale, felsite and andesite are also present to a lesser extent. The reserve can basically be divided into a northwestern sedimentary and southeastern granite section. A few faults are present as well as dykes and seams. The soil types are thus also mainly residual granite and quartzite or transferred soils originating from one of the above mentioned rock formations (Kriel 2000).

CLIMATE

The mean annual rainfall of Mabula Game Reserve is 602 mm, with the wet season stretching from October to April and the dry season from May to September. The mean annual temperature is 18.9° C with the warmest daily temperatures recorded in January and the coldest in June or July (Seliers 1998).

VEGETATION

According to Low and Rebelo (1998) the vegetation of this transition between Sour- and Mixed Bushveld region can vary from a dense, short bushveld to a rather open tree savanna. Trees that dominate on the shallow soils of this region include *Combretum apiculatum, Acacia caffra, Dichrostachys cinerea, Lannea discolor, Sclerocarya birrea* and *Grewia* species. On the deeper more sandy soils *Terminalia sericea, Ochna pulchra, Grewia flava, Peltophorum africanum* and *Burkea africana* are more dominant.

FAUNA

Other large mammal species besides the elephant that currently occur on Mabula Game Reserve include the following:

(1) Bulk grazers: white rhinoceros *Cerathotherium simum simum*, zebra *Equus burchelli*, hippopotamus *Hippopotamus amphibius* and buffalo *Syncerus caffer*
(2) Other grazers: blue wildebeest *Connochaetes taurinus*, red hartebeest *Alcelaphus buselaphus* and tsessebe *Damaliscus lunatus*
(3) Grazer/browser: gemsbok *Oryx gazella*, springbok *Antidorcas marsupialis*, sable antelope *Hippotragus niger*, eland *Taurotragus oryx* and impala *Aepyceros melampus*
(4) Large browsers: giraffe *Giraffa camelopardalis* and kudu *Tragelaphus strepsiceros*
(5) Carnivores: lion *Panthera Leo* (only on the 1500 ha Madjuma Lion Reserve section) and leopard *Panthera pardus*

Further, the reserve also hosts some 15 amphibian species, 48 reptile species and 308 species of birds (De Bruin 1995).

TOURIST ACTIVITY

Mabula Game Reserve consists of a main lodge capable of sleeping 150 people, three time-share camps (Bush lodge, Sunset hill and Modjadji) capable of sleeping 530 people, one private camp (Mannekamp) and two areas with 30 private houses (in the Mokaikai and Modjadji area). The reserve has an average daily load of 800 people and no 2 km² block without an accessible road. Private vehicles are only allowed to drive between residential areas and tourists can only view game on the rest of the reserve by booking a game drive on an open 4X4 vehicle which seats up to eight guests and is driven by a qualified ranger. Mabula Game Reserve utilizes a system that control game drive vehicle activity around the vicinity of the elephant. The vicinity of the elephant is defined as the estimated 500 m radius area around the exact location where the elephants have most recently being seen. The system operates through all reserve users keeping in contact through radio communication when entering the area of the elephant. A maximum of five vehicles are allowed in the area of the elephant and two vehicles at the elephant sighting itself at any particular time. As soon as a vehicle leaves the area another one can enter. The first vehicle at an elephant sighting usually assesses the elephants status and direction of movement before contacting other game drives in the area and before specifying the direction of approach for the rest of the game drive vehicles towards the elephant sighting so as not to block the elephants way, cut of their escape route or encircle them. Further no vehicles are allowed off road or closer than 30 m from the elephant. When the elephants occur away from any main roads between camps and only on or in the area of authorised game drive vehicle roads, no game drive vehicles are allowed in the area of the elephant during midday (10:00 to 15:00) and night (19:30 to 5:00) periods. The main game drive times are during the morning periods between 6:00 and 9:00 and during the afternoon periods between 15:30 and 18:30. On average 450 tourists go on drives to view game on the reserve every day.

THE HISTORY OF THE ELEPHANT OF MABULA GAME RESERVE

(See Appendix A for identification details on the elephants of Mabula Game Reserve)

In 1990, the first five elephant on Mabula Game Reserve had to be removed due to gradual habituation to humans via tourists feeding them and making close contact followed by the elephants losing their natural fear of humans, damaging property and threatening human life. In 1992 six juvenile African elephants were translocated from the Kruger National Park's annual culling operations to Mabula Game Reserve. The four cows and two bulls came from four different family groups and were aged between five and eleven years (De Bruin 1995). Because of increasing aggression towards rhinoceros *Ceratotherium simum,* one of the bulls was shot at the end of 1998. Since then no other incidences of physical interactions and aggression toward white rhinoceros have been recorded from any of the remaining elephant on the reserve. Thus far five elephant calves have been born on Mabula Game Reserve since the re-introduction of the group in 1992: one in 1999, one in 2000, two in 2002 and one in 2003.

In 1999, Mabula Game Reserve started to give the elephants feed supplementation in the form of lucern. The reason for this was to try and reduce the impact of the elephants on the vegetation, to maintain a good body condition of the elephants (especially the lactating cows), to increase the number of elephant sightings by tourists when the elephants were fed in more visible locations and to habituate the elephant to game drive vehicles. In the year 2000 the lucern was replaced by game pellets (mainly produced from *Dichrostachys cinnerea*) to reduce waste and also because the pellets were more preferred by the elephants. The composition of the game pellets is as follows:

Protein (min)	100 g/kg
Fibre (max)	350 g/kg
Moisture (max)	120 g/kg
Fat (min)	25 g/kg
Phosphorus (min)	3 g/kg
Calcium (max)	15 g/kg

The feeding recommendations on the bag states that the feed can be provided *ad lib.* to any game. The elephants are usually fed between four and eight bags (50 kg each) of game pellets at a time. Feeding takes place at random throughout the year with consecutive feedings ranging from every second day to every twentieth day at different times of day and locations in order to ensure that they do not become dependent on the feed. The feed is usually put out in an opening by the same person using the same vehicle with a minimum distance of 40 m from the closest accessible road to game drive vehicles and at a location closest to the area where the elephants occur according to the radio telemetry equipment (McMillan, pers.comm.2001).[1] On the 12th of April 2002 two of the four adult cows (Nikita and Dabula) on Mabula Game Reserve were put onto contraception for the first time. The porcine zona pellucida vaccine used for contraception (Berchinger *et al.* 1999) was injected via a drop out dart from a game drive vehicle. On the 2nd of May 2002 Nikita and Dabula was again darted from a vehicle and on the 14th of June 2002 Nikita, Dabula and Bekile were darted from a helicopter for contraception. The darting operations were not expected to have a long-term effect on the stress levels of the group of elephants. No data were collected during the periods immediately after the contraception dartings as the reserve was closed off to any vehicles around the elephants for a day. Other direct human interactions with the elephant on Mabula Game Reserve since 1992 included the following:

1992 – Elephants tracked and grouped via helicopters, captured in bomas in Kruger National Park and translocated to Mabula Game Reserve via trucks where they were initially released in a boma for a month.

1994- Bekile darted and immobilized from a helicopter to remove a piece of irrigation pipe from her tusk.

1996 – Ngama and Dabula darted and immobilized for collar fitting and removal.

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[1]Jock McMillan, Ecological manager. Mabula Game Reserve, Warmbaths, South Africa.

1998 – The oldest bull (16 years) darted from a helicopter and put down due to increased aggression towards rhinoceros.

2000 – Bontle and Ngama darted and immobilized from a helicopter to fit and exchange new collars for tracking purposes.

2001 – Ngama darted and immobilized from a helicopter and his collar removed due to a twist in the collar that had cut the skin on his neck.

DATA COLLECTION

The data collection period in the field on Mabula Game Reserve stretched from February 2002 to March 2003. One of the elephant cows on the reserve, Bontle, had a radio-collar fitted which made tracking of the group with a radio-telemetry possible for most of the observation period. During January 2003, however, the radio-telemetry equipment started giving trouble and the presence of fresh footprints and dung had to be used to track the elephants for the remainder of the time. During data collection periods, the elephants were observed through binoculars at distances ranging from 40 m to 150 m. Data was recorded either through completing data sheets and writing notes or by using a digital video camera to capture elephant activity. Observation time was reduced considerably as following the elephant on foot or off-road, using a 4x4 vehicle, was not viable because of added disturbance which might have affected behaviour and thus altered results on signs of stress observed for the elephants. The same vehicle to which the elephants had become habituated to at a minimum distance of 30 m during the previous study in 2001 was used for observation of elephant for the current study (Pretorius 2001). Because the vehicle used for observation was a constant factor present in the elephant's environment for the times of observation, the effect of the observer's vehicle on elephant behaviour was not considered to be biased in the results compared to other human activities which varied in presence and absence at elephant sightings. In other words although the elephants did respond to the observers vehicle at times, an observation session was classified as either a no disturbance period (with only the observers vehicle in the area of the elephant and no other observable human activity and game viewing vehicles present) or a disturbance period (with the observers vehicle in the area of the elephant as well as other game viewing vehicles and human activity). Any effect in the results introduced by the presence of the observers vehicle would only bias the data conservatively and reduce the probability of finding any effect of for example game drive vehicles. For the purpose of the study, Mabula Game Reserve was divided into eight sections according to topography (section borders along mountain ranges), intensity of human activity and the main areas that the elephants and game drive vehicles utilize (as estimated from the previous study, Pretorius 2001) (Figure 2.1).

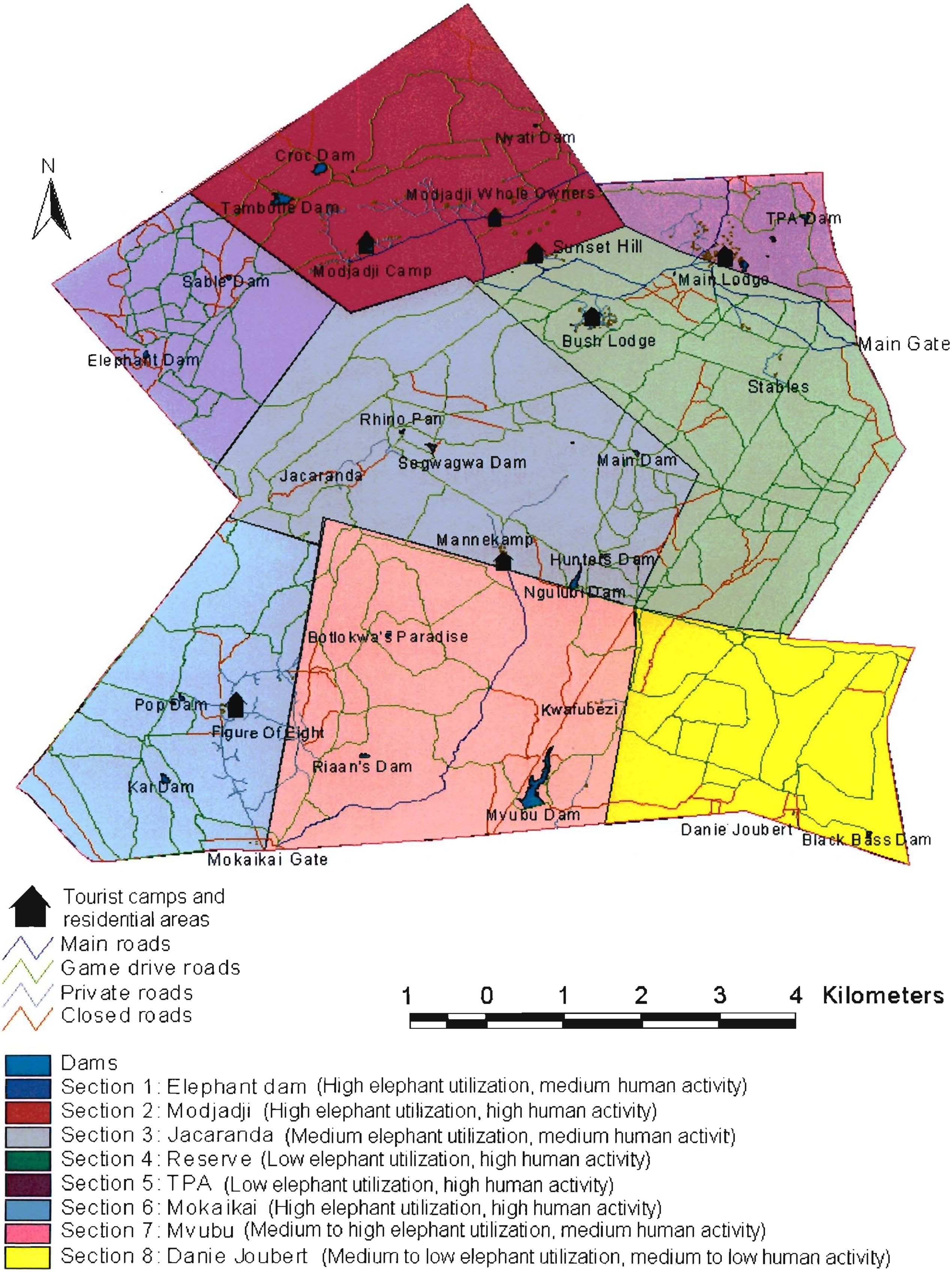


Figure 2.1: Mabula Game Reserve elephant area map

Whenever the exact location of the elephants could be determined reference was made to the following factors to describe the immediate environment around the elephants:

(1) GPS co-ordinates of the location

(2) Date

(3) Time observation starts and ends

(4) Elephant status:

 (a) visible (V) – one or more of the elephants visible enabling observation of behaviour

 (b) audible (A) – none of the elephants visible but close enough to observer for identification of sounds of feeding and vocalizations produced by the elephants (within a hearing range of 150 m from the observer)

 (c) not observable (N) – elephant location only confirmed through a clear signal from the telemetry equipment

(5) Estimated elephant distance from observer in meters using visual assessment, radio telemetry equipment and sounds produced by the elephant

(6) Bull presence (presence or absence of the only adult bull on the reserve in the female herd)

(7) Interval of observation divided into:

 (a) first ten minutes of observation after the first game drive vehicle arrived at an elephant sighting

 (b) the period of observation after ten minutes of the arrival of the first game drive vehicle

(8) Total amount of elephants present at the location of observation.

(9) Disturbance type present at an elephant sighting:

 (a) No disturbance (N)

 (b) Vehicle noises audible to the observer in the area of the elephant but no game drive vehicles visible at the elephant sighting (hearing range used for observation was an estimated 150 m from the location of the elephants) (A)

 (c) Other human disturbances like low flying helicopters present and visible at an elephant sighting (SO)

 (d) Other human disturbances like building activities close to residential areas audible but not visible to the observer in the area of the elephant (AO)

 (e) Other species like rhinoceros present at an elephant sighting closer than 40 m from the elephants (SS)

(10) Estimated distance of disturbance from elephants

(11) Number of vehicles present at an elephant sighting

(12) Number of vehicles present in the vicinity of the elephant determined via radio communication and defined by the sections into which the reserve has been divided into for

the study. For instances where the elephant were close to the border of an adjacent section which may have contained a large number of vehicles the vehicles in an estimated 500 m radius around the elephants were all counted.

(13) Presence of control of game drive vehicle activity at elephant sightings via radio communication:

(a) Game drive vehicle activity controlled through radio communication by qualified authorised game vehicle drivers (C)

(b) Game drive vehicle activity uncontrolled because the distance of one or more of the vehicles from the elephants are less than 40 m (UD)

(c) Game drive vehicle activity uncontrolled because the direction of approach by vehicles towards an elephant sighting are from more than one side (UDA)

(d) Game drive vehicle activity uncontrolled because more than five vehicles are in the area of an elephant sighting at a specific time as defined by the sections into which the reserve has been divided into for the study (UVA)

(e) Game drive vehicle activity uncontrolled because more than three vehicles are at an elephant sighting at a specific time (UVS)

(14) Time of day:

(a) Morning:05:30 – 10:00

(b) Midday: 10:01 – 14:30

(c) Afternoon: 14:31 – 19:00

After the environment around the elephants was described, data on the stress parameters chosen to be measured for the study for each of the elephants as well as for the group as a whole were collected. The possible stress that the elephants on Mabula Game Reserve experienced was allocated due to two sources, of which the effect of each was measured via different possible parameters, including:

(1) Internal sources (stress caused by disrupted social structure) - using a comparison between the role of the matriarch, calf play activity, mother-calf spacing, bull aggression and bull presence in complete elephant societies under conditions of minimal human disturbance to the elephant on Mabula Game Reserve. Deviations in behaviour of the study group of elephants from elephant behaviour as described by literature served as an indicator of possible added social stress for the elephants on Mabula Game Reserve.

(2) External sources (stress caused by direct human disturbances or other environmental factors) using stress behaviour response, group spacing, group mobility, vocalization and temporal gland secretion as possible stress parameters.

The stress hormone levels in the dung of the elephant and the general distribution and movement of the elephants across the reserve served as a parameter for both stress experienced due to internal and external disturbances. Although the parameters used for measuring the effect of direct human disturbances could also be affected by social disturbances among the elephants, the comparison of each parameter in the presence and absence of direct human disturbances served to eliminate this problem. For data capture and analysis the computer software programs Windows Office 2000, SPSS 11 and Arcview (version 3) were used.

In addition to the monthly reports showing the elephant distribution across the reserve, daily reports were also completed for the purpose of measuring the effect of general daily environmental factors present in the elephants environment on the measured parameters for stress, including the following information:

(1) Rainfall
(2) Minimum and maximum temperatures
(3) General weather conditions for the morning, midday and afternoon period (e.g. cloudy, windy or thunder)
(4) Total cumulative number of game drive vehicles present at the elephant sighting for each of the morning, midday and afternoon period
(5) Total cumulative number of game drive vehicles present in the vicinity of the elephant determined via radio communication with other reserve users for the morning, midday and afternoon period
(6) Other disturbances present around the elephants for the morning, midday and afternoon period (e.g. fires or low flying helicopters doing game counts)
(7) General control of game drive vehicle activity in the vicinity of the elephant for the morning, midday and afternoon period
(8) Notes on any significant events concerning the elephants (e.g. estrous or injury)

Chapter 3
INDIVIDUAL VARIATION IN BEHAVIOUR AND DEVIATION IN SOCIAL ROLE PLAY OF A GROUP OF ELEPHANTS ON A SMALL RESERVE COMPARED TO ELEPHANT BEHAVIOUR AS DESCRIBED BY LITERATURE

Abstract

Indirect disturbances or internal sources of stress affecting an animal such as disrupted social structure caused by human interference are often difficult to measure. The social role play and behaviour of a group of elephants (re-introduced to the study area ten years earlier from culling operations as juveniles, without any adult elephant) were compared with elephants with complete social structures under conditions of minimal human interference as described in the literature in an attempt to identify possible added social stress. None of the five adult elephant in the study group initiated change of group activity significantly more than another. Although one of the adult female elephants in the group dominated over all the other adult females, the twenty-year-old bull on the reserve dominated her. The twenty-year-old bull further spent most of his time with the herd and was aggressive towards other cow herd members. Some calves did not spend the amount of time specified by literature with their biological mothers and adult elephants secreted more from their temporal glands and displayed more behaviours associated with stress than did elephant calves. The results indicate a lack of social structure among the study group of orphan elephants even after ten years of introduction to the reserve, which corresponds to studies conducted in other small reserves with the same elephant history before elder elephants were introduced.

3.1 Introduction

African elephants live in matriarchal societies. Their basic social unit is a family group composed of adult females (mostly closely related) and dependent offspring (Laws & Parker 1968). As herd size increases (usually beyond ten animals), the herd splits, but remains in loose association as "bond groups". These bond groups are thus families that are mostly related and that like to associate with each other for short periods of time (depending on the relationship between particular individuals and the time span of separation). Bond groups that inhabit the same home range are called "clans" that sometimes come together in aggregation. The bonds among elephants in a clan are not close but during these periods of aggregation older females re-establish dominance hierarchies and young males challenge each other to test their strength (Moss 1988).

Today it is recognised that the elephant's lifespan of over fifty years provides for a long period of development and learning in which members of a family develop close and lasting relationships through regular vocal and tactile interactions. The matriarch (usually the oldest and most experienced member of the family) is the most important animal in a family in training the young, though other members also assist. She will implement the protective circle when she feels the young in the herd are threatened, will be the one to charge out of the circle to carry the attack to an enemy if necessary and always directs movement (Lee 1997). A matriarch is also always dominant over the other members in the group (Lawley 1994).

Family groups are synchronized in activities and it is rare to find members doing several things. All the individuals of a family group are together for about 90% of the time (Moss 1988). Females reach the reproductive stage of their lives at about ten years of age and produce a calf after a gestation period of 22 months at four to five year intervals (Lee 1997). According to Moss (1988) mothers and calves spend 99 % of their time together. Other literature reports young calves in their first year to spend most of their time relatively close to their mothers (within a couple of elephant lengths) and for calves to spend more than 5% of their time playing (Lee 1997). Playing behaviour is mainly limited to the younger aged animals that are going through a stage of growth that involves a flexibility of behaviour to prepare them for survival. (MacKenzie 1998).

When males reach puberty between the ages of 10 to 12 years, they leave the matriarchal herd and form small bachelor groups with individuals coordinated in their activities (Douglas-Hamilton 1972). To prevent inbreeding, although young males can successfully mate when they reach puberty, males between the age of 10 and 18 years are chased out of the family group by the matriarch assisted by other adult females if they do not leave by themselves. Transitional bulls (about 20 years) though will be dominant over the matriarch because of shear size but will not fight with her or be aggressive towards other cows. Usually to prevent young bulls from staying with the family groups, older bigger bulls and bulls in musth also dominate and chase young bulls away from the herds (Moss 1988). When compared to members of a true family, bonding in bull herds is on a very low level. As males mature, they become more solitary, occasionally approaching matriarchal herds to presumably test for receptive females (Moss 1988).

Adult male elephants also periodically enter a state of musth that is characterized by aggressive behaviour, restlessness and dribbling of urine from the prepuce (Poole & Moss 1981). Poole (1989a) reports that a musth bull is always dominant over a non-musth bull when they compete for an estrous female. Those bulls with signs of musth have been observed to spend more time with females, to be solicited more often by estrous females, to mate more often with them and to travel greater distances (Poole 1989b).

Diurnal activity patterns of the African elephant are dependent on a variety of factors and have been described in several studies. The biggest environmental influences on activity seem to be the time of day, season and climate of a specific area. In general, according to Poole (1997), elephants feed for 60% - 70% of the time. Feeding activity for most studies increased during the dry months while daily feeding peaks occurred mostly in the morning and afternoon (Wyatt & Eltringham 1974; Guy 1976; Kalamera (1987). Both Kalamera (1987) and Wyatt and Eltringham (1974) observed elephants drinking 1.5 times a day. According to Guy (1976) resting occurs mostly during midday for the elephant of Sengwa (Zimbabwe) and increases up to 42% during the hot season. Guy (1976) also noticed an increase in wallowing activity during the wet season. On Mabula Game Reserve De Bruin (1995) observed the elephants to feed an average of 62% of the time with feeding peaks occurring mostly in the morning and resting peaks at midday.

The main aim of this study was to describe and measure the possible occurrence of social stress in elephants that has been translocated and introduced into fenced areas without a complete social structure. By identifying and describing all the elements that elephants require from their environment including social structure and security, wildlife managers can ensure the well-being of elephants in fenced areas and thereby reduce incidences of aggression towards and injury of other species and provide better quality and higher quantity sightings of relaxed elephants to tourists. Each organism is to an extent adapted to cope with every day changes in the environment in which it evolved. Possible disturbances or stressors which cause stress for an animal can be divided first of all into indirect (internal) stressors or direct (external) stressors and then further divided into natural stress (stress caused by changes in the environment that the animal evolved with) or stress induced through human interference. For the current study, indirect stressors originating from human interference and more specifically disrupted social structure as a cause for stress in the African elephant was investigated. The elephants of Mabula Game Reserve were originally introduced as a group of juvenile elephants from the Kruger National Park ten years ago without a matriarch or any adult bulls and cows in the herd. The social behaviour of this group of elephant with disrupted social structure were compared with the social behaviour of elephants with complete social structures under conditions of minimal human interference as described by literature.

3.2 Methodology

3.2.1 Matriarch dominance

A matriarch is always dominant over other group members (Lawley 1994) except for transitional bulls (about 20 years) which will dominate over the matriarch because of shear size (Moss 1988). A dominance hierarchy was established for all the adult elephants on Mabula Game Reserve in order to determine whether one of the adult female elephants dominated over all the others. A total of 10 observations of each of the five adult elephant interacting with any of the remaining adult elephant in the group were collected. The interactions were only recorded when they caused one or the other of the two elephants interacting to be displaced from their current position either by being pushed away or by moving away when the other elephant approached that particular position. When an elephant moved away from his/her current feeding spot without any physical contact with the elephant approaching, the observation was only recorded when the elephant moving away noticed the other elephant approaching first by, stopping to feed, lifting the head and ears and turning the head slightly side-ways away from the approaching elephant, and when after moving away the dominant elephant started to feed at the displaced elephants previous feeding spot. The dominance hierarchy was described by compiling a dominance matrix for the five adult elephant on Mabula Game Reserve and the linearity measured using Landau's index of linearity (h) (Martin & Bateson 1993):

$$h = \frac{12}{n^3 - n} \cdot \sum_{a=1} (v_a - ½(n-1))^2$$

v_a = number individuals whom individual a has dominated

n = number of animals in group

Index: 0 – 1, 1 = perfect linearity

3.2.2 Matriarch lead

A matriarch always directs movements (Lee 1997). A single cow on Mabula Game Reserve was identified as being dominant (see results) and the prediction was tested that, as with a normal elephant society, this cow would initiate movement by the group. A total of 25 observations were made of the first elephant identified to initiate change of the general activity of the group of elephants on Mabula Game Reserve. According to Poole (1997), the matriarch's lead is subtle and she is not necessarily the individual walking in front at all times. Therefore the animal initiating change was not necessarily the elephant walking in front of the group but was identified as being the first individual to terminate the current general activity (e.g. feeding, drinking, resting, mud bathing, dust bathing, moving and other) of the group and start moving to a new location joined by the others where the same group activity was resumed or a new activity initiated. The group had to have moved more than 100 m from their original location before the observation was considered to be valid. The data were analysed statistically using the log-likelihood ratio test (G-test):

$$G = 2 \sum^{a} h_i \ln \left(\frac{h_i}{\hat{h}_i}\right)$$

a = number classes, h_i = observed frequencies, $\hat{h}_i$ = expected frequencies (Sokal & Rohlf 2001).

3.2.3 Bull presence

When males reach puberty between the ages of 10 to 12 years, they leave the matriarchal herd and form small bachelor groups with individuals coordinated in their activities (Douglas-Hamilton 1972). For this study a prediction of 50% or less was used as an indicator of the maximum amount of time that an adult bull elephant normally spends with a cow herd. This is a conservative value, as the normal value is probably closer to 80%. However no quantified data were available from the literature to provide for a more accurate prediction. For all observations note was taken on the amount of time that the twenty year old bull spent with the cow herd and the amount of time that he was absent from the herd. If the bull could not be spotted within an estimated 250 m radius around the cows he was recorded as being absent. To verify this, his actual location was confirmed through utilizing spoor and radio communication with the other reserve users. All days that the elephants were observed for more than 10 minutes at a time were used for analysis. The data were pooled into days instead of minutes to avoid the effect of pseudo-replication. Each day of observation was divided into one of either two categories. If the bull was with the cows for the entire time of observation the day was categorized as "bull present" and if the bull was absent from the cow herd during the time of observation the day was categorized as "bull absent". The data were analysed statistically using the chi-square test.

3.2.4 Bull aggression

Bulls are rarely aggressive towards cows (Moss 1988). Any aggression from the bull towards any of the cow herd members served as an indicator of disrupted social structure and possible social stress. Data were collected throughout the study period from March 2002 to March 2003. Each day, as soon as the bull was confirmed to be with the cow herd and was visible, data collection started until the elephants disappeared into the bush away from any accessible roads. During these data collection periods note was made of any aggressive interactions initiated by the bull towards any of the other herd members. An index value was awarded to each type of aggression according to the degree of aggression as follows (a high index indicate high aggression):

(1) Head shake towards another elephant (HSE), Index value: 1
(2) Chasing another elephant (CH), Index value: 2

(3) Pushing another elephant out of the way (PU), Index value: 2
(4) Kicking another elephant (K), Index value: 3
(5) Pushing hard/bumping another elephant with the head (PH), Index value: 3
(6) Sparring with another elephant (SP), Index value: 4
(7) Tusking another elephant (TK), Index value: 4
(8) Trunk slapping another elephant (TSE), Index value: 4

Further the elephant with whom the bull was aggressively interacting with was identified together with the type of interaction, for example bull-cow or bull-calf. All days that the elephants were observed for more than 10 minutes at a time were used for analysis (N = 21 days). The data were pooled into days instead of minutes to avoid the effect of pseudo-replication. The days of observation when the bull was with the cow herd were divided into one of either two categories for statistical analysis, namely "bull aggressive" or "bull not aggressive" days. The data were analysed statistically by comparing the number of days that the bull was aggressive towards the cows to the number of days when he was not aggressive using the chi-square test.

For further descriptive analysis a score for each observation session was calculated by multiplying the number of aggressive interactions of the bull with the other cow herd members with the index values for each type of aggression. The purpose of this score was to indicate whether the bull was more aggressive towards some elephant cows and calves than others.

3.2.5 Mother-calf spacing

According to Lee (1997) young calves in their first year spend most of their time relatively close to their mothers (within two adult elephant lengths) and according to Moss (1988) mothers and calves spend 99% of their time together. For the study a prediction of 90% (to be conservative) or more of the time was used an indicator of how much time elephant calves normally spend with their biological mothers. A total of 100 observations were collected of the mother-calf spacing of each of the elephant calves younger than two years from the group of elephants on Mabula Game Reserve. The mother-calf spacing was categorized as follows: For each observation the calf was recorded as either being together with its biological mother (in which case the calf was estimated to be between 0 – 8 m from the mother) or being apart from its biological mother (in which case the calf was estimated to be more than 8 m from the mother). The data were analysed statistically using the chi-square test.

3.2.6 Calf play behaviour

Calves spend more than 5% of their time playing (Lee 1997). For the study a prediction of 5% or more was used as an indicator of how much time elephant calves normally spend playing. A total of 100 observations were collected for ten-minute instantaneous samples throughout the study period of the play behaviour of each of the elephant calves younger than two years. For the purpose of analysis each of the minute intervals were divided into either one of two categories, namely "calf playing" or "calf not playing". Playing was defined as calves exploring the environment through pushing and throwing small objects around, rolling on the ground on their backs and sides, interacting with each other by entwining trunks, climbing on top of each other when lying down, chasing each other and other small animals like birds around and gently sparring or pushing each other. The data was analysed statistically using the chi-square test.

3.2.7 Nearest neighbour

Garaii (1997) described through nearest neighbour analysis, group cohesion and the changing social positions of some juvenile elephants relative to other individuals which were affected by dominance hierarchies, individual social relationships and care taking of young. A minimum of 10 samples per elephant was collected of the nearest elephant to the focal elephant as well as the estimated distance (in metres) from the nearest elephant. When vegetation was to thick to identify the nearest elephant to the focal elephant, data collection was terminated until the closest elephant to the focal elephant could be identified. The difference in the average distance from the nearest neighbour between individual elephants was analysed using the Kruskal-Wallis test for independent samples.

Indices of association were calculated for all the elephants on Mabula Game Reserve:

$$\text{Index of association} = N_{AB}/ (N_A + N_B + N_{AB})$$

Where N_{AB} is the number of occasions A and B are seen together; N_A is the number of occasions A is seen without B; and N_B is the number of occasions B is seen without A. Index 0 = no association, index 1 = complete association.

For descriptive analysis, a score was calculated for each individual by dividing the index of association of the elephant with the average distance from the nearest neighbour for that particular elephant with each of the remaining elephant. The purpose of this analysis was to graphically demonstrate whether some elephants had closer bonds with other elephants and socialized more.

3.2.8 Individual variation in temporal gland secretion

Data were collected for a minimum of 20 observation sessions (minimum 7 minute duration) per elephant between March 2002 to March 2003 of the amount of times that the elephant secreted from their temporal glands during each observation session. When temporal gland secretion was present the time of secretion, the name of the elephant secreting and the extent of secretion was recorded for the particular elephant under observation and categorized with ranked index values as follows (Poole 1987):

(1) Temporal secretion to the lower extent of the eye. Index: 1
(2) Temporal secretion to the top part of the lower jaw. Index: 2
(3) Temporal secretion to the corner of the mouth. Index: 3
(4) Temporal secretion to the base of the lower jaw. Index: 4

For the purpose of analysis a value was calculated for each session of observation of temporal gland secretion of each elephant by multiplying the index values with the amount of times that each type of secretion occurred and then summing all values to obtain a total score for each session of observation. For comparison with other elephants, because not all observation sessions stretched over the same amount of time, an index of secretion per minute was calculated by dividing each score with the amount of time that an elephant was observed for each session, to obtain a relative rate per minute.

3.2.9 Individual variation in behavioural response

Data were collected for a minimum of 10 observation sessions (minimum 7 minute duration) per elephant between March 2002 to March 2003 of the number of times that the elephant showed stress behaviour response during each observation session. The type of behaviour associated with stress for each individual elephant under observation was recorded and categorized with index values as follows (high index indicates high stress):

(1) Disturbed behaviour (low response, disturbance and stress)
    (a) Front foot swung not directed towards a disturbance (fsn). Index: 1
    (b) Smelling disturbance with trunk lifted towards disturbance (smd). Index: 1
    (c) Touching temporal gland (ttg). Index: 1
    (d) Abrupt termination of current action while listening (atc). Index: 2
    (e) Head shake not directed towards a disturbance (hsn). Index: 2
    (f) Breaking vegetation without consuming (bv). Index: 2
    (g) Coiling, uncoiling and twitching trunk (ct). Index: 2

(2) Threatened behaviour (medium response, disturbance and stress)
    (a) Turning towards a disturbance with ears spread (tt). Index: 2
    (b) Flapping ears directed towards a disturbance (fe). Index: 2
    (c) Foot swung directed towards a disturbance (fs). Index: 2
    (d) Head shake or head jerk directed towards a disturbance (hs). Index: 3
    (e) Standing tall (head raised high, elephant peering over tusks, ears cocked and trunk hanging at an acute angle) (st). Index: 3
    (f) Threat display (bending down with front of body and pushing head towards ground) (td). Index: 5
    (g) Throwing objects towards a disturbance (to). Index: 5
    (h) Charge towards a disturbance (c). Index: 5
(3) Distressed behaviour (high response, disturbance and stress)
    (a) Ears tilted up and back (eub). Index: 3
    (b) Tail held up and straight while moving around cautiously (tsu). Index: 4
    (c) Move away from a disturbance fast with ears laid flat against shoulders (raf). Index: 5

For the purpose of analysis a value was calculated for each session of observation of behavioural response of each elephant by multiplying the index values with the amount of times that each type of behaviour occurred and then summing all values to obtain a total score for each session of observation. For comparison with other elephants, because not all observation sessions stretched over the same amount of time, an index of stress behaviour per minute was calculated by dividing each score with the amount of time that an elephant was observed for each session.

3.2.10 General activity

A total of 225 ten-minute instantaneous samples for the elephant calves and 403 samples for the adult elephants consisting of a minimum of 5 observations per elephant were collected on activity. For each activity the detail of the type of activity was also recorded, including:

(1) Feeding (F)
(2) Suckling (Su), (together with elephant suckling from)
(3) Resting (R) (trunk hanging down, standing still, head lowered and breathing deeply or lying down still)
(4) Moving (Mo)
(5) Playing (P) (exploring the environment through pushing and throwing small objects around, rolling on the ground on back and sides, interacting with each other by entwining

trunks, climbing on top of each other when lying down, chasing each other and other small animals like birds around and gently sparring or pushing each other)

(6) Drinking water (Dr)

(7) Mud bathing (Mb)

(8) Dust bathing (Db)

(9) Other (O) (standing still not in a resting position, exploring environment with trunk)

(10) Stress behaviour (SB) (see above)

(11) Physical interaction with another elephant (I)

The difference in elephant calf and adult activities were described and the daily activity patterns of adult elephants compared with elephants in general as described by literature. The predicted daily activity values were calculated as an average from the different percentages found by Wyatt and Eltringham (1974), Guy (1976) and Kalamera (1987).

The data was analysed statistically using the log-likelihood ratio test (G-test):

$$G = 2 \sum^{a} h_i \ln \left(\frac{h_i}{\hat{h}_i} \right)$$

a = number classes, h_i = observed frequencies, $\hat{h}_i$ = expected frequencies (Sokal & Rohlf 2001).

3.3 Results

3.3.1 Matriarch dominance

Landau's index of linearity was h = 1 with the twenty-year old bull, Ngama, being dominant over all the other adult elephant on the reserve, Dabula being second in hierarchy, Bekile third, Bontle fourth and Nikita last (Table 3.1). Dabula was therefore defined as being the matriarch of the breeding group.

3.3.2 Matriarch lead

The adult elephant cow identified to most likely be the matriarch of the group (Dabula) did not initiate change of activity at all times and thereby did not lead the group significantly more than any other female (G-test: $G_3 = 432.3$, $P < 0.05$) (Figure 3.1).

3.3.3 Bull presence

Of the 92 days of observation the twenty-year old bull, Ngama, was with the cow herd for 68 days. The twenty-year-old adult bull on Mabula Game Reserve spent significantly less than half of the time away from the cow herd ($\chi^2_1 = 21.043$, $P < 0.05$) (Figure 3.2).

3.3.4 Bull aggression

Of the 331 minutes that the bull was monitored with the cow herd 21 aggressive interactions were initiated by the bull towards other herd members. The same calf (Botlokwa) was kicked on two separate occasions by the bull. The cow involved in most of the aggressive interactions with the bull was Bekile and the fewest Bontle. Bekile was attacked nine times with an aggression score of 32 of which the most common interaction was sparring while Bontle was only pushed away by the bull once (Table 3.2). The elephant bull on Mabula Game Reserve was aggressive towards the other cow herd members on the reserve significantly more than expected (Chi-square test: $\chi^2_1 = 3.857$, $P < 0.05$) (Figure 3.3).

3.3.5 Mother-calf spacing

Nikita and her calf Botlokwa spent less than 90% of the time together (Chi-square test: $\chi^2_1 = 13.4$, $P < 0.05$) while Dabula and her calf Semaka spent 90% or more of the time within 8 m of each other (Chi-square test: $\chi^2_1 = 0.11$, $P > 0.05$) (Figure 3.4).

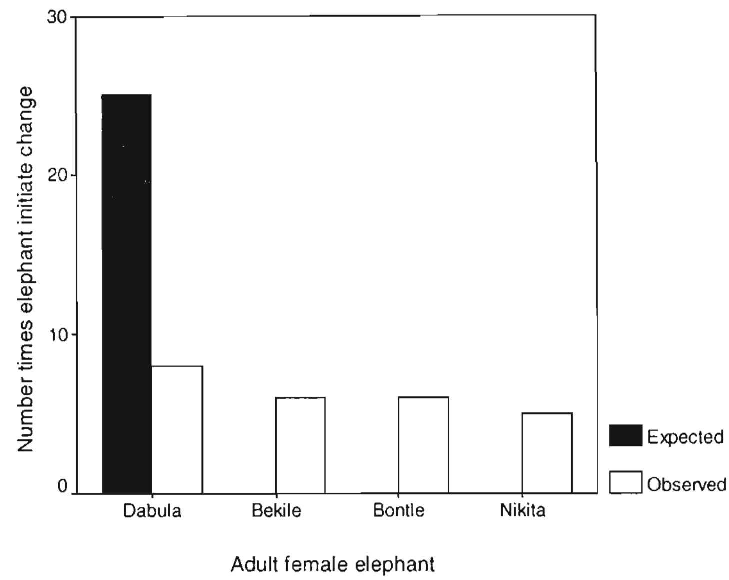


Figure 3.1: Matriarch lead behaviour of the adult female elephant on Mabula Game Reserve Expected: A matriarch always initiates change of activity (see text). The matriarch on Mabula Game Reserve (Dabula) was defined from the dominance hierarchy (see Table 1).

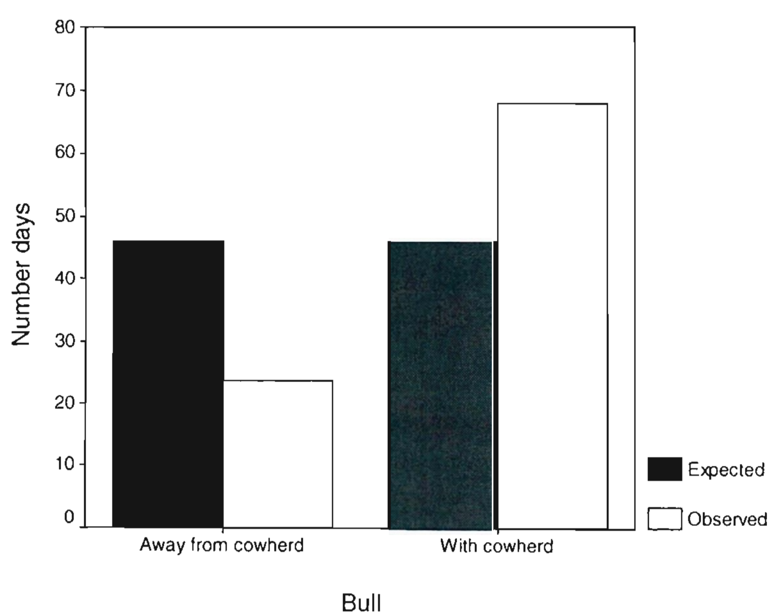


Figure 3.2: Presence of the twenty-year-old bull, Ngama, with the cow herd on Mabula Game Reserve. Expected: prediction of the 50% time an adult male elephant spends with a female family group (see text).

Table 3.1

Dominance matrix for the adult elephant on Mabula Game Reserve.

Individual	Ngama	Dabula	Bekile	Bontle	Nikita	Dominance hierarchy
Ngama		10	10	10	10	1st
Dabula	0		10	10	10	2nd
Bekile	0	0		10	10	3rd
Bontle	0	0	0		10	4th
Nikita	0	0	0	0		5th

* Observation of interaction was halted after 10 interactions between any two individuals had been made.

Table 3.2

Aggressive interactions initiated by the twenty-year old bull, Ngama, towards the other cow herd members on Mabula Game Reserve.

Elephant Interacting With	Type Interaction	Type Aggression	Number of occasions	Index [a]	Score [b]
Bekile	Bull-Cow	Bumping hard with head	2	3	6
Bekile	Bull-Cow	Pushing	1	2	2
Bekile	Bull-Cow	Sparring	4	4	16
Bekile	Bull-Cow	Tusking	1	4	4
Bekile	Bull-Cow	Trunk slapping	1	4	4
Bontle	Bull-Cow	Pushing	1	2	2
Dabula	Bull-Cow	Sparring	3	4	12
Dabula	Bull-Cow	Trunk slapping	1	4	4
Nikita	Bull-Cow	Kicking	1	3	3
Nikita	Bull-Cow	Bumping hard with head	1	3	3
Nikita	Bull-Cow	Pushing	2	2	4
Nikita	Bull-Cow	Sparring	1	4	4
Botlokwa	Bull-Calf	Kicking	2	3	6

[a] an index value was awarded to each type of aggression according to the degree of aggression, [b] a score was calculated from the number of aggressive interactions multiplied by the index values.

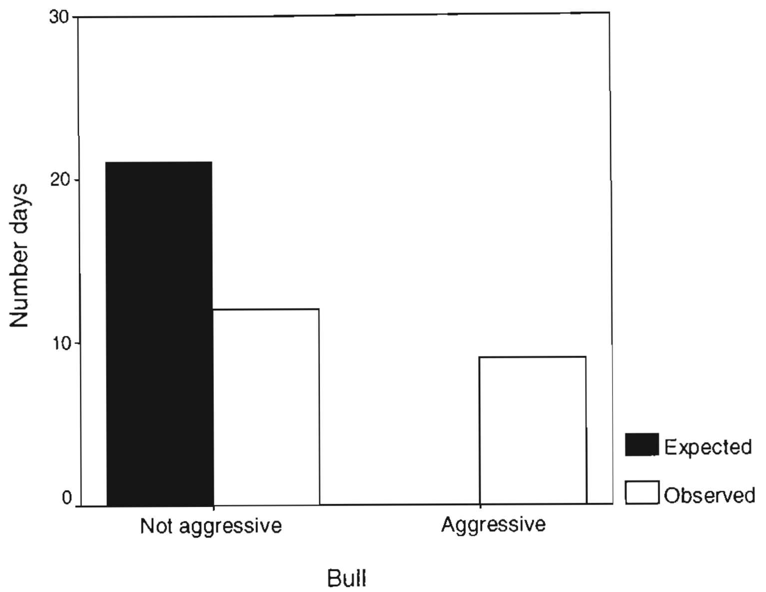
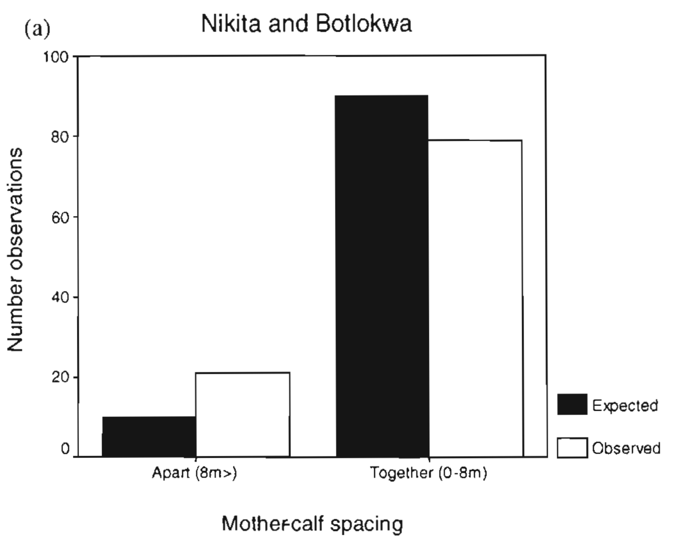


Figure 3.3: Aggression of the twenty-year-old bull, Ngama, towards the females and calves on Mabula Game Reserve. Expected: Adult bulls are not aggressive towards other cow herd members (see text).



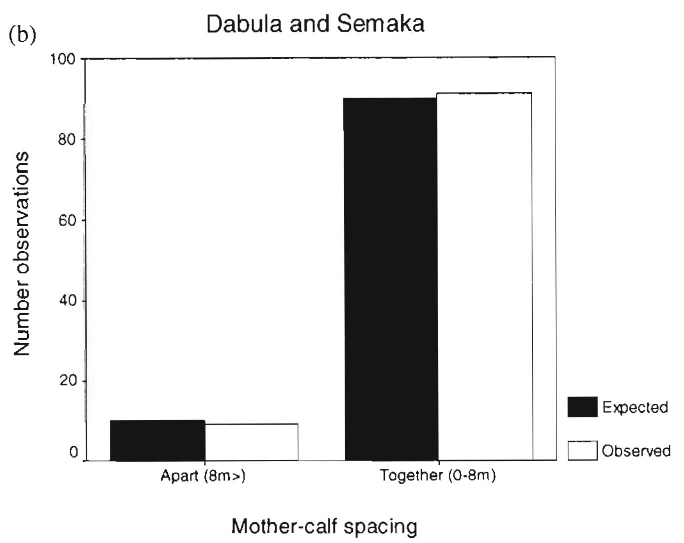


Figure 3.4: Mother-calf spacing between one year-old elephant calves and their biological mothers. (a) spacing between a sixteen-year old cow and her female one-year-old calf, (b) spacing between a nineteen-year-old cow and her second female one-year-old calf. Expected: Elephant calves spend 90% of their time with their biological mothers (see text).

3.3.6 Calf play behaviour

Both Botlokwa (Chi-square: $\chi^2_1 = 30.32$, $P < 0.05$) and Semaka (Chi-square: $\chi^2_1 = 10.32$, $P < 0.05$) played for 5% or more of the time as predicted by literature (Figure 3.5).

3.3.7 Nearest neighbour

The average distance to the nearest neighbour differed significantly between the individual elephants on Mabula Game Reserve (Kruskal-Wallis: $\chi^2_8 = 61.66$, $N = 254$, $P = 0.001$) (Figure 3.6). Although Mafuta was the elephant that associated least with the other elephants, and Ngama the most, Mafuta's average distance from the nearest neighbour was the smallest (1 m) while Ngama's average distance from the nearest neighbour was the largest (63 m) (Appendix B). After accounting for both distance from nearest neighbour and index of association, Bekile was identified to be the most social elephant within the group of elephants on Mabula Game Reserve according to spatial analysis (Figure 3.7,3.8, 3.9 & 3.10).

3.3.8 Individual variation in temporal gland secretion

The individual elephants on Mabula Game Reserve varied in the extent of temporal gland secretion (Figure 3.11). Adult elephants secreted significantly more than calves (Mann-Whitney U-test: $Z = -5.254$, $N = 294$, $P = 0.001$) and adult female elephants secreted significantly more frequently than male elephants (Mann-Whitney U-test: $Z = -4.233$, $N = 172$, $P = 0.00$) (Figure 3.12).

3.3.9 Individual variation in behavioural response

The adult elephants on Mabula Game Reserve displayed significantly more behaviours associated with stress than the elephant calves on the reserve (Mann-Whitney U-test: $Z = -4.132$, $N = 297$, $P = 0.001$) (Figure 3.13). In general Bekile revealed the most behaviours associated with stress while Dabula revealed the least (Figure 3.14).

3.3.10 General diurnal activity

The major differences in activity patterns between individual adult elephants were for Bekile (female) interacting with other elephants the most (14%) compared to Bontle (female) who did not interact, Ngama (male) who rested the most (25%) compared to Nikita (female) who did not rest and Nikita who showed the most signs of stress (8%) compared to Dabula (female) who did not show any signs of stress as measured here (Figure 3.15).

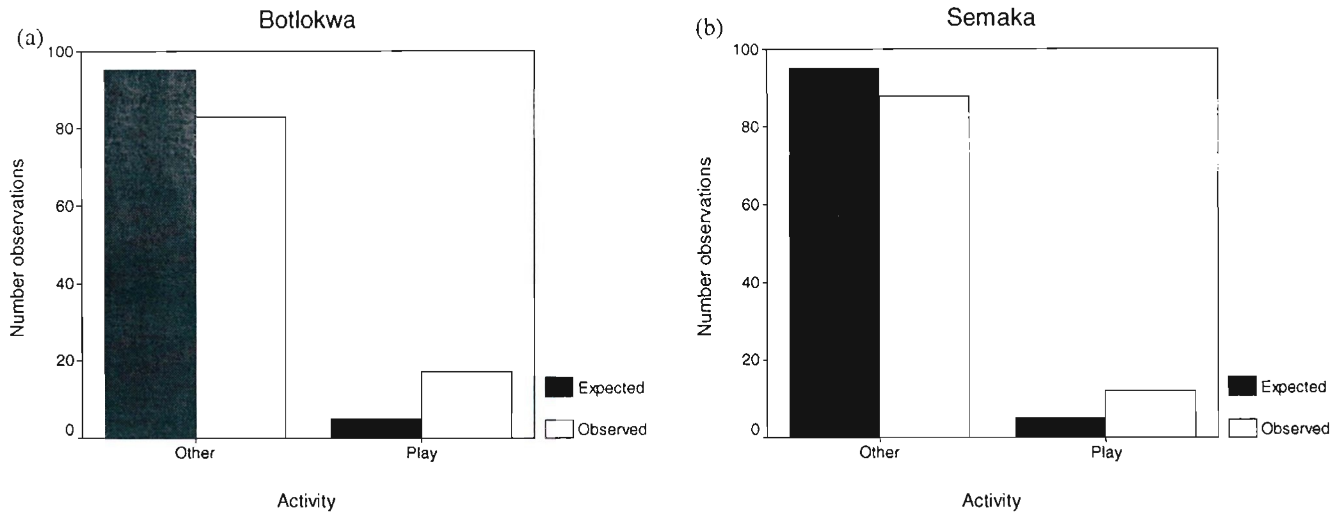


Figure 3.5: Amount of time spent playing by the one-year-old elephant calves on Mabula Game Reserve. (a) play activity of one-year-old female calf Botlokwa, (b) play activity of one-year-old female calf Semaka. Expected: Elephant calves play 5% of the time (see text).

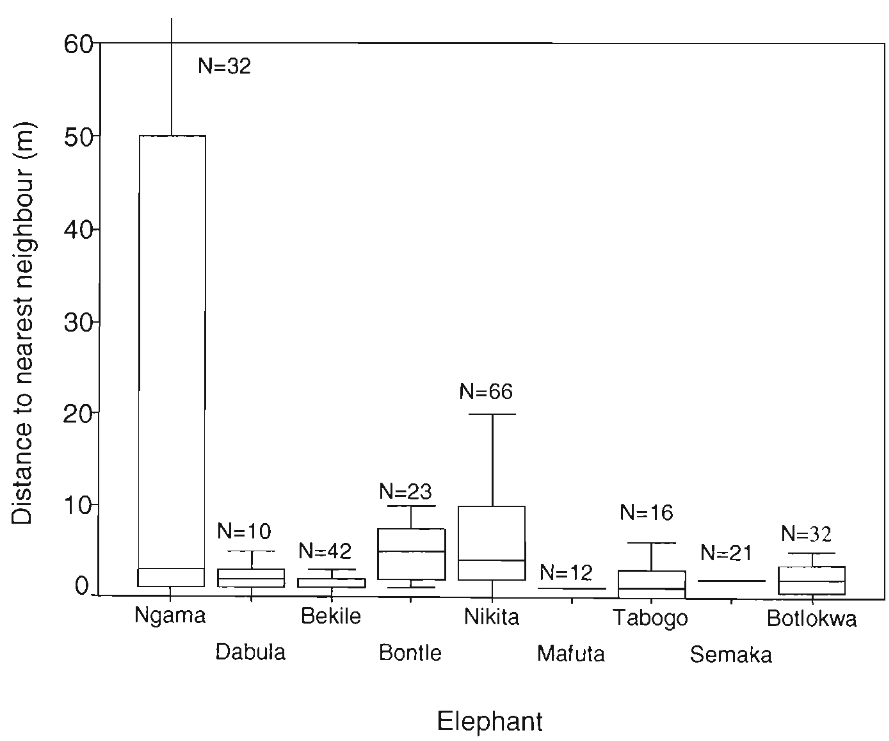


Figure 3.6: Individual variation in average distance from nearest neighbour of the elephant on Mabula Game Reserve ($P < 0.05$) (N = Number of observations).

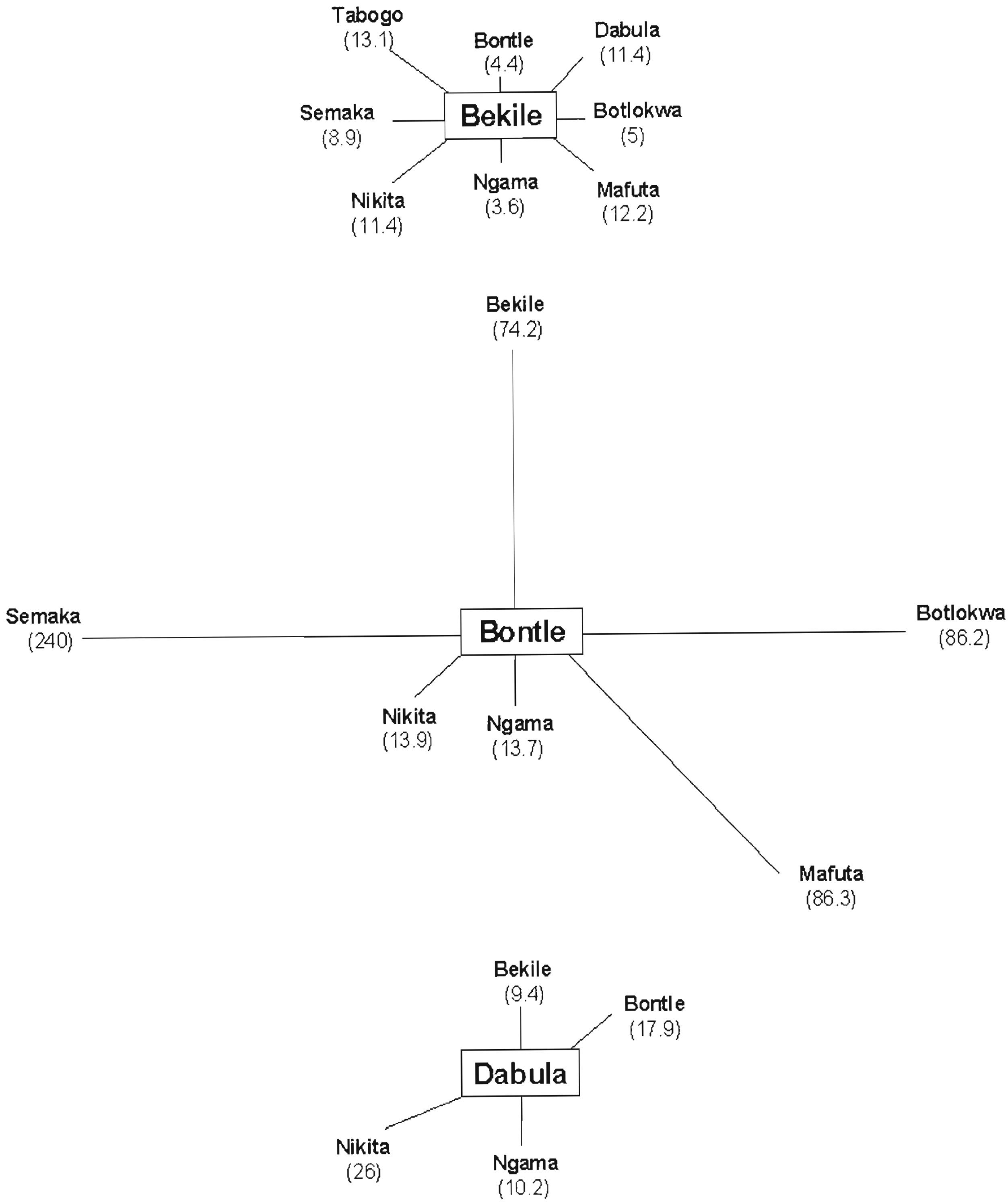


Figure 3.7: Nearest neighbour analysis for Bekile (adult female without calf), Bontle (adult female with a calf, Tabogo) and Dabula (adult female with calf, Semaka). Distances and length ratio of lines = Average distance nearest neighbour / Index of association nearest neighbour. A high value represents a low social association (see text).

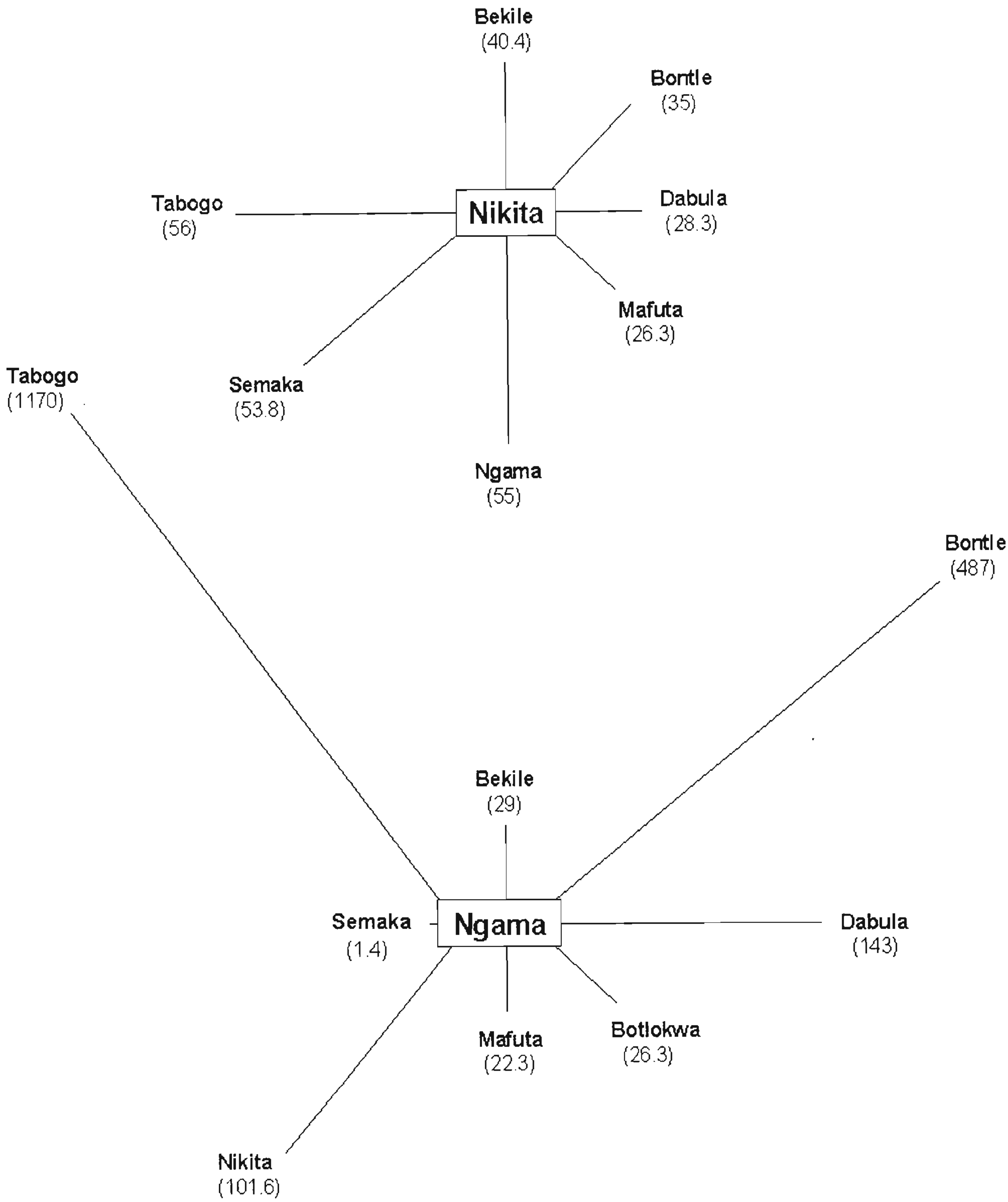


Figure 3.8: Nearest neighbour analysis for Nikita (adult female with calf, Botlokwa) and Ngama (adult male). Distances and length ratio of lines = Average distance nearest neighbour / Index of association nearest neighbour. A high value represents a low social association (see text).

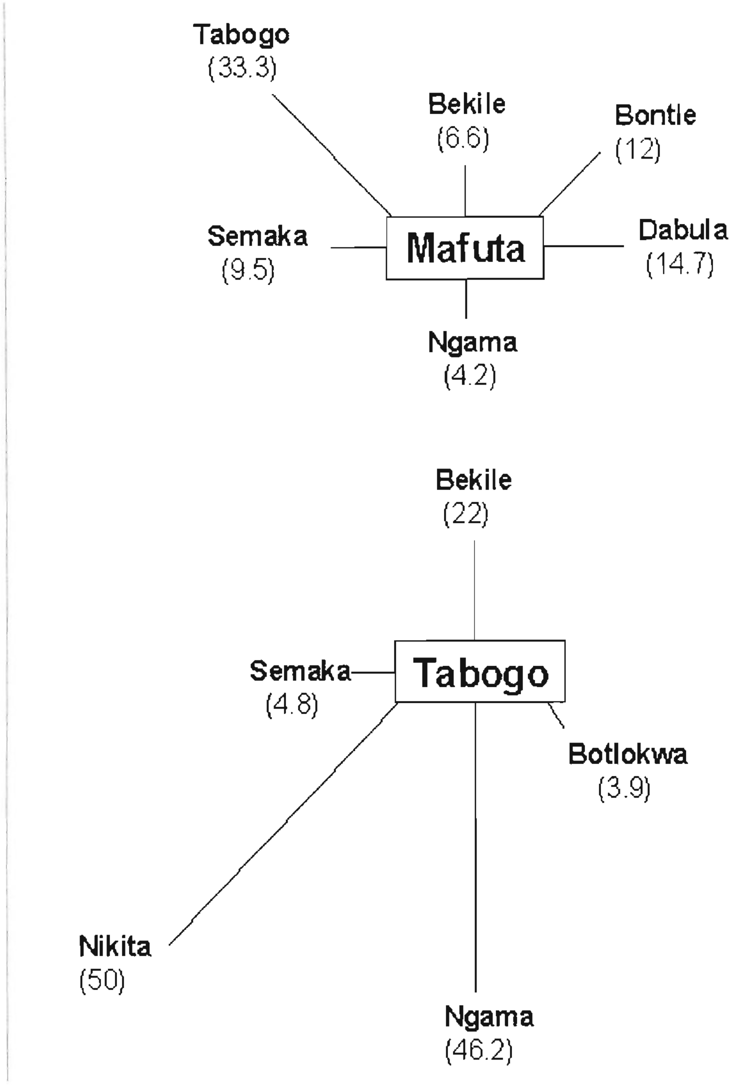


Figure 3.9: Nearest neighbour analysis for Mafuta (male calf) and Tabogo (male calf). Distances and length ratio of lines = Average distance nearest neighbour / Index of association nearest neighbour. A high value represents a low social association (see text).

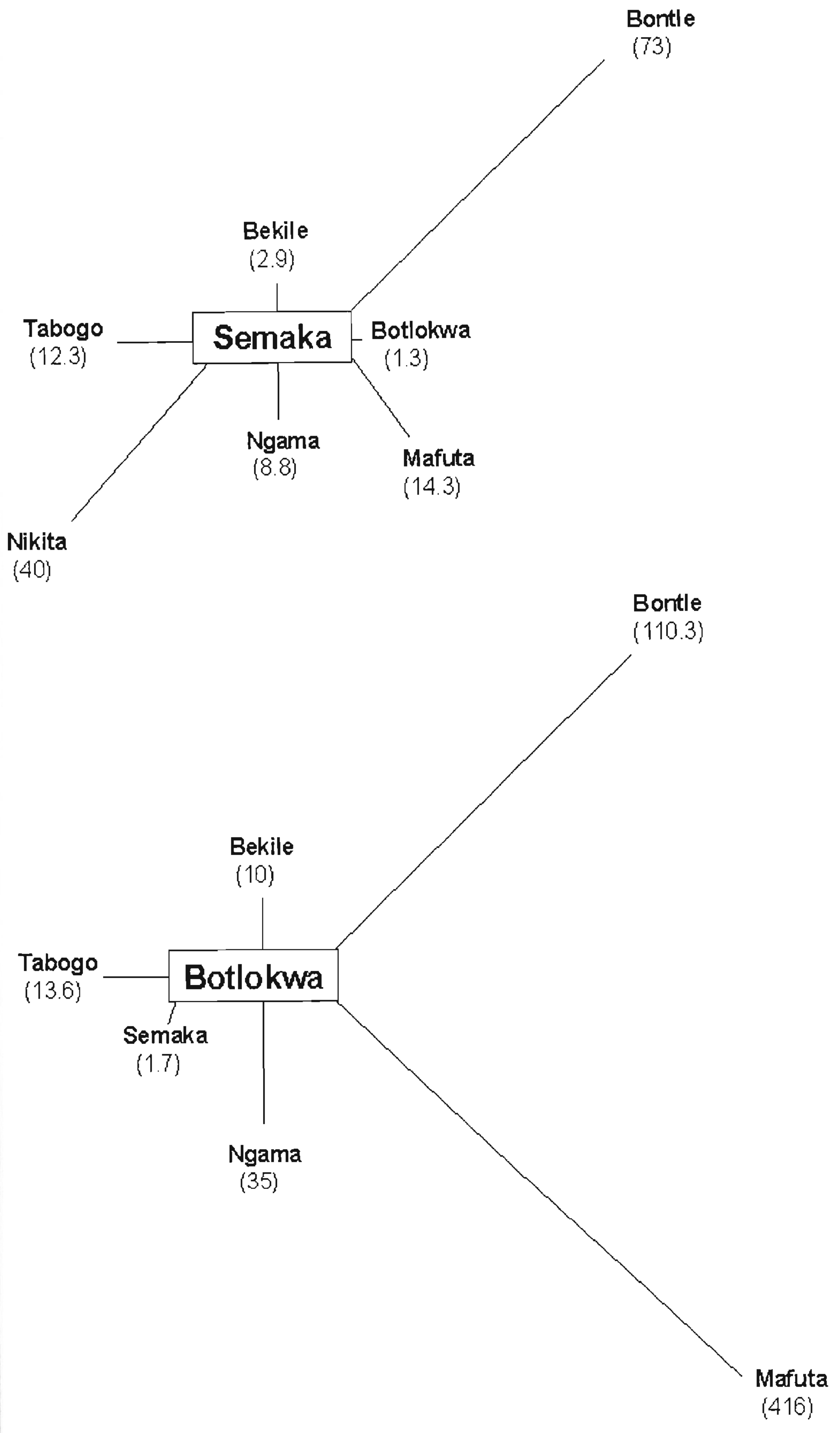


Figure 3.10: Nearest neighbour analysis for Semaka (female calf) and Botlokwa (female calf). Distances and length ratio of lines = Average distance nearest neighbour / Index of association nearest neighbour. A high value represents a low social association (see text).

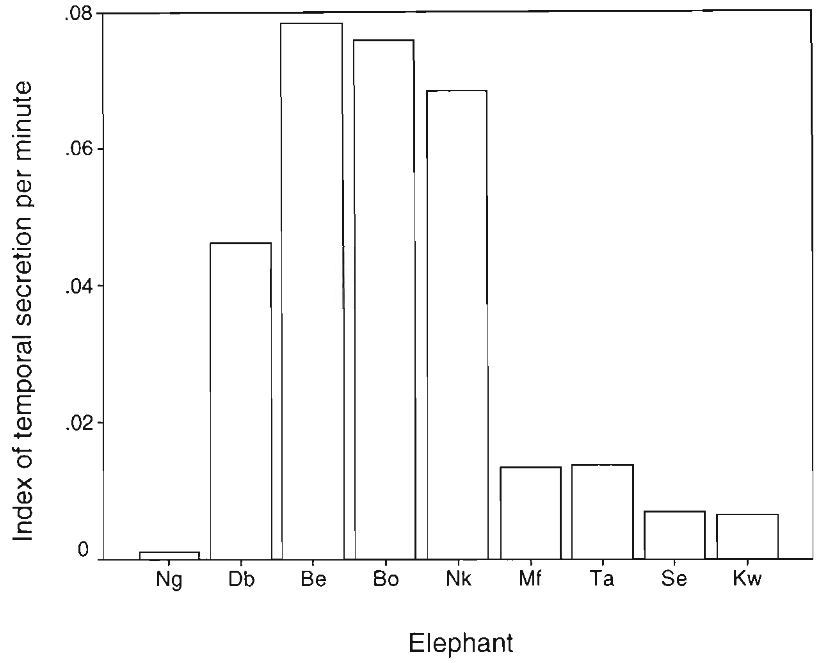


Figure 3.11: Individual variation in temporal gland secretion among elephants. Be – Bekile (adult female), Bo – Bontle (adult female), Db – Dabula (adult female), Nk – Nikita (adult female), Ng – Ngama (adult male), Mf – Mafuta (male calf), Ta – Tabogo (male calf), Kw – Botlokwa (female calf), Se – Semaka (female calf) (see text).

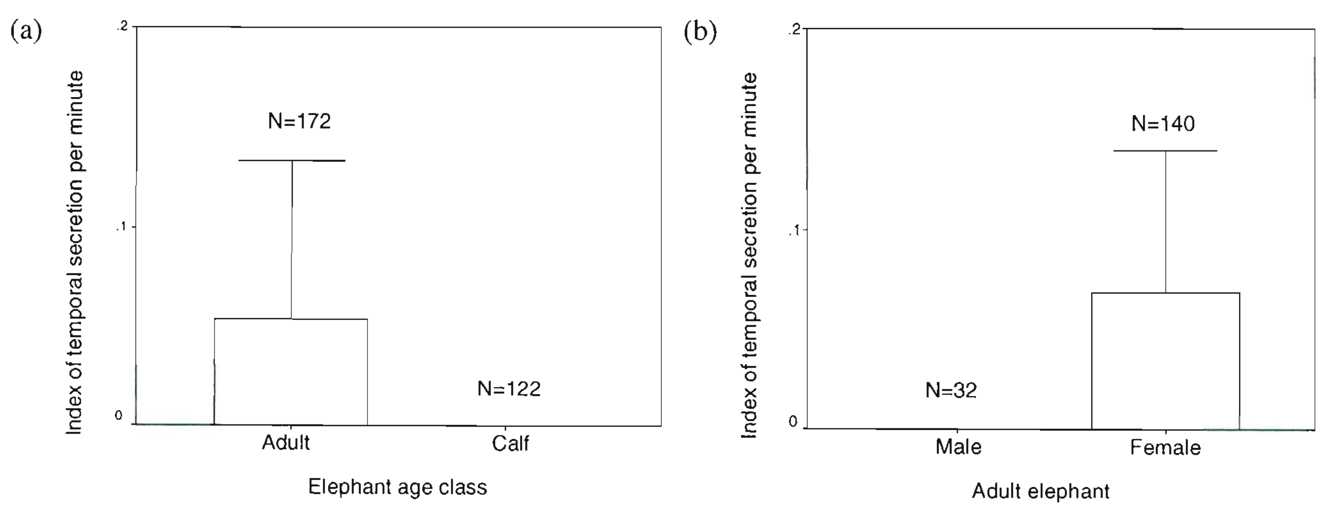


Figure 3.12: Variation in temporal gland secretion (tgs) between sexes and age classes. (a) the difference between extent of tgs between adult elephants and calves ($P<0.05$), (b) the difference between extent of tgs between adult male and female elephants ($P<0.05$) (N = Number observation sessions).

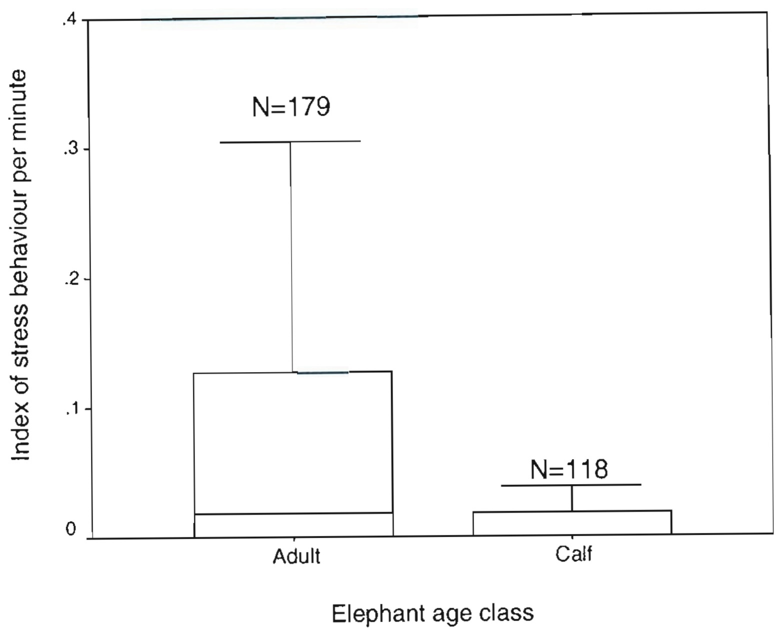


Figure 3.13: Variation in behaviours associated with stress between adult elephants and calves (P < 0.05) (N = Number observation sessions).

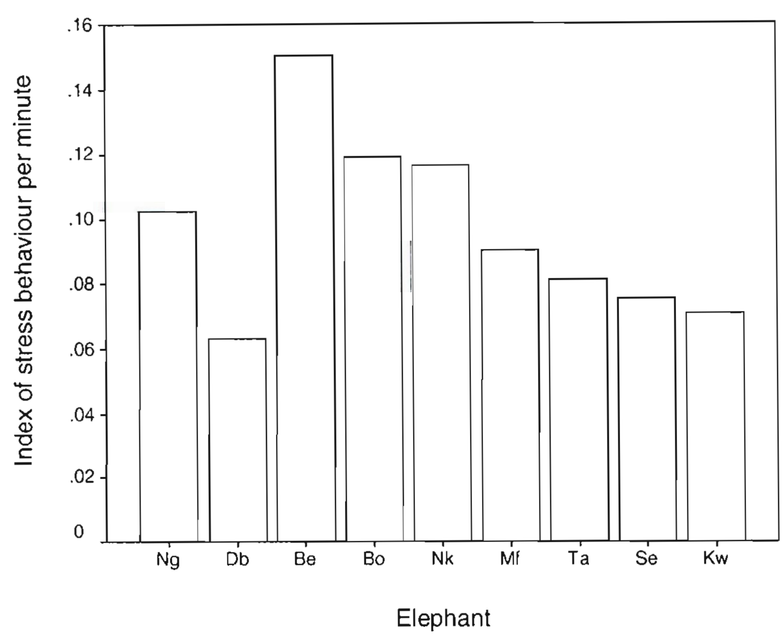


Figure 3.14: Individual variation in behaviours associated with stress for the elephants on Mabula Game Reserve. Be – Bekile (adult female), Bo – Bontle (adult female), Db – Dabula (adult female), Nk – Nikita (adult female), Ng – Ngama (adult male), Mf – Mafuta (male calf), Ta – Tabogo (male calf), Kw – Botlokwa (female calf), Se – Semaka (female calf).

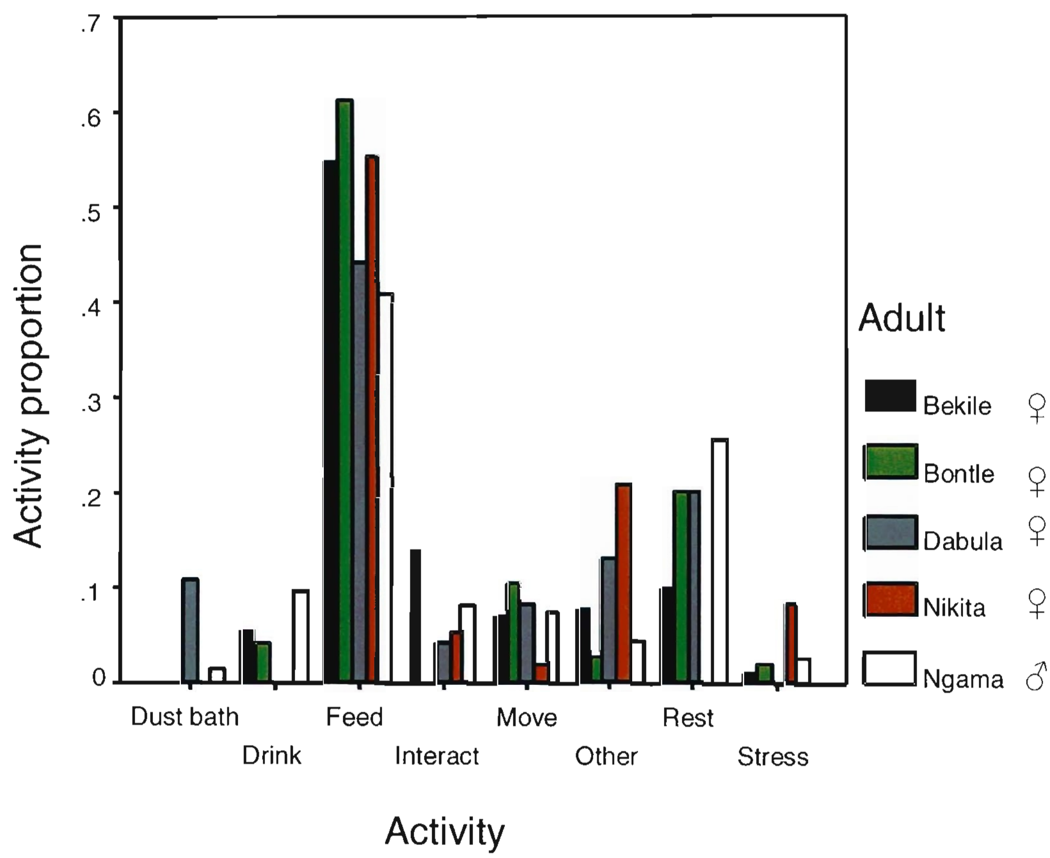


Figure 3.15: Activity patterns of individual adult elephant (See text for details).

The major differences in activity patterns between individual elephant calves were for Mafuta (three and a half year old male) who fed the most (80%) compared to Botlokwa (one-year-old female) who only fed 1% of the time, Botlokwa who played the most (13%) compared to Mafuta not playing, Semaka (one-year-old female) suckling the most (11%) compared to Mafuta not suckling at all (Figure 3.16). The general differences between the adult and calf activity patterns were for the calves playing 5.6% of the time compared to the adults not playing, the adults showing signs of stress for 6.5% of the time compared to the calves not showing signs of stress, the calves exploring and standing around not resting (any activity excluding general activity) 36.34% of the time compared to the 10.51% of the adults and the adults feeding 54.51%.

Daily activity patterns between the adult elephants on Mabula Game Reserve and the predicted daily activity patterns of elephants in general as derived from literature differed significantly (G-test: $G_4 = 63.2$, $P < 0.05$). The elephants on Mabula Game Reserve walked 6.7% of the time and were involved in other activities for 20% of the time (which included 2% dust bathing, 4% social interactions, 3% showing behaviours associated with stress and 11% exploring the environment and standing around) compared to elephants in general as predicted by literature walking 16% of the time and spending only 2.1% involved in other activities such as dust bathing and socializing (Table 3.3 and Figure 3.17).

3.3.11 Additional observations on calf rearing and reproductive behaviour

According to Moss (1988) estrous behaviour in the African elephant can be divided into five different stages: 1- wariness, 2- the estrous walk, 3- the chase, 4- the mounting and 5- consortship. All of the estrous behaviour stages have been observed with most of the adult female elephants on Mabula Game Reserve during the period of observation from March 2002 to March 2003 except for the cow, Bontle, that gave birth to a male calf in February 2003. The female in estrous usually leaves the herd with a bull to mate and is, if inexperienced, sometimes accompanied by an older female (Moss 1988). For the elephant on Mabula Game Reserve however, especially when the adult cow Dabula was in estrous, the whole herd ran after and followed her and the male each time he solicited her and she tried to get away from him. The chase would occur around at least five times a day for about two days during which time the whole herd would cover great distances across the reserve following the male and female in estrous.

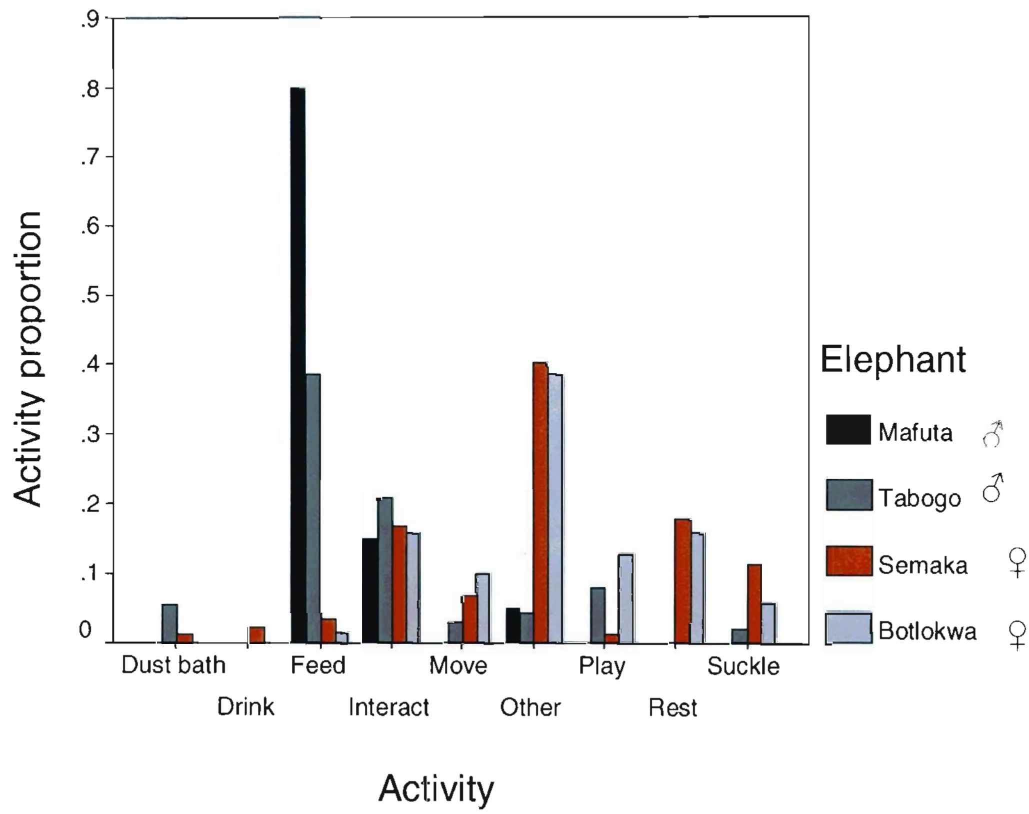


Figure 3.16: Activity patterns of individual elephant calves (See text for details).

Table 3.3

Diurnal activity patterns of elephants in general as described by literature and as observed for the elephant on Mabula Game Reserve.

Activity	Wyatt & Eltringham (1974) (%)[a]	Guy (1976) (%)[b]	Kalamera (1987) (%)[c]	Predicted from average of literature (%)[d]	Observed for current study (%)
Feeding	74.2	46.5	55.5	58.5	52
Drinking		1.9	2.3	2	3.2
Walking	11.3	17.8	19.3	16	6.7
Resting	13.2	31.5	19.7	21.4	18.1
Other	1.3	2.3	3.2	2.1	20
Total	**100**	**100**	**100**	**100**	**100**

*a, b and c represents daily activity percentages for elephants as found by other studies. $d = \frac{a+b+c}{3}$

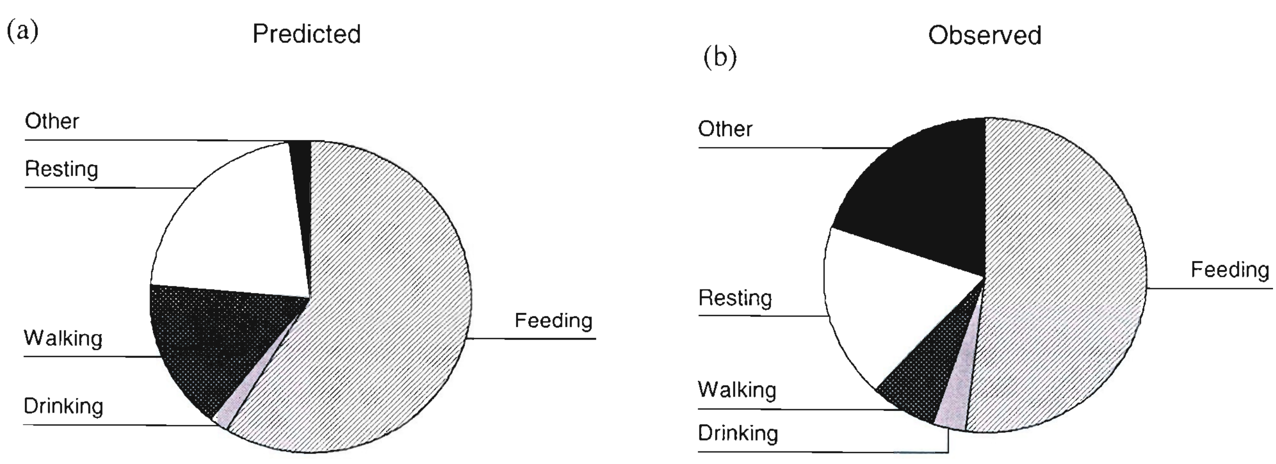


Figure 3.17: Diurnal activity patterns of elephants. (a) A prediction for elephants in general calculated as an average from percentages by three different studies, (b) Observed percentages for the study group of elephants on Mabula Game Reserve (see Table 3.3).

The calving interval for elephants are usually between 4 and 6 years depending on the condition of the animals (Lawley 1994) but for the elephant of Mabula Game Reserve the elephant cows came into estrous, mated and successfully conceived within six months after the birth of the previous calf. With the birth of Dabula's second calf, Semaka, her first calf Mafuta was just over two years of age. Dabula did not allow Mafuta to suckle from her after the birth of her second calf which lead to Mafuta suckling more from Bekile. It was speculated that Bekile lost her baby at the same time that Mafuta was born and has been lactating ever since because most of the calves born on Mabula since then have been observed suckling from her. When Bontle's second calf, Fejane, was born she also did not allow her first calf, Tabogo (just over two years of age then) to suckle from her any more. For a yet unknown reason Bekile would not allow Tabogo to suckle from her at that stage. Tabogo lost condition because he had to obtain his nutritional requirements from the vegetation. He was also observed to lag behind the herd for long periods of time on his own for distances of up to 150 m and secreted from his temporal glands more during this stage.

3.4 Discussion

An increasing number of elephants are being confined in fenced areas in South Africa for ecotourism. Two main management issues arise in areas where elephants are fenced off, the extent of both depending on the size of the property. First of all, the maximum number of elephants that can be sustained in a specific area needs to be determined depending on the carrying capacity or the vegetation type and annual rainfall of the area (for example, according to Bothma (1996) 25 elephants can be kept on a 10 000 ha reserve with an annual average rainfall of 500 mm). Secondly the minimum number of elephants that can be kept needs to be established according to the social requirements of the elephant as a species. In the past the main emphasis has been on determining the carrying capacity of specific areas for elephants and controlling elephant numbers that exceeded these levels while the social requirements of elephant were often neglected.

The Kruger National Park along with a range of other parks (for example the Luangwa valley) has used culling as a means of controlling their elephant numbers from 1967 to 1995 (Whyte & van Aarde 1998). These culling operations involved the killing of all adult members of a family unit and capturing the calves from 2 to 12 years old. Between 1980 and 1993 many elephant calves were sold by the Kruger National Park and translocated in groups of similar ages (mostly unrelated) to small fenced reserves without any adult elephants. The consequences of these actions only became apparent years later on the reserves and parks where these juvenile elephants have been re-introduced. In Pilanesberg National Park and Hluhluwe-Umfolozi Park, in the north western and eastern parts of South Africa, young elephant bulls killed over 100 rhinoceros because of lack of male social structure (Slotow, Balfour & Howison 2001). Introduction of older adult male elephants solved the problem by dominating the younger problem males (Slotow *et al.* 2000).

The purpose of the study conducted on Mabula Game Reserve was to investigate whether the social behaviour of the current elephant herd on the reserve deviated from elephant societies as described by literature. None of the cows have been able to establish the lead as a proper matriarch. The twenty-year-old bull on the reserve still spends most of his time with the cows and is more aggressive than expected towards the cows and calves. There is therefore a deviation in general activity and social role play of the elephants on Mabula Game Reserve relative to normal behaviour as described in the literature. This deviation may be attributed to orphan-hood but other factors such as feed supplementation and high tourism (human density) may also contribute. The effects of the absence of older male and female elephants from a herd is still not clear and needs to be further investigated. Preliminary observations by managers and current studies in other reserves indicate constant movement of these orphan herds across the reserves without establishing proper bull and cow areas and without keeping to a specific area for long. Physical aggression of especially young bulls towards tourist vehicles have also been reported as well as general fear and avoidance of humans and tourist roads by the cow herds.

Much like humans, an elephant is born with only 30 – 40% of its adult brain which is highly convulated allowing for a long period of learning and development. Species with this capacity tend to rely less upon instinctual behaviours and more upon socially learned behaviours (MacKenzie 1998). In humans social changes and the resultant need to adapt to it create stress. Symptoms of this stress are confusion, anxiety, depression and behavioural disorders such as disobedience (Sengendo & Nambi 1997). In studies done on orphaned human children it was found that the children often suffer from identity loss, depression and especially among child migrants it was difficult for these individuals to form and keep relationships with other people (Palmer 2002 and Brangwen-Jones 2002). Nearest neighbour analysis on the elephants on Mabula Game Reserve revealed some individuals like Bekile (adult female without a calf) to be more social while others like Bontle (adult cow with a calf) often keep their distance. This might further indicate the genetic distance between these orphans in terms of possibly being originally translocated from different clans and areas in the Kruger National Park. In complete families all the adult elephant females are usually related and stand together in order to chase young males out of the herd (Moss 1988), which the adult cows on Mabula Game Reserve have not been able to achieve with Ngama, the twenty-year-old male. According to Poole (1997) calf mortality is significantly higher among young mothers and many calves of young mothers spend a large portion of their time with their grandmothers. The event of the calf Botlokwa on Mabula Game Reserve not spending the amount of time with her mother as described by literature compared to Semaka might be because Botlokwa's mother (Nikita) is a first time mother where as Dabula (Semaka's mother) has already had a calf before.

Although the study group only consisted of nine animals, which limits the significance of the results for orphan elephants in general, the aim was to quantify social structure for elephants in order to help further develop methods of measuring social stress. The study area together with the small amount of elephants on the reserve allowed for detailed research on a daily basis of individual elephants. The results of the study emphasises the need for future research on the social requirements of elephants under varying environmental conditions. Research is only in the beginning phases of discovering the consequences of breaking up an elephant family and disrupting the age structure. Although culling or population size control is necessary in certain fenced areas the method of doing so must be revised and more attention given to identifying the best animals to remove that will minimize impact on elephant social structure in general. For future elephant re-introductions on small fenced areas, the minimum size property required on which complete populations of elephants (more than one family with adult females and matriarchs and bull areas with adult bulls) can be hosted needs to be determined. Removing key individuals or not providing the correct age and sex structures for newly introduced populations of elephants on a reserve might lead to more incidences of elephants not only threatening the life of other elephants and species but also of humans.

This study demonstrates that there are quantifiable deviations in social behaviour in the elephant population of Mabula Game Reserve. Deviations such as the frequent presence of bulls (around the age of twenty years) in the cow herds may be used by managers on other reserves to indicate possible future problems. This will hold regardless of whether the cause of social problems is orphan-hood, high tourism or other unidentified factors.

Chapter 4
BEHAVIOURAL RESPONSE OF THE AFRICAN ELEPHANT TO STRESS CAUSED BY DIRECT HUMAN DISTURBANCES ON A SMALL RESERVE

Abstract

Being one of Africa's large charismatic animals, the African elephant is not only kept in fenced parks and reserves for conservation purposes but also for financial benefits to the reserve owner through eco-tourism. Along with the increase in tourism in recent years incidences of aggressive interactions of elephants towards humans have also increased. For the purpose of the current study the effect of increased tourism (number and intensity of game viewing vehicles) on the occurrence of stress related behaviours for a group of elephant on a small reserve was investigated. There was a significant increase in behaviours associated with stress in adult elephants in the presence of direct human disturbances, vocalizations associated with stress were produced more often, individuals within the group clustered more together and the group as a whole moved more frequently. Stress behaviour and group mobility in the presence of game drive vehicles were significantly higher when the bull was with the herd. Stress behaviour and group mobility increased significantly from morning to afternoon. General activity patterns were affected by game drive vehicle activity on the reserve for both adult elephants and calves. Adult elephants interacted more with each other and showed signs of stress more often, while calves played less and suckled more in the presence of game drive vehicles. The results emphasise the necessity to further investigate the impact of tourism on elephants in general and the importance of educating people coming into contact with elephants in better understanding elephant behaviour in order to prevent possible injury or even death.

4.1 Introduction

The eco-tourism industry in South Africa is growing more and more every day. In general tourists want good quality sightings of a few charismatic species and high quantity sightings of a variety of species (Kerley, Geach and Vial 2003). Space, however, is limited due to the demands on natural resources by a growing human population. In order to reap maximum financial benefits from the tourism industry, game ranch owners are often forced to aim at maintaining a balance between the minimum size property required to host African wildlife in a fenced sustainable habitat and meet the demands of tourists.

Strategies for managing direct interactions and conflict between humans and elephants concerning the competition for natural resources and space have been researched extensively and possible solutions well described in various studies (Smith *et al.* 1995; Abel & Blaikie 1996, Sukumar 1997, Barnes 1999 and Hoare 2000). The influence of tourism on wildlife however is a relatively new field in research which is becoming more important as direct interactions of man with wildlife increase along with incidences of aggression of wild animals towards humans. This is often because of a lack of understanding by humans of the behaviour and personal space required by different species of animals. The first step in identifying what an animal requires from its environment other than the basic physical needs is to determine how an animal responds to unfavourable circumstances.

When social species experience stress from the environment they communicate the presence of the stressor to other group members of the same species, which makes communication the ideal variable to measure for the purpose of monitoring stress. Allaby (1996) defines communication as the transfer of information from one animal to another through the sense organs, resulting in behavioural changes that have survival value to one or both of the animals. Elephant communication consists of short-distance and long-distance signalling. Short-distance communication includes visual displays, tactile displays, vocalizations and chemical signalling whereas long-distance communication includes infrasonic vocalization and chemical signalling (Langbauer 2000). For the current study focus is placed on short-distance communication through vocalization.

Most of the vocalizations that elephants make consist of very low frequency sounds (infrasound) and 31 calls have been described (Langbauer 2000). Vocalizations audible to the human ear can be divided into four different sounds (rumbling, trumpeting, squealing and screaming), but gradations in pitch, duration and volume of these sounds enables the elephant to express a broad range of emotional states (Estes 1991). Reports on the relation of vocalization with stress contradict each other. Although Moss (1988) noted that when elephants are frightened they are usually silent she also states that in the presence of a threat (e.g. lions) young female elephants sometimes utter a shrill trumpet. Young newly captured elephants which are more stressed in terms of anger, frustration and fright, vocalize more than less stressed elephant (Garaii 1997).

Elephants are highly social animals and all members of a family group are usually co-ordinated in general activities (Moss 1988), which provide the opportunity of not only studying individual responses to stress but also the effect of stressors on the group as a whole. For the current study group spacing or distances of elephants in a group from each other together with mobility of a group of elephants as a whole were investigated. According to Eltringham (1977) there is a positive correlation between poaching pressure and group size of elephants. Garaii (1997) described a marked difference in behaviour patterns during resting times when groups of elephants without adults kept within touching distance from one another. For group defence Estes (1991) describes elephants to usually cluster together and stand in front of their calves facing the danger.

As for mobility, the normal walking speed of an elephant have been estimated to be around 6 km/h that can be increased to a shuffling gait of around 40 km/h and distances of 25 kilometres, which elephants walk in a day, have been recorded (Poole 1999). Literature on group mobility of elephants however sometimes contradicts each other. Wyatt and Eltringham (1976) found elephants to move mainly at dusk while Guy (1976) found elephants to move 34 % of the time and mostly during the morning period. Kalamera (1987) and Guy (1976) reported the least walking to occur during midday.

In order to confirm and justify the existence of tourism as a stressor for wildlife and develop management strategies to reduce this effect, methods of measuring stress for different species of animals must be described. Two major problems that can be pointed out in using biological responses as stress parameters includes the fact that different stressors elicit different biological responses in the same animal and that when the same stressor is experienced, the mode of response varies among individuals (Moberg 1983). The main aims of this study were to assess tourism effects on elephants, to determine the suitability of using behavioural responses towards stressors as parameters of measuring and describing stress in elephants and to identify which environmental factors present in the elephant's environment cause stress for elephants. The benefit of this type of research to wildlife managers is that through continuous monitoring of stress using the correct methods, stressors in the environment of the elephant from human interference can be identified and either eliminated or reduced to prevent possible incidences of aggression from elephants towards humans and to provide better quality and higher quantity sightings of relaxed elephants to tourists.

4.2 Methodology

Data collection on Mabula Game Reserve stretched from March 2002 to March 2003. Each day the elephants were located using telemetry equipment and observed using binoculars at distances ranging from 40 m to 150 m. A minimum distance of 30 m was always kept from the elephants. Data were collected through focal sampling on the general activity of elephants per minute for ten-minute observation periods, the spacing between individuals of the group of elephant for every ten-minute interval, the number of times the group of elephants moved, the number of times that the elephants produced vocalizations audible to the observer, the number of times that the adult elephant bull was aggressive towards other cow herd members and the number of times each individual elephant showed signs of behaviours associated with stress during each observation session. Each day the elephants were observed during either the morning, midday or afternoon for the time visible before arrival of the first game drive vehicle at the elephant sighting (first observation session in the absence of game drive vehicles) and after arrival of the first game drive vehicle at the sighting (second observation session in the presence of game drive vehicles). Any sessions that stretched over less than 10 minutes were not used for statistical analysis.

4.2.1 Behavioural response

Typical responses of elephant towards threats from the environment have been described in various studies. Elephants in any encounter usually swish their trunks up toward a threat (Wickler & Seibt 1997). According to Moss (1988), elephants usually run away with ears laid flat against their shoulders and tails held up and out when threatened by humans. A trunk is often swung towards predators like lion while air is blown through the nose, and when elephants are in a state of fear and distress they hold their tails up and their ears tilted up and back (Moss 1988). Typical displays of threat behaviour includes an elephant turning toward a disturbance while spreading the ears, standing tall (head raised high while peering over its tusks, ears cocked and trunk hanging at an acute angle), nodding, jerking, shaking and tossing the head, swinging the trunk forward, mock charging and charging towards the disturbance (Estes 1991). Aimed object throwing by elephants have also been recorded in aggressive situations and to make a motionless opponent move and reveal its intentions (Wickler and Seibt 1997).

The type of behaviour associated with stress for each individual elephant under observation was recorded and categorized with index values as follows (high index indicate high stress)(Appendix C):

(1) Disturbed behaviour (low response, disturbance and stress)

(a) Touching temporal gland (ttg). Index: 1

(b) Front foot swung not directed towards a disturbance (fsn). Index: 1

(c) Smelling disturbance with trunk lifted towards disturbance (smd). Index: 1

(d) Breaking vegetation without consuming (bv). Index: 2

(e) Head shake not directed towards a disturbance (hsn). Index: 2

(f) Coiling, uncoiling and twitching trunk (ct). Index: 2

(g) Abrupt termination of current action while listening (atc). Index: 2

(2) Threatened behaviour (medium response, disturbance and stress)

(a) Turning towards a disturbance with ears spread (tt). Index: 2

(b) Flapping ears directed towards a disturbance (fe). Index: 2

(c) Foot swung directed towards a disturbance (fs). Index: 2

(d) Head shake or head jerk directed towards a disturbance (hs). Index: 3

(e) Standing tall (head raised high, elephant peering over tusks, ears cocked and trunk hanging at an acute angle) (st). Index: 3

(f) Trunk swish towards a disturbance (ts). Index: 3

(g) Throwing objects towards a disturbance (to). Index: 5

(h) Charge towards a disturbance (c). Index: 5

(i) Threat display (bending down with front of body and pushing head towards ground) (td). Index: 5

(3) Distressed behaviour (high response, disturbance and stress)

(a) Ears tilted up and back (eub). Index: 3

(b) Tail held up and straight while moving around cautiously (tsu). Index: 4

(c) Move away from a disturbance fast with ears laid flat against shoulders (raf). Index: 5

The behavioural responses directed to disturbances were measured for both periods of disturbance and no disturbance as the observer's presence could have been a cause even in the absence of other disturbances. This, however, biased the results only conservatively as it was a constant factor present during observation, which could only reduce the probability of finding any effect of, for example, game drive vehicles.

For the purpose of analysis a value was calculated for each session of observation of behavioural response of each elephant by multiplying the index values by the amount of times that each type of behaviour occurred and then summing all values to obtain a total score for each session of observation. For comparison across sessions and with other elephants, because not all observation sessions stretched over the same amount of time, an index of stress behaviour per minute was calculated by dividing each score with the amount of time that an elephant was observed for each session. Each daily sample for each elephant consisted of a session when game drive vehicles were absent from the area of the elephant and a session when game drive vehicles were present at an elephant sighting. The affect of game drive vehicle presence on behaviour of each elephant in general was tested using the Wilcoxon test with each observation session as a sample point. For example, monitoring Bekile's (a female adult elephant) stress behaviour:

Day 1: 16:10 to 16:30 without game drive vehicles at the elephant sighting (no stress response)

Day 1: 16:40 to 17:10 with game drive vehicles (2 head shakes towards a disturbance, Index: 3)

Day 2: 7:00 to 7:40 without game drive vehicles (no response)

Day 2: 7:41 to 8:21 with game drive vehicles (1 trunk swish towards a disturbance, Index: 3)

Day 3: 17:30 to 17:35 without game drive vehicles (1 head shake towards a disturbance (observer), Index: 3)

Day 3: 17:40 to 18:00 with game drive vehicles (1 smelling towards the disturbance with trunk lifted, Index: 1 and 1 standing tall, Index: 3),

Day 4: 17:50 to 18:10 with game drive vehicles (no response)

Day 4: no observation without game drive vehicles because the elephants were not visible for the remainder of the afternoon period.

The data were captured as follows:

- Day 1, 16:10 to 16:30 (20 minutes) was defined as an observation session.
- A sample equalled two observation sessions on the same day both during either the morning, midday or afternoon where one session had to be in the presence of game drive vehicles and the other session in the absence of game drive vehicles, for example: Day 1, 16:10 to 16:30 and 16:40 to 17:10.
- Day 3 was discarded for statistical analysis because one of the observation sessions stretched over less than 10 minutes.
- Day 4 was discarded for statistical analysis because the elephants were only visible in the presence of game drive vehicles.
- Because the observation sessions varied in duration an index of stress behaviour per minute was calculated for comparison across sessions: Day 1, 16:10 to 16:30: 0 stress response divided by 20 minutes = 0, Day 1, 16:40 to 17:10: 2 responses multiplied by Index 3 and then divided by 30 minutes = 0.2.
- For descriptive analysis all the type stress behaviours were added and then divided by the total amount of time that the elephants were observed for either sessions when game drive vehicles were present or when game drive vehicles were absent, for example: Headshakes in the

presence of game drive vehicles: 2 divided by (30 + 40 + 20 + 20 minutes) = 0.018, Headshakes in the absence of game drive vehicles: 1 divided by (20 + 40 + 5 minutes) = 0.015.

4.2.2 Vocalization

Data on the vocalization of the elephant on Mabula Game Reserve were collected over 34 sessions and a total of 29 hours throughout the study period between March 2002 and March 2003. The type of vocalization audible and recognizable to the observer was recorded and categorized with ranked index values (where a high value represented a higher level of stress) as follows (Appendix D):

(1) Rumble (RU) - deep soft growling sound. Index value: 1
(2) Calf moan (CM) – a juvenile producing a drawn-out growl. Index value: 2
(3) Calf scream or squeal (CS) - a juvenile distress call. Index value: 3
(4) Growl or roar (G) – loud low guttural rolling sound. Index value: 3
(5) Scream or bellow (SB) - screaming is a very high, pitched loud sound and bellowing is a very low, pitched loud sound. Index value: 3
(6) Trumpet (T) - a sound produced by blowing through the nostrils hard enough to make the trunk resonate. Index value: 3

Rumbling sounds have a lower score because they are mostly used for daily general communication. The calf moan sound is normally produced when the calf cannot get to its mother's milk. As an indirect response to a disturbance the mother might not allow the calf to drink and for this reason the vocalization was given a slightly lower score. All other vocalizations were given equally high indexes of three because of difficulty assigning objective relative scores.

For the purpose of analysis a value was calculated for each session of observation of vocalization by multiplying the index values by the amount of times that each type of vocalization occurred and then summing all values to obtain a total score for each session of observation. Because not all observation sessions stretched over the same amount of time, an index of vocalization per minute was calculated by dividing each score with the amount of time that the elephants were observed for each session. The affect of game drive vehicle presence on vocalization in general was tested using the Wilcoxon test with each observation session as a sample point (see stress behaviour example above).

4.2.3 Group mobility

Data on the group mobility of the elephant on Mabula Game Reserve were collected over 82 sessions and a total of 48 hours throughout the study period between March 2002 and March 2003. A group movement was defined as when all individuals present in the herd were moving in the same direction for an estimated distance of 30 m or more. When the animals stopped for more than a minute and started to move again the movement was recorded as a new movement.

(1) Type of movement:
   (a) moving fast with a shuffling gait (R) (An elephant can not really run or jump and has at least on foot on the ground at all times (Poole 1997))
   (b) walking in a fixed direction at a fast pace not feeding (WF)
   (c) walking slowly not feeding exploring the environment (WS)
   (d) walking slowly feeding (WSF)

(2) Movement direction:
   (a) moving away from roads into an open area like a plain (Aro)
   (b) moving away from roads into a thicket (Art)
   (c) moving along the road for more than 50 m at a time (Mr)
   (d) moving towards a human disturbance like a game drive vehicle (Td)
   (e) crossing a road (Cr)
   (f) other (for example moving parallel to road) (O)

(3) Distance moved. Distance was estimated from the point where the hindmost elephant in the herd started to move to the point of the hindmost elephant when herd movement ended.

Because not all observation sessions stretched over the same amount of time, an index of group mobility per minute was calculated by dividing the number of times that the elephants moved with the amount of time that the elephants were observed for each session. The affect of game drive vehicle presence on mobility was tested using the Wilcoxon test with each observation session as a sample point (see stress behaviour example above).

4.2.4 Group spacing

At ten minute intervals the spacing of the group of elephants was recorded and classified according to four categories with ranked index values (where a high value represented a higher level of stress):

(1) Clustered (C). When the estimated distance of the elephant furthest away from any other elephants in the group was 2 m or less. Index value: 4

(2) Relatively spread (R). When the estimated distance of the elephant furthest away from any other elephants in the group was 3 m to 10 m. Index value: 3
(3) Spread (S). When the estimated distance of the elephant furthest away from any other elephants in the group was 11 m to 100 m. Index value 2
(4) Split (SP). When the estimated distance of the elephant furthest away from any other elephants in the group was more than 100 m. Index value 1

A total of 153 observations of the spacing of the group of elephant on Mabula Game Reserve were collected over 30 days. At least three observations per observation session per day had to be collected for the purpose of statistical analysis. An observation session consisted of all the observations for periods when game drive vehicles were either present or absent each day. For each observation session, the observed proportion was calculated of each of the four spacing categories. The index value for each category was then multiplied by the observed proportion and all values added to obtain a total score for each session in order to compare scores across sessions. The effect of game drive vehicle presence on group spacing was tested using the Wilcoxon test for two related samples.

For further analysis a value was calculated for each session of observation on group spacing by multiplying the index values with the amount of times that each spacing category occurred and then summing all values to obtain a total score for each session of observation. For each session the score for the period was further divided by the total number of samples for each session in order to compare scores across sessions.

4.2.5 General activity

Activity patterns of elephant calves and adults were monitored for periods when game drive vehicles were present at an elephant sighting and periods when game drive vehicles were absent by focal sampling for ten-minute intervals. For each activity the detail of the type of activity was also recorded, including:

(1) Feeding (F)
(2) Suckling (Su), (together with elephant suckling from)
(3) Resting (R) (trunk hanging down, standing still, head lowered and breathing deeply or lying down still)
(4) Moving (Mo)
(5) Playing (P) (exploring the environment through pushing and throwing small objects around, rolling on the ground on back and sides, interacting with each other by entwining

trunks, climbing on top of each other when lying down, chasing each other and other small animals like birds around and gently sparring or pushing each other)

(6) Drinking water (Dr)

(7) Mud bathing (Mb)

(8) Dust bathing (Db)

(9) Other (O) (standing still not in a resting position, exploring environment with trunk)

(10) Stress behaviour (SB) (see detail above)

(11) Physical interaction with another elephant (I), Detail type:

(a) Aggressive

(i) chasing (ch)

(ii) pushing hard or bumping another elephant with the head (ph),

(iii) head shake towards another elephant (hse)

(iv) kicking another elephant (k)

(v) pushing each other out of the way (pu)

(vi) sparring (sp)

(vii) trunk slapping another elephant (tse)

(viii) tusking another elephant (tk)

(b) Sexual

(i) mating with another elephant (mat)

(ii) trunk-genital contact with another elephant (tg)

(c) Social

(i) being suckled by another elephant (su)

(ii) trunk-mouth contact with another elephant (tme)

(iii) trunk contact with trunk or head or body of other elephant (tte)

(iv) playing (interacting with other elephant by entwining trunks, climbing on top of each other when lying down, chasing each other and other small animals like birds around and gently sparring or pushing each other)

The effects of game drive vehicles on the activity patterns of the elephant were described and analyzed using the chi-square test.

4.2.6 Bull aggression

Each day, as soon as the bull was confirmed to be with the cow herd and was visible, data collection started until the elephants disappeared into the bush away from any accessible roads (N = 23). During these data collection periods note was made of any aggressive interactions initiated by the bull towards any of the other cow herd members. An index value was awarded to each type of aggression according to the degree of aggression as follows (a high value represented a higher level of aggression):

(1) Head shake towards another elephant (HSE), Index value: 1
(2) Chasing another elephant (CH), Index value: 2
(3) Kicking another elephant (K), Index value: 3
(4) Pushing another elephant out of the way (PU), Index value: 2
(5) Pushing hard/bumping another elephant with the head (PH), Index value: 3
(6) Sparring with another elephant (SP), Index value: 4
(7) Tusking another elephant (TK), Index value: 4
(8) Trunk slapping another elephant (TSE), Index value: 4

For analysis a score for each observation session was calculated by multiplying the number of aggressive interactions of the bull with the other cow herd members with the index values for each type of aggression. This score was then divided by the session duration. Using the Mann-Whitney test for two independent samples the affect of game drive vehicle activity on aggression of the bull towards other elephants was analysed.

Analysis of other environmental effects

Further data analysis of the various stress parameters listed before were divided according to the type of environmental factors influencing the elephants at various time intervals during each session of observation, including:

(1) Immediate environmental influences (univariate ANOVA):
    (a) Bull presence (comparing each stress parameter for times when the twenty year old bull on the reserve was with the herd to times when he was not with the herd),
    (b) Time of day (comparing each stress parameter for morning (5:30 – 10:00), midday (10:01 – 14:30) and afternoon periods (14:31 – 19:00)),
    (c) Interval (comparing each stress parameter for the first ten minutes after arrival of the first game drive vehicle to the time period after ten minutes of arrival of the first game drive vehicle),
    (d) Sight control (comparing each stress parameter for periods when game drive vehicle activity was controlled at elephant sightings using radio communication to periods when game drive vehicles are not controlled leading to vehicles either not keeping a minimum distance of 30 m from the elephants, more than three vehicles being at an elephant sighting at a time, more than five vehicles being in the

general vicinity of the elephant at a time and vehicles approaching the elephant from more than one direction thereby blocking the direction of movement of the elephants),

(e) Distance of a disturbance from the elephants (comparing each stress parameter when disturbances like game drive vehicles are present at an elephant sighting between periods when the closest disturbance to the elephants is 0 to 49 m, 50 to 99 m and more than 100 m).

(2) Time of day influences (univariate ANOVA):

(a) Cumulative number of game drive vehicles present at an elephant sighting for each morning, midday and afternoon period,

(b) Cumulative number of game drive vehicles present in the vicinity of the elephant for each morning, midday and afternoon period,

(c) General weather conditions for the entire morning, midday and afternoon periods

(d) Area or section on the reserve where the elephants occurred in for most of the morning, midday and afternoon periods,

(3) Daily environmental influences (linear regression)

The affects of daily rainfall and average temperature on behaviour associated with stress, vocalizations produced, group spacing and group mobility of elephant were analyzed as continuous variables using linear regression models.

H_0: $\beta_1 = 0$

Where β_1 represents the slope of the regression curve in the estimated simple linear regression equation: $\hat{y} = \beta_0 + \beta_1 x$

When data were normally distributed (Kolmogorov-Smirnov test $P > 0.05$) parametric statistics were used. When data were not normally distributed the appropriate non-parametric test were used. Data are presented as box-and-whisker plots without out lies and extremes (maximum, 75% quartile, median, 25% quartile and minimum).

4.3 Results

4.3.1 Behavioural response

Data on the stress behaviour of the elephant on Mabula Game Reserve were collected over 139 sessions and a total of 36 hours. All adult elephants showed a significant increase in behaviours associated with stress for periods when game drive vehicles were present at an elephant sighting compared to when game drive vehicles were absent. (Wilcoxon test: all $P < 0.05$) (Figure 4.1). Except for Mafuta, the oldest male calf on the reserve, none of the other elephant calves on Mabula Game Reserve showed any significant change in behaviours associated with stress between periods when game drive vehicles were present at an elephant sighting and periods when game drive vehicles were absent (Wilcoxon test: all $P > 0.05$) (Figure 4.2). For adult elephants the most common type of stress behaviour were head shakes directed towards direct human disturbances (20.5%) and abrupt termination of the current action while listening (13.7%) for periods when game drive vehicles were at an elephant sighting. The only stress behaviours that occurred during periods when game drive vehicles were absent from the area of the elephant were head shakes directed and not directed towards other disturbances (4%) and forward trunk swishes (0.5%) (Figure 4.3).

(a) Immediate environmental influences

Stress behaviours increased significantly when the bull was absent from the cow herd and game drive vehicles were present at an elephant sighting (Mann-Whitney test: $Z = -2.172$, $N = 64$, $P = 0.03$) (Figure 4.4). Control of game drive vehicle activity via radio communication at elephant sightings which limits game drive vehicle numbers at an elephant sighting to three and ensures that game drive vehicles do not drive closer than 40 m to the elephants, the first ten minute period after arrival of the first game drive vehicle at an elephant sighting and the distance of game drive vehicles from elephants did not significantly affect the occurrence of behaviours associated with stress for the elephants as a group (all $P > 0.05$). The affects of these factors on each individual elephant were not tested due to small sample sizes ($N < 5$).

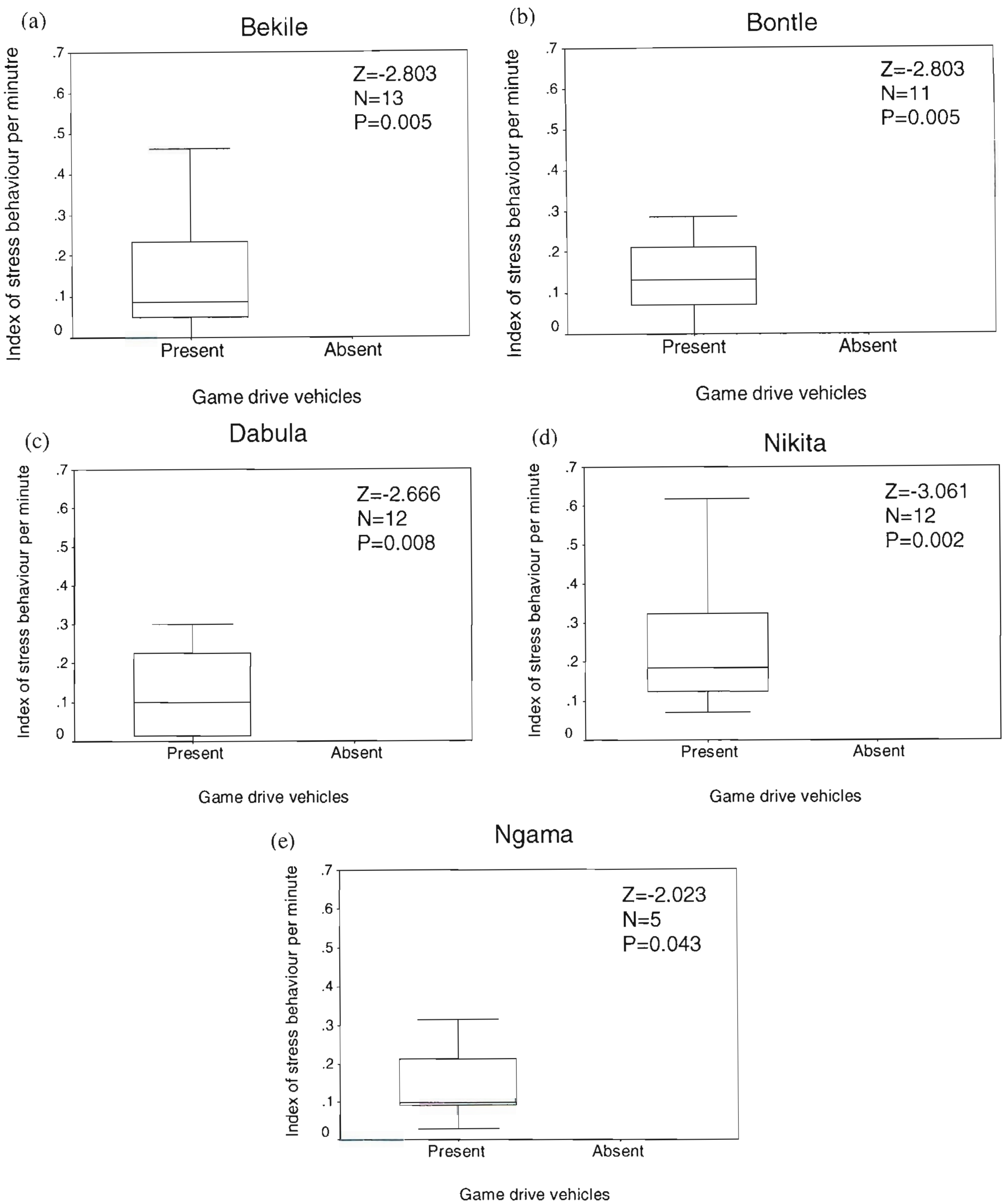


Figure 4.1: The influence of game drive vehicle presence on stress behaviour in adult elephants. (a) Bekile (female), (b) Bontle (female), (c) Dabula (female), (d) Nikita (female) and (e) Ngama (male). N = number of samples, outliers and extremes are not shown (see text).

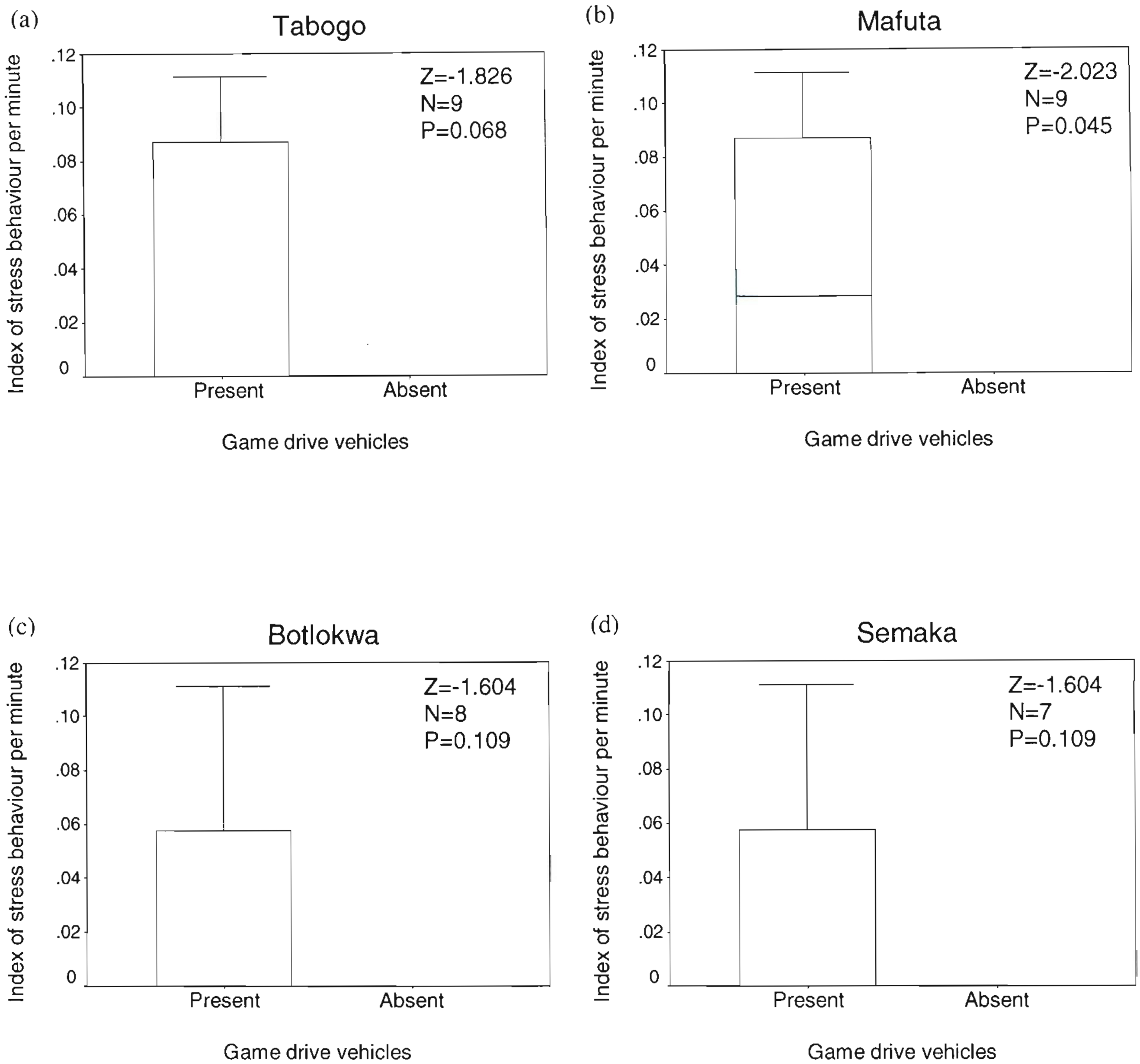


Figure 4.2: The influence of game drive vehicle presence on stress behaviour in elephant calves. (a) Tabogo (3.5 year male), (b) Mafuta (2 year male), (c) Botlokwa (one year female) and (d) Semaka (one year female). N = number of samples, outliers and extremes are not shown (see text).

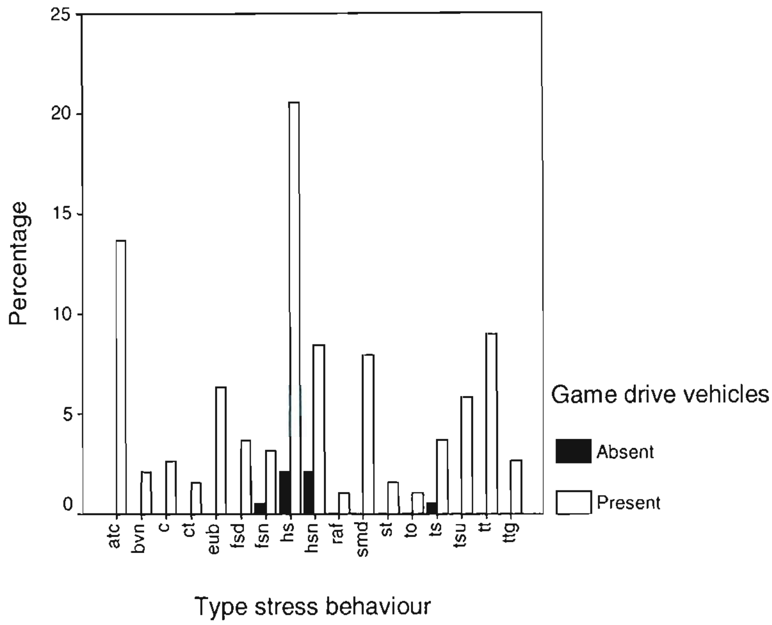


Figure 4.3: The influence of game drive vehicle presence on the type of stress behaviour displayed by elephants. atc- abrupt termination of current action, bvn- breaking vegetation without consuming, c- charge, ct- coiling & twitching trunk, eub-ears tilted up & back, fsd- foot swing towards disturbance, fsn- foot swing, hs- head shake towards diturbance, hsn- head shake, raf- moving away fast from disturbance with ears flat against head, smd- smelling disturbance, st- standing tall, to- throwing object, tt- turning towards, ts- forward trunk swish, tsu- tail held straight & up, ttg- touching temporal gland (see text for detail).

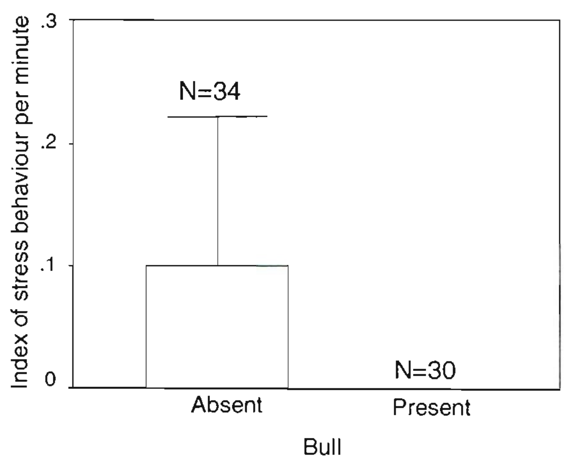


Figure 4.4: The influence of the presence of the bull in the cow herd on the occurrence of behaviours associated with stress for a group of elephants in the presence of game drive vehicles (P < 0.05) (N = Number observation sessions, outliers and extremes are not shown).

(b) Time of day influences

Stress behaviour for the group of elephants on Mabula Game Reserve increased significantly from morning to afternoon periods (Kruskal-Wallis test: $\chi^2_2 = 9.522$, N = 70, P = 0.009) (Figure 4.5), increased significantly with an increase in the number game drive vehicles at an elephant sighting (Kruskal-Wallis test: $\chi^2_2 = 6.543$, N = 49, P = 0.038) (Figure 4.6) and increased significantly with increased game drive vehicles in the area of the elephant (Kruskal-Wallis test: $\chi^2_3 = 9.445$, N = 59, P = 0.024) (Figure 4.7).

4.3.2 Vocalization

A significant increase in vocalization for the elephants of Mabula Game Reserve occurred for periods when game drive vehicles were present at an elephant sighting compared to periods when vehicles were absent (Wilcoxon test: Z = -2.979, N = 23, P = 0.003) (Figure 4.8). Elephants rumbled more during periods when game drive vehicles were absent while growling and trumpeting occurred more during periods when game drive vehicles were present (Figure 4.9).

(a) Factors present in the immediate environment of the elephant

Analysis of data using parametric tests were not possible because the residual values for vocalizations produced for the immediate environmental data were not normally distributed according to the one-sample Kolomogorov-Smirnov test (N = 41, P < 0.05). Stress vocalizations decreased significantly when game drive vehicle activity was controlled via radio communication (through limiting game drive vehicle numbers to three at an elephant sighting and not allowing any vehicles closer than 40 m from the elephants) compared to periods when game drive vehicle activity was not controlled (Mann-Whitney test: Z = -3.509, N = 42, P = 0.001) (Figure 4.10). Stress vocalizations were significantly higher for the first ten minute period after arrival of the first game drive vehicle at an elephant sighting compared to the second ten minute period after arrival of the first game drive vehicle (Mann-Whitney test: Z = -2.585, N = 42, P = 0.01) (Figure 4.11). The elephant distance from disturbance did not reveal any significant changes in vocalizations associated with stress produced by the elephant (all P > 0.05) (Figure 4.12).

(b) Factors present for the different times of day (morning, midday and afternoon)

Analysis of data using parametric tests were not possible because the residual values for vocalizations for the time of day data were not normally distributed (Kolomogorov-Smirnov test: N = 31, P < 0.05). The location of the elephants on the reserve did not significantly change vocalizations produced associated with stress by elephants (all P < 0.05) (Figure 4.13).

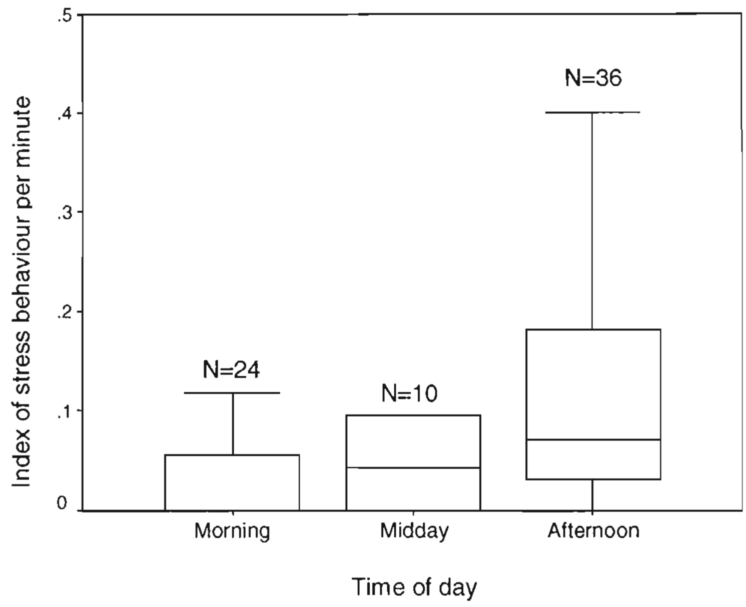


Figure 4.5: The effect of time of day on the occurrence of behaviours associated with stress of a group of elephants (P < 0.05) (N = Number of observation sessions).

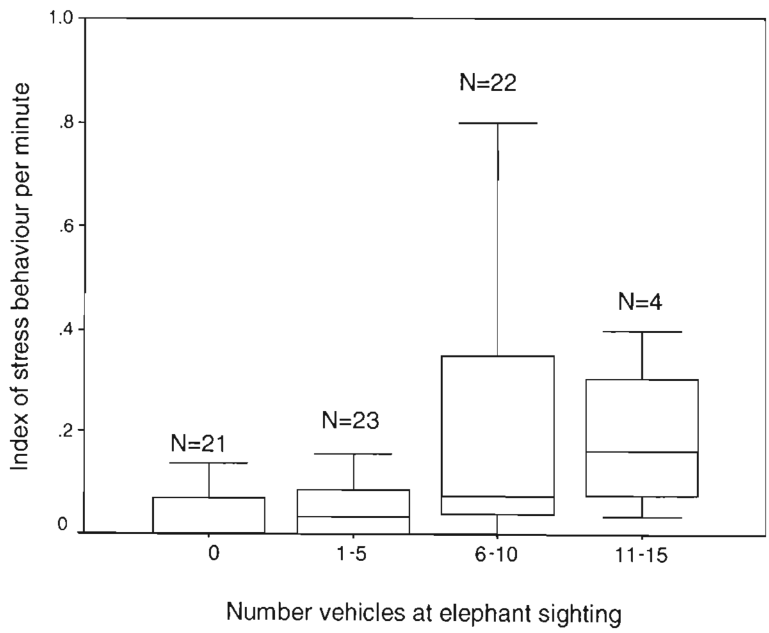


Figure 4.6: The effect of the number of game drive vehicles at an elephant sighting on the occurrence of behaviours associated with stress of a group of elephants (P < 0.05) (N = Number of observation sessions).

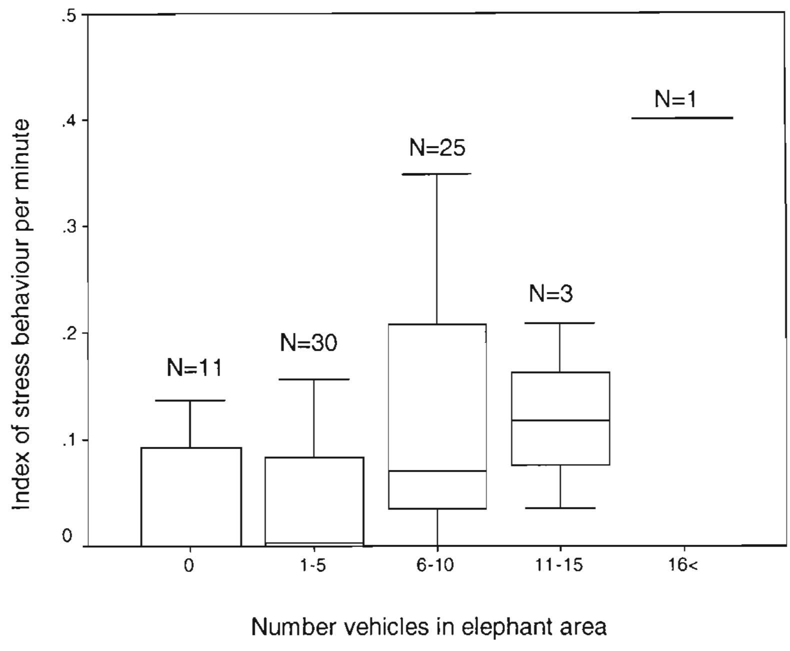


Figure 4.7: The effect of the number of game drive vehicles in the area of the elephant (according to the eight sections that Mabula Game Reserve were divided into) on the occurrence of behaviours associated with stress for a group of elephants (P < 0.05) (N = Number of observation sessions).

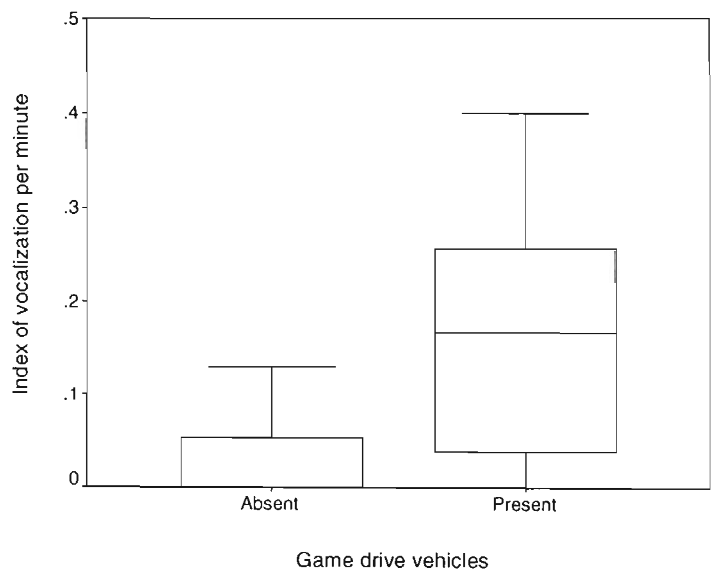


Figure 4.8: The influence of game drive vehicle presence on vocalizations associated with stress produced by elephants (Wilcoxon test: N = 46, P < 0.05).

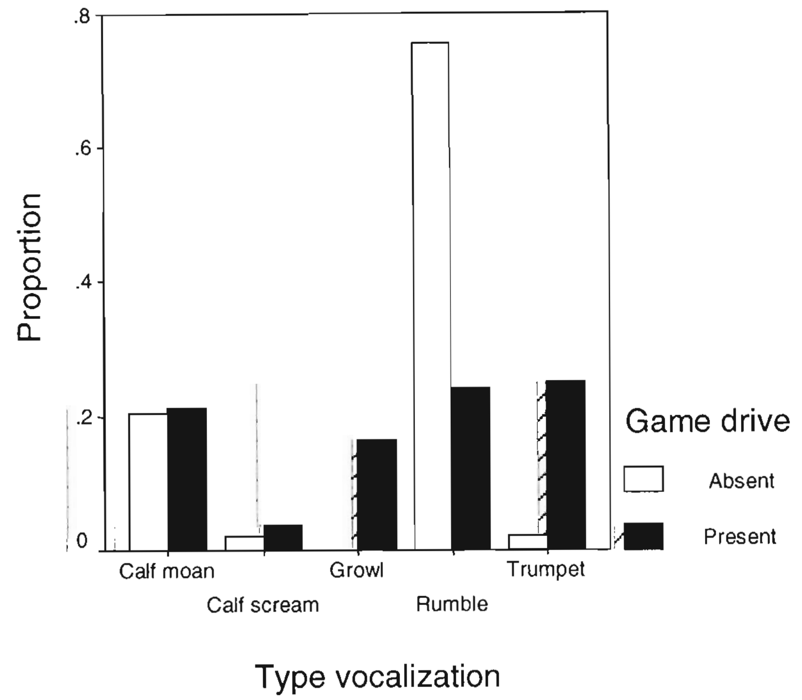


Figure 4.9: The influence of game drive vehicles on the type of vocalizations produced by a group of elephant.

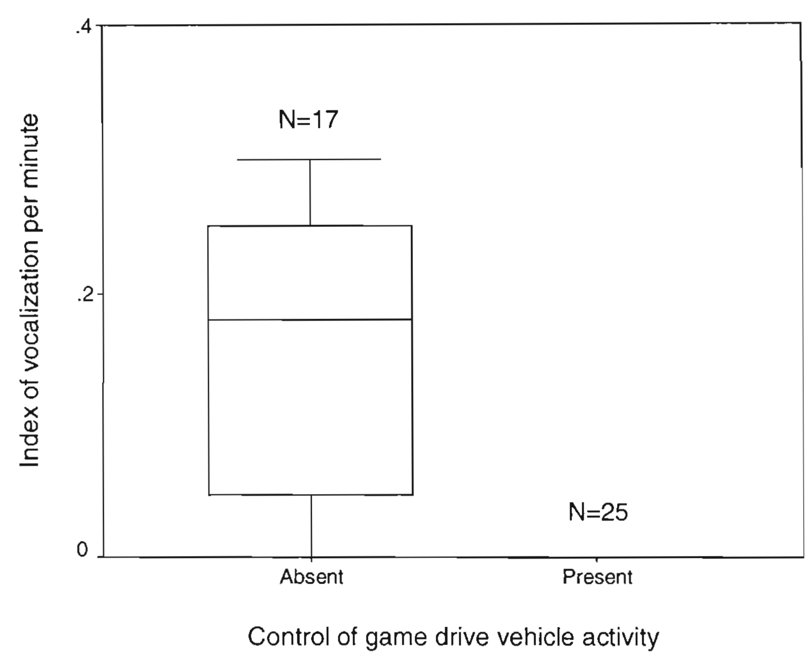


Figure 4.10: The effect of control of game drive vehicle activity at elephant sightings on the vocalizations associated with stress produced by elephants ($P < 0.05$) (N = Number of observation sessions, outliers and extremes are not shown).

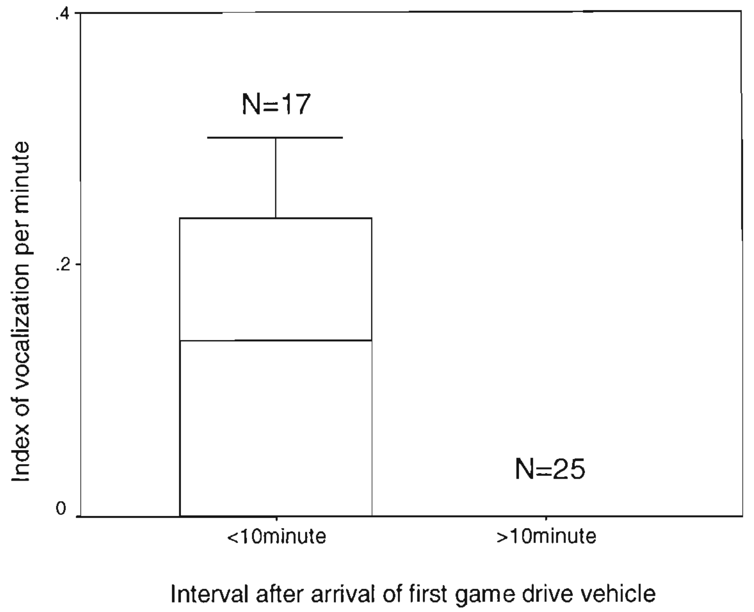


Figure 4.11: The influence of the first ten minutes after arrival of the first game drive vehicle at an elephant sighting and the period thereafter on vocalizations produced by elephants (P < 0.05) (N = Number of observation sessions, outliers and extremes are not shown).

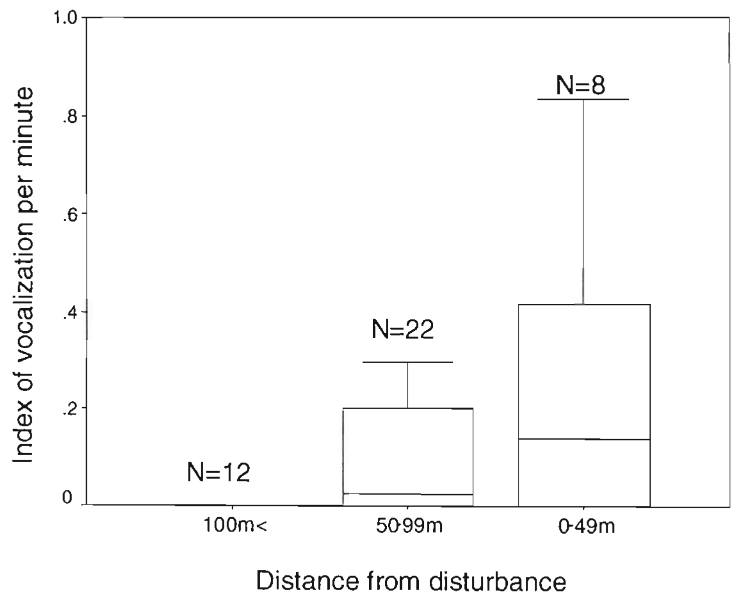


Figure 4.12: The influence of elephant distance from a game drive vehicle on the vocalizations associated with stress produced by elephants (P > 0.05) (N = Number of observation sessions, outliers and extremes are not shown).

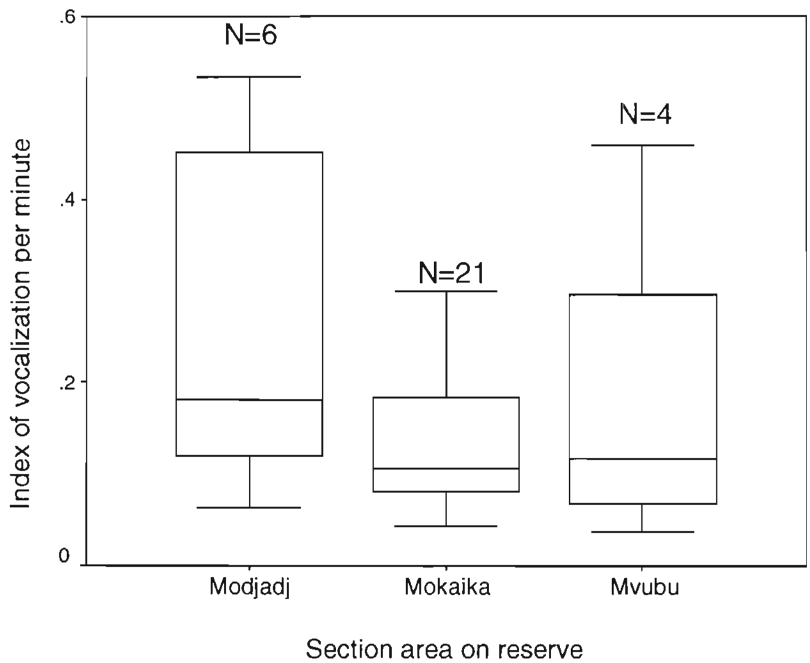


Figure 4.13: The influence of the area that the elephants occur on Mabula Game Reserve on vocalizations associated with stress produced by elephants (P = 0.414) (N = Number of observation sessions).

(c) Daily environmental influences

According to the linear regression analysis average daily temperature did not influence vocalizations produced by elephants ($F = 0.105$, $P = 0.749$, $\beta_1 = 0.069$). As daily rainfall increased so did vocalizations produced by the elephants significantly increase ($F = 4.796$, $P = 0.039$, $\beta_1 = 0.423$) (Figure 4.14).

4.3.3 Group mobility

Group mobility of the elephants was significantly higher in the presence of game drive vehicles at an elephant sighting compared to periods when game drive vehicles were absent (Wilcoxon test: $Z = -3.623$, $N = 26$, $P = 0.001$) (Figure 4.15). The elephants walked slower while feeding more when game drive vehicles were absent (96.8 %) compared to when game drive vehicles were present (54.4 %) and moved faster more often when game drive vehicles were present (44.7 %) compared to when game drive vehicles were absent (3.2%) (Figure 4.16).

Elephants when mobile walked in the road 16.1 % of the time when game drive vehicles were absent and were not observed to walk in the road when game drive vehicles were present. Movement away from the roads into thickets occurred 50 % of the time when game drive vehicles were present compared to only 12.9% when game drive vehicles were absent from an elephant sighting (Figure 4.17).

(a) Factors present in the immediate environment of the elephant

Elephants moved significantly more in the presence of game drive vehicles when the adult bull elephant was absent from the herd (Mann-Whitney test: $Z = -2.638$, $N = 24$, $P = 0.007$) (Figure 4.18). Group mobility of elephants increased from morning towards afternoon periods (Kruskal-Wallis test: $\chi^2_2 = 5.799$, $N = 82$, $P = 0.05$) (Figure 4.19). The residual values of the data for control of game drive vehicle activity via radio communication, the first ten minute interval after arrival of the first game drive vehicle and the distance of the elephants from a disturbance were normally distributed (Kolomogorov-Smirnov test: $N = 24$, $P > 0.05$). There were however no significant changes in group mobility for the elephants on Mabula Game Reserve for any of these independent factors (ANOVA: all $P > 0.05$).

(b) Daily environmental influences

According to the linear regression analysis rainfall did not influence group mobility ($F = 0.075$, $P > 0.05$, $\beta_1 = -0.044$). As average daily temperature increased however group mobility decreased significantly ($F = 9.274$, $P < 0.05$, $\beta_1 = -0.443$) (Figure 4.20).

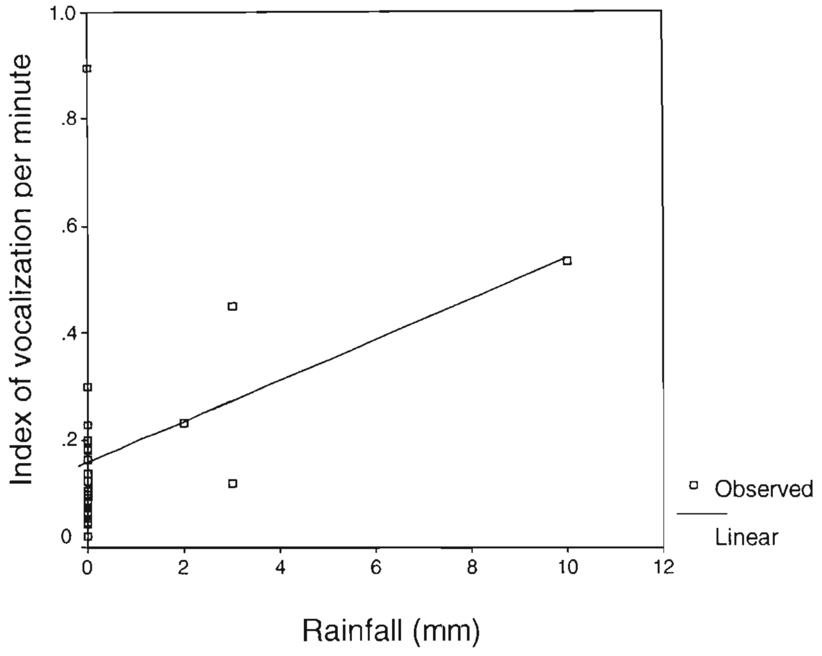


Figure 4.14: The effect of daily rainfall (mm) on vocalizations produced by a group of elephants ($F = 4.796$, $P = 0.039$, $\beta_1 = 0.423$).

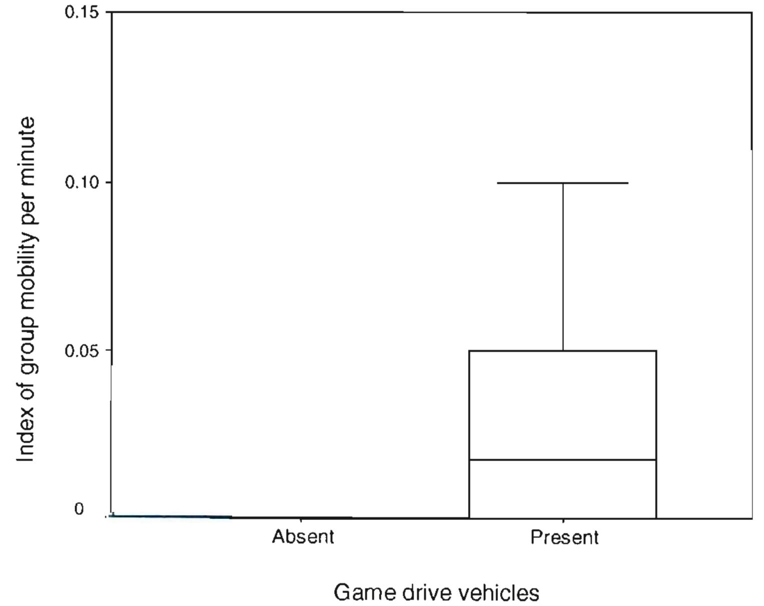


Figure 4.15: The influence of game drive vehicle activity on the mobility of a group of elephants (Wilcoxon test: $N = 26$, $P < 0.05$, outliers and extremes are not shown).

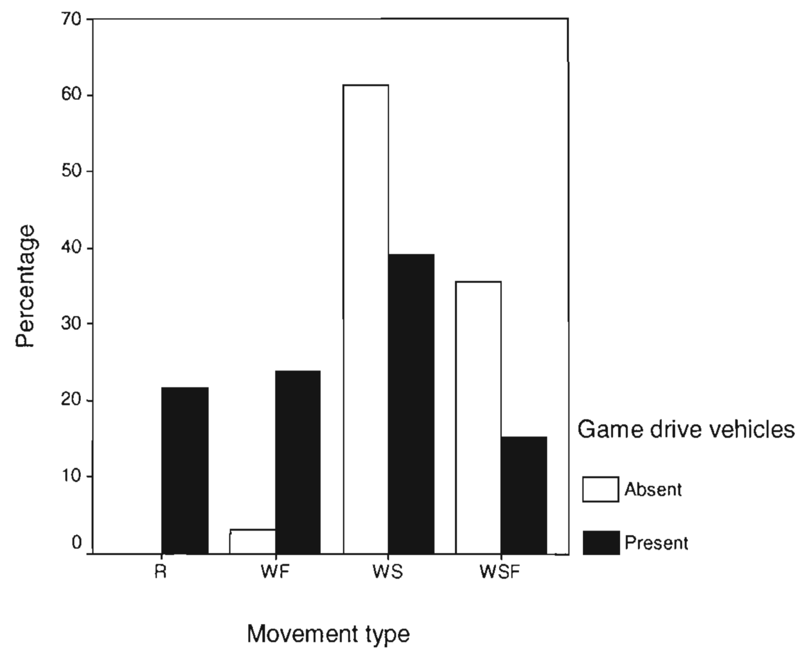


Figure 4.16: The influence of game drive vehicle activity on the type of movement of a group of elephants. R- Moving very fast, WF- Walking fast, WS- Walking slow, WSF- Walking slow feeding (see text).

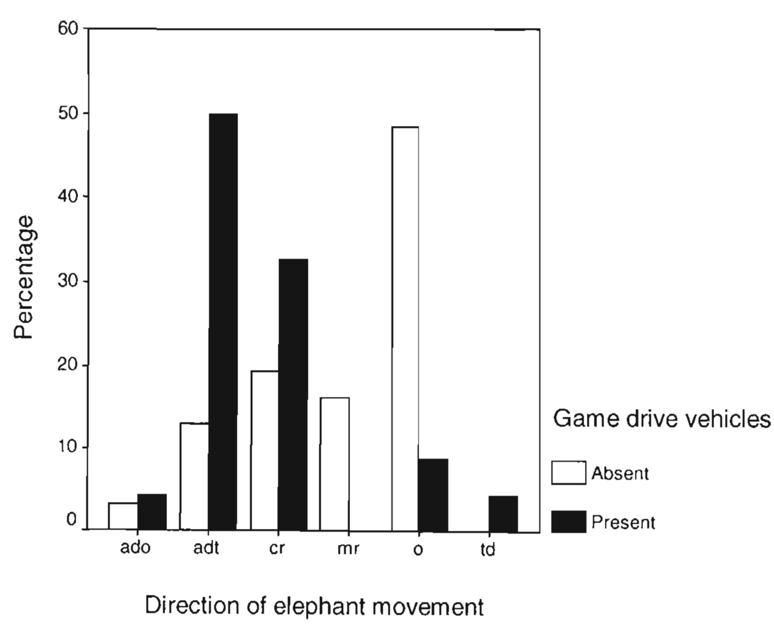


Figure 4.17: The influence of game drive vehicle activity on the direction on elephant movements. ado- away from disturbance into open area, adt- away from disturbance into thicket, cr- crossing a road, mr- mobile in road, o- other, td- moving towards disturbance (see text).

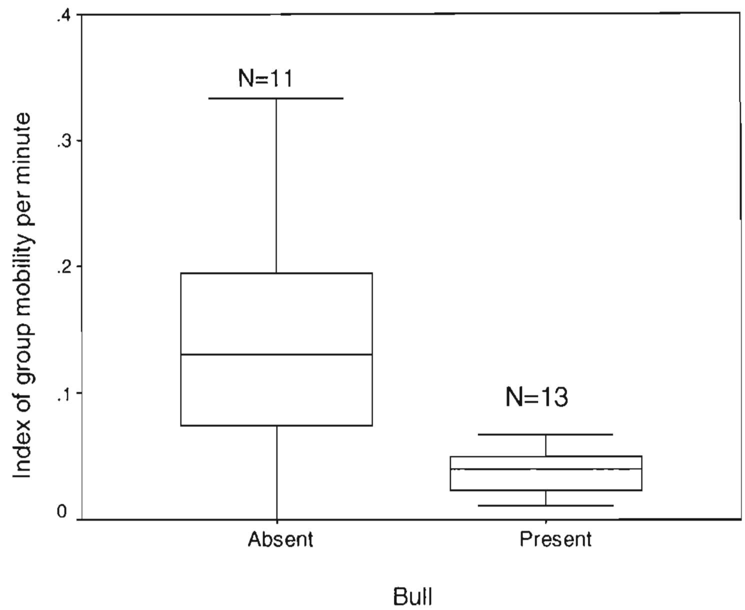


Figure 4.18: The influence of bull presence on the group mobility of elephant when game drive vehicles are present at an elephant sighting (P < 0.05) (N = Number of observation sessions).

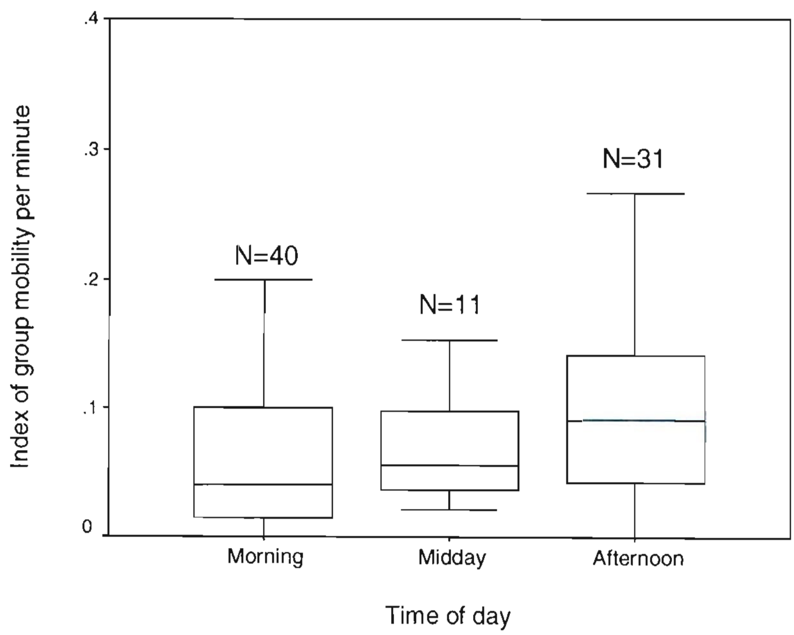


Figure 4.19: The influence of the time of day on group mobility of elephant (P < 0.05) (N = Number of observation sessions).

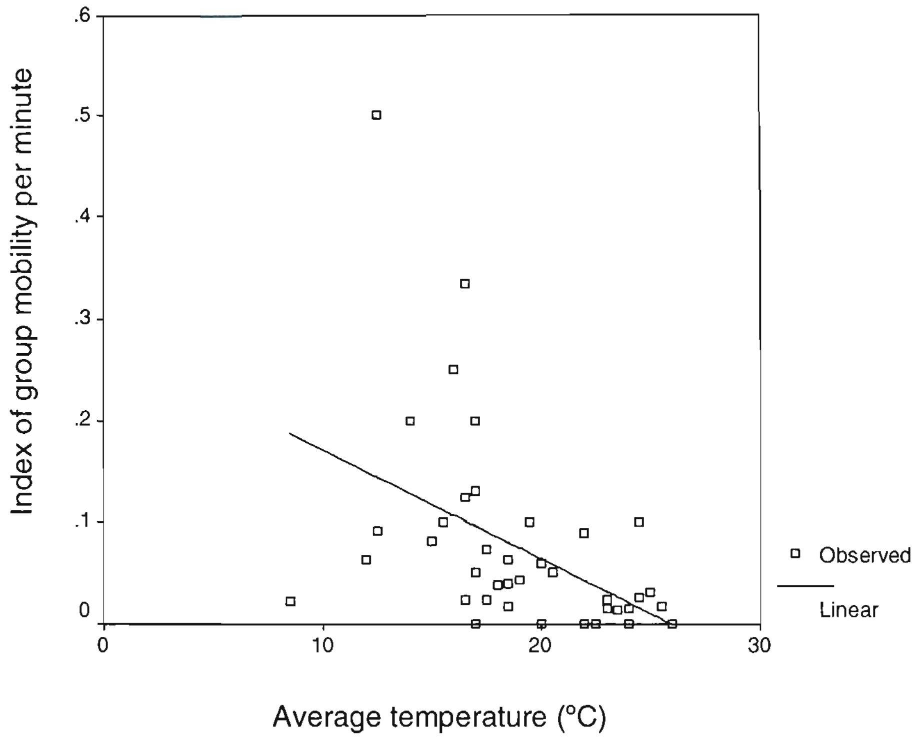


Figure 4.20: The effect of average daily temperature (°C) on group mobility of elephants ($F = 9.274$, $P < 0.05$, $\beta_1 = -0.443$).

4.3.4 Group spacing

Individuals in the group of elephants were significantly more clustered together in the presence of game drive vehicles and more spread out when game drive vehicles were absent from the area of the elephants (Wilcoxon test: $Z = -2.314$, $N = 10$, $P = 0.021$) (Figure 4.21).

(a) Factors present in the immediate environment of the elephant

Neither time of day, presence of the bull, control of game drive vehicle activity at an elephant sighting via radio communication, the first ten minute interval after arrival of the first game drive vehicle or the distance of elephants from disturbances significantly changed spacing of individuals within the group of elephants (all $P > 0.05$).

(b) Factors present for the different times of day (morning, midday and afternoon)

Elephants significantly clustered more together as the total number of game drive vehicles at an elephant sighting for an observation session increased (Kruskal-Wallis test: $\chi^2_3 = 8.596$, $N = 26$, $P = 0.035$) (Figure 4.22). There was no significant difference in spacing of the group of elephant on Mabula Game Reserve for other major disturbances present in the elephant's environment (like helicopters) and for the area that the elephants occurred on according to the eight sections that the reserve were divided into for the purpose of the study (all $P > 0.05$) (Figure 4.23).

4.3.5 General activity

The most marked differences in activity patterns between periods when direct human disturbances were present in the elephant's environment for the elephant calves on Mabula Game Reserve were for suckling and playing activities (Figure 4.24). Suckling activity was significantly higher for periods when direct human disturbances were present in the elephant's environment compared to when direct human disturbances were absent (Chi-square test: $\chi^2_1 = 9.94$, $P < 0.05$). Playing activity occurred significantly less for the calves on Mabula Game Reserve during periods when direct human disturbances were present in the area of the elephant compared to when direct human disturbances were absent (Chi-square test: $\chi^2_1 = 4.49$, $P < 0.05$). The most marked differences in activity patterns between periods when direct human disturbances were present in the elephant's environment for the adult elephants occurred with physical interactions with other elephants, resting and activity associated with stress (Figure 4.25).

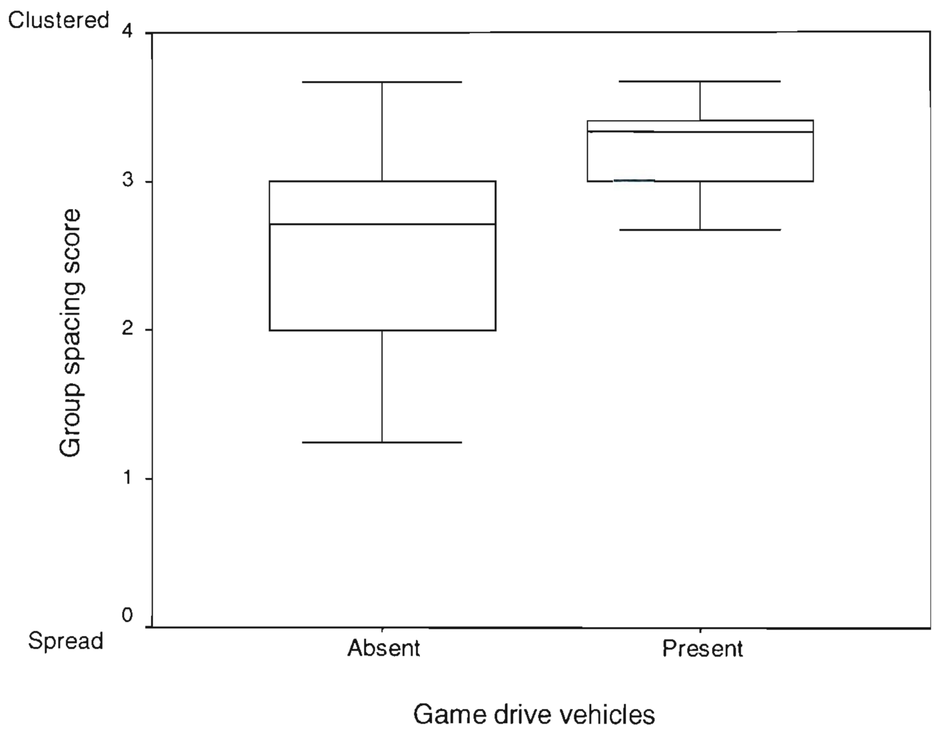


Figure 4.21: The influence of game drive vehicle activity on spacing of individuals within a group of elephants. Group spacing score = Σ (Index value for spacing category * Observed proportion of spacing category) (Wilcoxon test: N = 10, P < 0.05) (see text).

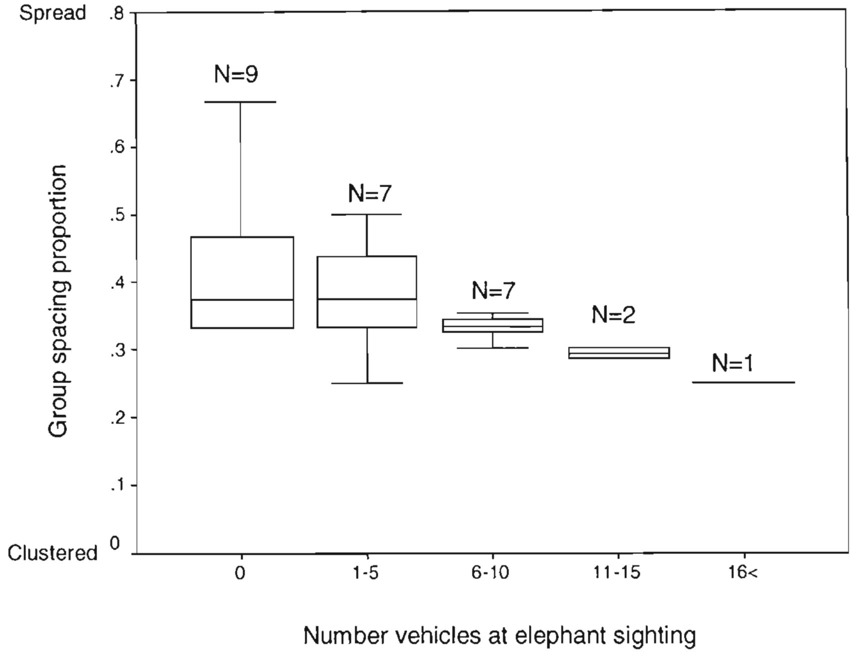


Figure 4.22: The influence of the number of game drive vehicles at an elephant sighting on the spacing between individuals in a group of elephants. Group spacing proportion = (Σ (Index values for spacing categories * number observations of each spacing category))/ Total number of observations per session. ($P < 0.05$) (N = Number observation sessions).

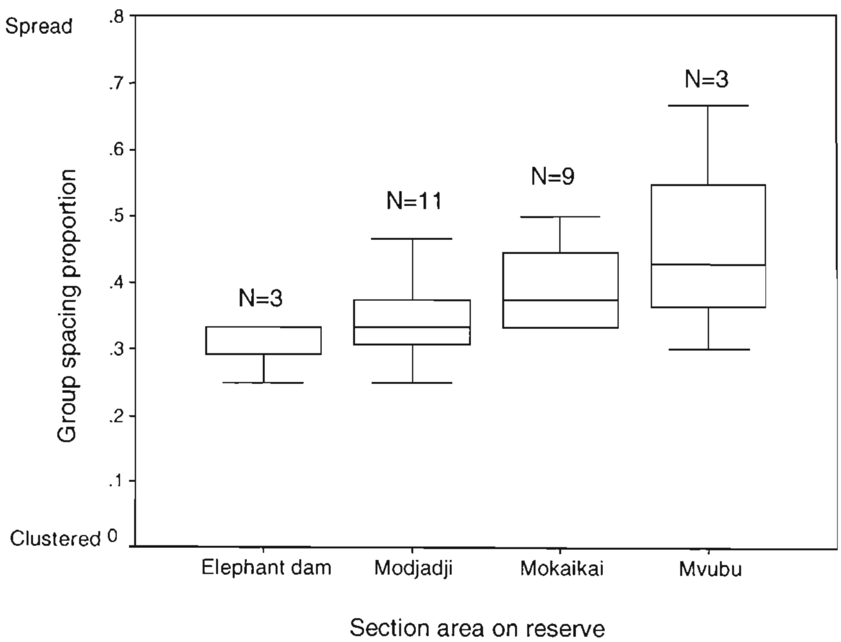


Figure 4.23: The influence of the area that the elephants occur on Mabula Game Reserve on the spacing between individuals in a group of elephants. Group spacing proportion = (Σ (Index values for spacing categories * number observations of each spacing category))/ Total number of observations per session. ($P > 0.05$) (N = Number observation sessions).

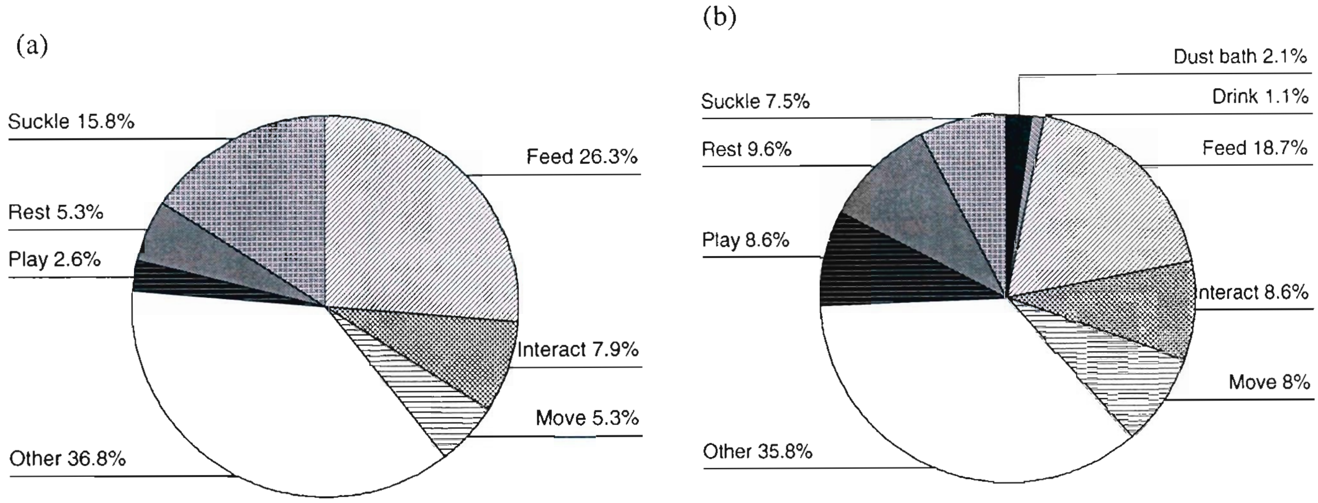


Figure 4.24: The effect of game drive vehicle presence on elephant calf activity patterns. (a) game drive vehicles present at elephant sighting, (b) game drive vehicles absent (see text).

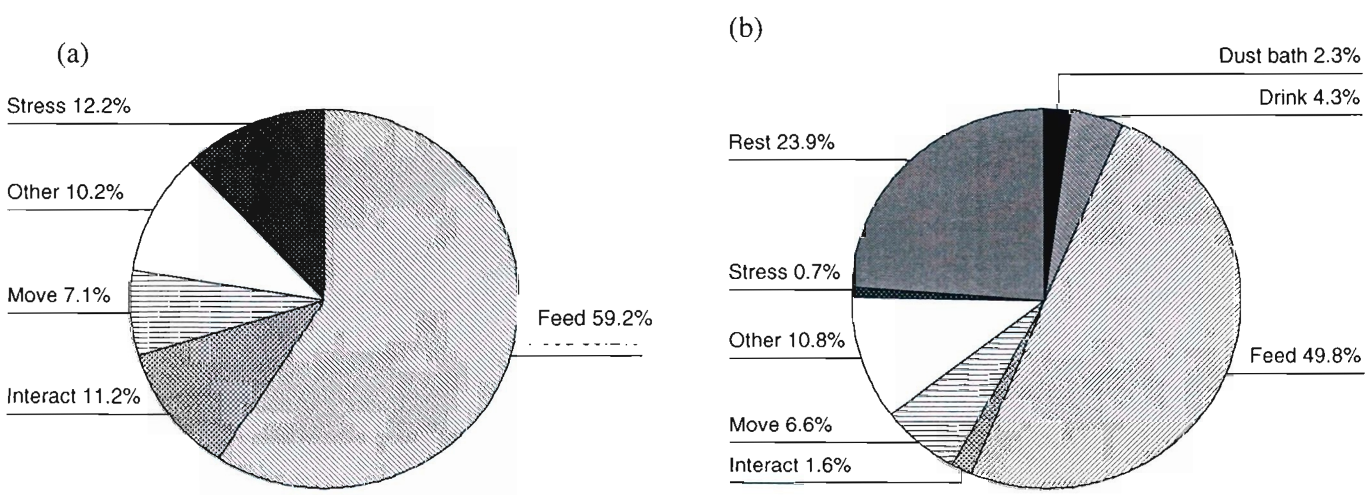


Figure 4.25: The effect of game drive vehicle presence on adult elephant activity patterns. (a) game drive vehicles present at an elephant sighting, (b) game drive vehicles absent (see text).

Physical interactions among adult elephants were significantly more for periods when direct human disturbances were present in the elephant's environment compared to when direct human disturbances were absent (Chi square test: $\chi^2_1 = 56.89$, $P < 0.05$). Trunk to mouth contact and the adults being suckled at by a calf were the most common physical interactions among elephants (Figure 4.26). Resting occurred significantly less for the adult elephants on Mabula Game Reserve during periods when direct human disturbances were present in the area of the elephant compared to when direct disturbances were absent (Chi-square test: $\chi^2_1 = 31.48$, $P < 0.05$). Stress behaviour occurred significantly more for the adult elephants on Mabula Game Reserve when direct human disturbances were present in the area of the elephant compared to periods when disturbances were absent (Chi-square test: $\chi^2_1 = 204.88$, $P < 0.05$). Headshakes not directed towards disturbance (4.08%), standing tall with head lifted and ears spread towards disturbances (1.02%) and forward trunk swishes (2.04%) were the most common behavioural responses when direct human disturbances were present (Figure 4.27).

4.3.6 Bull aggression

The presence of game drive vehicles significantly increased aggression of the bull towards other cow herd members (Mann-Whitney test: $Z_1 = -2.319$, $N = 23$, $P = 0.036$) (Figure 4.28).

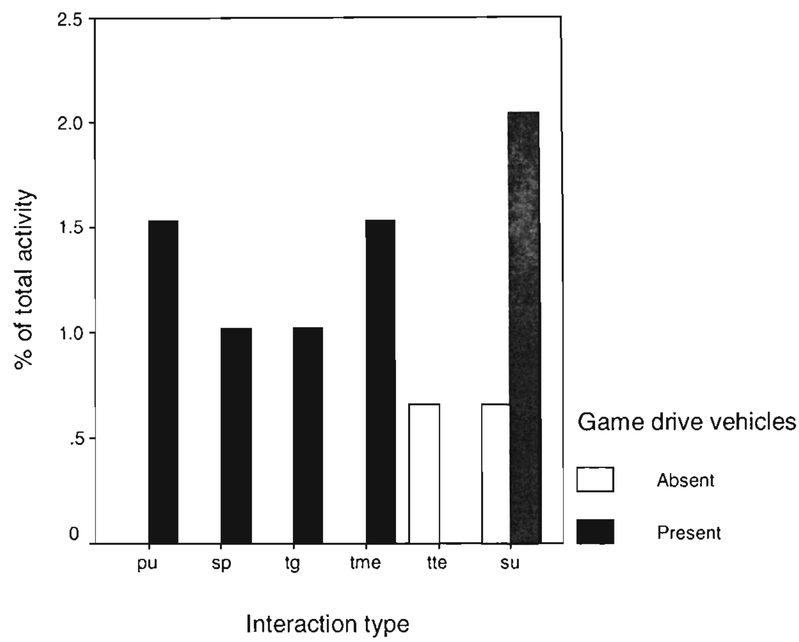


Figure 4.26: The influence of game drive vehicle presence on the type interactions between elephants (pu- pushing each other out of the way, sp- sparring, tg- trunk-genital contact with another elephant, tme- trunk-mouth contact with another elephant, tte- trunk contact with trunk or head or body of other elephant, su - being suckled from by another elephant).

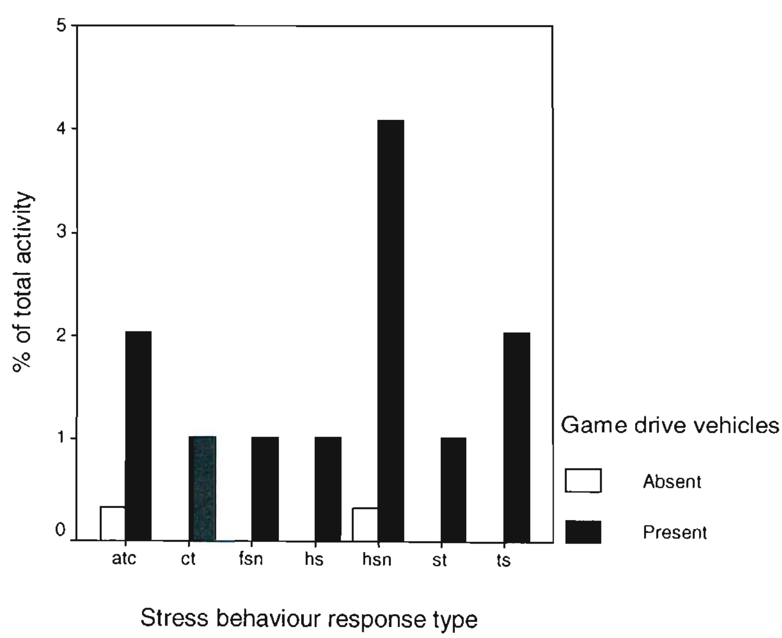


Figure 4.27: The influence of game drive vehicle presence on the type of stress behaviour response in elephants. (atc – abrupt termination of current action while listening, ct- coiling and twitching trunk, fsn- foots swung not directed towards disturbance, hs- head shake towards disturbance, hsn – head shake not directed towards disturbance, st – standing tall with head lifted peering over tusks, ts – forward trunk swish).

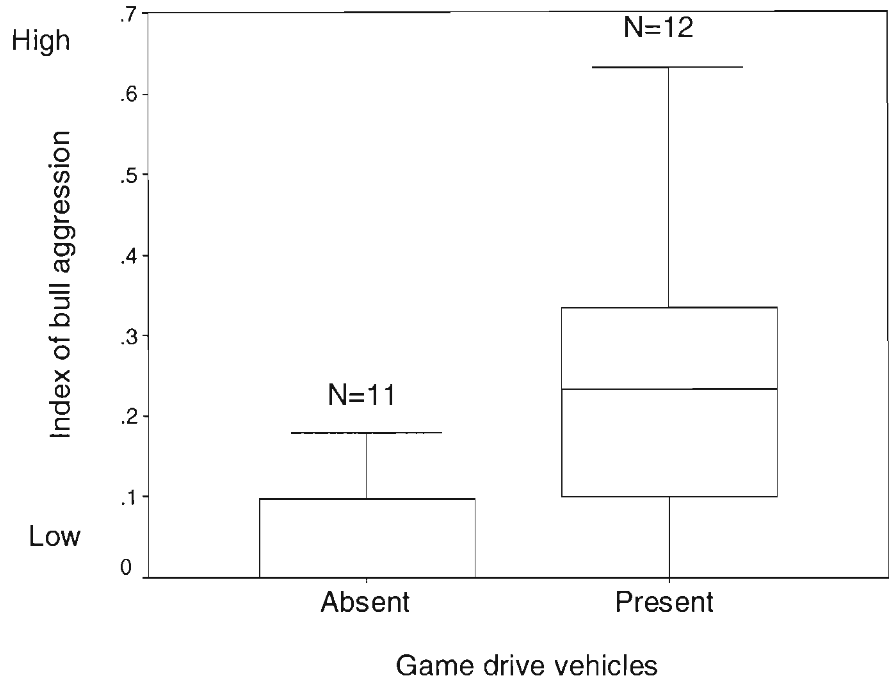


Figure 4.28: Aggression of the twenty-year-old elephant bull, Ngama, towards the other cow herd members on Mabula Game Reserve in the presence and absence of game drive vehicles ($P < 0.05$) (N = Number observation sessions).

4.4 Discussion

According to Roe *et al.* (1997) it is not currently possible to make generalizations concerning the environmental effects associated with wildlife tourism because they are poorly understood and the available literature relating to environmental impacts of wildlife tourism shows little quantitative basis. The current study aimed at developing methods of measuring behavioural stress response, describing individual variation in behavioural stress response and investigating game viewing vehicles as possible stressors for the African elephant. The small number of elephants and extensive road network of the study area provided for detailed research on a daily basis of the impact of tourism on elephant behaviour. In order to be able to generalize the results more studies, using similar methods of monitoring, need to be conducted under varying environmental conditions. On Mabula Game Reserve the occurrence of the elephants clustering together and interacting through mouth to trunk contact significantly more in the presence of game viewing vehicles may indicate a lack of social security due to the absence of elder experienced animals. Comparing results across studies done in different areas and under different environmental conditions will further help identify the effects of possible added social stress as the results of the current study may have been altered due to the disrupted social structure of the study group.

For the elephants on Mabula Game Reserve the presence of game viewing vehicles at elephant sightings significantly increased group mobility, the occurrence of stress behaviour and vocalizations associated with stress. In Chitwan National Park, Nepal during tourist visits rhinoceros spent more time on alert and less time feeding (Lott 1995). Since tourism as a stressor cannot be eliminated, strategies must be developed to reduce where possible the negative effects of tourism on wildlife. According to Roe *et al.* (1997) direct strategies of managing the impact of tourism on wildlife include limiting the total number of visitors to an area, dispersing visitors, using fixed viewing points and setting guidelines for minimum viewing distances while indirect strategies aim to modify the behaviour of tourists. Possible solutions for elephant managers on small reserves may include the following:

(1) Incorporating the use of stress parameters into the general monitoring system of elephants on a reserve thereby identifying and reducing the effect of stressors in the elephant's environment at an early stage.

(2) Providing sufficient space on a reserve in order to host a complete population of elephants with more than one related family group with adult elephants and matriarchs and bull areas with adult bulls. This will not only relieve the tourist pressure from only hosting one group of elephants on a reserve but will also provide young elephants with social security from the

presence of adult experienced elephants. De Villiers and Kok (1997) found that association between female groups could be attributed to kinship and not to the overlapping of range areas. The minimum required home ranges for males in the Lowveld area of South Africa is 157 km^2 and for female elephants ranges from 115 km^2 (De Villiers & Kok 1997) to 717 km^2 (Verlinden & Gavor 1998). Preliminary observations by managers and current studies in reserves where orphan elephants were originally re-introduced from culling operations without adults indicate a general fear and avoidance of humans and tourist roads by cow herds and have reported physical aggression of especially young bulls towards tourist vehicles.

(3) Expanding the size of a reserve to such an extent that wilderness areas can be provided to where elephants can escape to with no accessible roads for tourists. In studies done on reindeer (Tyler 1991) and moose (Colescott & Gillingham 1998) it was found that both these species avoided snowmobiles by retreating to refugee.

(4) Educating the general public and any people who come into regular contact with elephants on how elephants behave and how to respond when encountering elephants. Parks and reserves hosting elephants may have to implement rules and regulations for visitors and field guides around elephant sightings which for example includes a minimum distance that vehicles should keep from elephants and which limits the number of vehicles at a sighting. In Chitwan National Park, Nepal, close approaches by tourist to rhinoceros were more disruptive and frequently displaced the rhinos from the meadows where they preferred to feed. On Mabula Game Reserve the elephants clustered more together and stress behaviour increased significantly with an increase in the number of game viewing vehicles at an elephant sighting while vocalizations associated with stress were produced more often when game drive vehicle activity was not controlled.

(5) Making use of trained guides to do game drives and take tourists to the elephants. According to Kerley, Geach and Vial (2003) the quality of wildlife viewing may be significantly improved through the use of guides because tourists on self-guided drives often focus only on a few charismatic species and may hold misconceptions of the nature of biodiversity.

This study demonstrated that game drive vehicle activity significantly changed the behaviour of the elephants on Mabula Game Reserve. The behaviours measured in the study, which were assumed to indicate stress for elephants, needs to be confirmed and better developed for use by all elephant managers in future to detect stress in their elephant populations and eliminate the causes at an early stage.

Chapter 5
PHYSIOLOGICAL RESPONSE AS AN INDICATOR OF STRESS IN THE AFRICAN ELEPHANT

Abstract

Response to the stimulus from a stressor in an animal's environment causes immediate physiological changes to take place inside the animal, one being the release of glucocorticoids. For social animals like the elephant, these physiological changes do not only prepare an individual for the appropriate response but are also accompanied by communication of the acknowledgement of a stressor in the environment to other group members through chemical signalling. The effect of the presence of direct human disturbances as well as other environmental factors on faecal glucocorticoid (stress hormone) metabolite levels and temporal gland secretion of the African elephant was investigated. Although the age of dung at collection did not change the stress hormone metabolite levels of dung collected within 48 hours, dung which was soft and without structure had lower levels of stress hormone metabolites whereas dung with traces of blood had much higher levels of stress hormone metabolites compared to dung with an apparent normal appearance. Faecal glucocorticoid metabolite levels were significantly higher when collected in certain areas of the reserve and at the sites where feed supplement were provided to the elephants. The adult male elephant in the study group had significant higher faecal stress hormone metabolite levels than both the male calves and adult females on the reserve. The average faecal stress hormone metabolite levels for the group of elephant significantly changed as did the intensity of game drive vehicle activity in the area of the elephant for the different times of day. Temporal gland secretion only increased significantly in the presence of direct human disturbances like game drive vehicles for adult female elephant and were more frequent when game drive vehicle activity were not controlled via radio communication which lead to more than three vehicles being at an elephant sighting at a time, vehicles approaching an elephant sighting from more than one direction and game drive vehicles driving closer than 30 m from the elephants. Because of significant changes in the presence and absence of disturbances and variation among individual elephants of both faecal glucocorticoid metabolite levels and the rate of temporal gland secretion, these two physiological parameters may be useful to measure and indicate the extent of stress experienced by elephants in future studies.

5.1 Introduction

In the past the emphasis concerning the role of the eco-tourism industry in wildlife conservation has mainly been on the financial benefits that it provides and not always on the possible disadvantages or negative influences on wildlife. Together with the demand of tourists to view big game (Kerley, Geach & Vial 2003) comes not only the influence of direct human disturbances in the form of game drive vehicles on elephant behaviour but also the indirect effect of more and more small reserves, which cannot host entire populations of elephants (in other words a population consisting of more than one family group with sufficient adult animals, matriarchs and bull areas), stocking elephants to reap the increased financial benefits from satisfied tourists. This provides for both added internal social stress in the elephant and external direct stress from disturbances in the elephant's environment. Behavioural changes can be measured as an indicator of stress caused by direct disturbances in the elephant's environment due to the variability in the presence and absence of different disturbances (see chapter 4). Social stress are difficult to measure using behavioural changes as a parameter on a single group of elephant because of the constant presence of lack in correct social structure for some elephant populations on small reserves. Under such conditions it may be necessary to compare behaviour of elephants across groups under various environmental conditions and social structures.

Measurement of physiological responses to stressors has the advantage of producing fixed values whereas behavioural responses often involve a subjective approach. For the current study faecal glucocorticoid metabolite levels and temporal gland secretion were measured as physiological responses to both social stress and stress caused by direct disturbances present in the elephants environment. Elephants defecate at an hourly rate of 0.71 totalling 6 boluses at a time with an average weight of 8 kg (Wing & Buss 1970). The main advantage of collecting dung to measure stress levels is that the method is not invasive which eliminates added stress for the animal during collection and allows for more studies to be conducted on wild free-ranging animals.

As a response to the stimulus from a stressor the release of corticotropin-releasing hormone (a polypeptide which is synthesized by the neurosecretory cells of the hypothalamus) is activated via a neuroendocrine reflex (Frandson 1992). Corticotropin-releasing hormone is the substance responsible for adrenocorticotropic hormone (ACTH) to be released from the adenohypophysis of the pituitary gland. The primary effects of ACTH are hypertrophy and hyperplasia of adrenal cortical tissue as well as increased production of adrenal cortical steroid hormones (glucocorticoids). These hormones stimulate conversion of proteins to carbohydrates for energy and decrease inflammatory and immunologic response. Metabolism of glucocorticoids occurs mainly in the liver (Frandson 1992) and there is a lag between the stressor and subsequent secretion of stress hormones (glucocorticoids) in faeces (Wasser *et al.* 2000).

For social animals like the elephant physiological changes due to stimuli from a stressor do not only prepare an individual for the appropriate response but are also accompanied by communication of the acknowledgement of a stressor in the environment to other group members through chemical signalling. Chemical signalling through the temporal gland, situated between the eye and ear of the African and Asian elephant, is unique to these species (Buss, Rasmussen & Smuts 1976). Although the entire function of the gland is not known secretions from this organ occurs in both male and female African elephants. Poole (1987) reports that during periods of musth bulls secrete at times a dark, viscous and at times a lighter, more liquescent fluid from their temporal glands.

For the current study, faecal glucocorticoid metabolite levels and temporal gland secretion were measured to determine whether these parameters are suitable for measuring stress in the elephant, which other environmental factors changes these parameters, whether individual differences occur among elephants for these parameters and whether more specifically game drive vehicle activity causes stress for elephants. The study aims to develop practical methods of measuring stress that can be implemented by reserve managers as part of a monitoring program to detect possible occurrences of elevated stress levels in elephants so that the stressors in the elephants environment can be identified and either be eliminated or reduced which might prevent possible injury of elephants to tourists and other species in future.

5.2 Methodology

5.2.1 Dung collection

Throughout the study period from March 2002 to March 2003 dung was collected whenever present during daily field observations of behaviour of elephant on Mabula Game Reserve. Two samples the size of a golf ball each was collected from the middle of a single dung bolus and note taken on the consistency and appearance of the dung:

(1) normal
(2) soft (breaks and loses structure easily when handled)
(3) very soft (in a heap not in the form of a bolus)
(4) bloody (traces of blood in and on the outside of the bolus)

Time and date of sampling, the time of defecation or the estimated age of the dung if unknown, the name of the elephant observed to have defecated and the location of the dung were also recorded. All the dung samples on Mabula Game Reserve were collected within 48 hours of deposition. Dung samples were stored in freezer bags and frozen after each daily session of field data collection. Every second month the samples collected were prepared and treated according to the protocol set by Millspaugh (Appendix E) before it was shipped to a laboratory in the United States for further analysis. According to Millspaugh (2001) only fresh dung samples should be collected for more accurate measurements because environmental conditions may influence faecal glucocorticoid metabolite levels if faeces cannot be collected immediately after deposition, and if faecal samples are exposed to rainfall for one week glucocorticoid measurements may be artificially inflated.

5.2.2 Radio immunoassay procedures and assay validation.

Faecal glucocorticoid metabolite levels in elephant faecal extracts were measured using a commercially available corticosterone I125 radioimmunoassay kit (Cat. 07-120102, ICN Biomedicals, Costa Mesa, California). Elephant faecal samples were analysed in 4 assays, with each assay including all the samples from an individual elephant. The ICN protocol for the I125 corticosterone RIA were followed, except that the volume of all reagents were halved (Wasser *et al.* 2000). A standard assay validation were conducted including assessment of parallelism, recovery of exogenous analyte, intra- and interassay precision, and assay sensitivity (Jeffcoate 1981, Grotjan & Keel 1996, O'Fegan 2000) to confirm that the assay accurately and precisely measured glucocorticoid metabolites in elephant faeces. Parallelism and recovery of exogenous corticosterone validation assays were conducted on two pooled faecal extract samples (low and high; each pool consisted of faeces from three individuals). Parallelism ensures the assay maintains linearity under dilution, and recovery of exogenous corticosterone verifies accurate measurement throughout the working range of the assay (Jeffcoate 1981). Elephant faecal samples were selected and analysed in each assay and interassay variation was calculated from these three samples. Intra-assay variation was calculated by averaging the CV's of replicate tubes from 20 randomly chosen samples.

5.2.3 Analysis of faecal stress hormone metabolite levels data

(1) Influence of the age of dung at sampling (time between deposition and sampling)

Using the Kruskal-Wallis test for independent samples the effect of dung age on the fecal stress hormone metabolite levels were determined after division of samples into the following five categories:

(a) Fresh – dung 0 to 1 hour old (Bolus warm on the inside or still wet on the outside and the elephants located using radio telemetry equipment within 2 kilometres from the location of the dung)
(b) Dung 1 to 5 hours old (Bolus cold and wet on the inside with a little moisture on the outside)
(c) Dung 5 to 12 hours old (Bolus dry on the outside and cold and wet on the inside)
(d) Dung 12 to 24 hours old (Bolus dry on the outside and cold with a little bit of moisture on the inside)
(e) Dung more than 24 hours old (Bolus dry on the outside and cold and dry on the inside. Sample collected at the elephant observation sight of the previous day)

(2) Dung consistency and appearance

Using the Kruskal-Wallis test for independent samples the effect of dung appearance on the stress hormone metabolite levels of dung samples were analysed with division of dung samples into the categories specified above.

(3) Location of dung

The dung samples were pooled and compared according to the eight area sections that the reserve were divided into for the purpose of the study. The dung samples collected at the sites where feed supplement were provided for elephants were pooled and compared with dung collected elsewhere on the reserve. According to the location of each dung sample, the effect of the feed supplement sites and the general area in which the dung were sampled in on the faecal stress hormone metabolite levels were analysed using non-parametric tests for independent samples.

(4) Variation in stress hormone metabolite levels between individual elephants

(a) The differences in faecal stress hormone metabolite levels between the adult male elephant and the four adult female elephants on Mabula Game Reserve were analysed using the Mann-Whitney test for two independent samples.

(b) The differences in faecal stress hormone metabolite levels between the five adult elephants and the two male calves on Mabula Game Reserve were analysed using the Mann-Whitney test for two independent samples.

(c) The differences in faecal stress hormone metabolite levels between the adult male elephant and the two male calves on Mabula Game Reserve were analysed using the Mann-Whitney test for two independent samples.

The data were pooled and analysed using the above methods due to the small number of known faecal samples for each individual elephant. The purpose was to investigate whether there are significant differences in faecal stress hormone metabolite levels among different individual ages and sexes of elephant. N did not equal the number of elephant but rather the number of faecal samples. The samples were independent from each other because they were collected throughout the study with a minimum of four days of no sampling between the known samples collected for each individual elephant.

(5) Lag time

According to Wasser *et al.* (2000) it takes about 36 hours for a stressful event to be maximally detected in elephant faeces. For the current study lag time is defined as the length of time between the time a stressor is present in the elephants environment stimulating a physiological response and the time faecal stress hormone metabolite levels increase because of the previous presence of the stressor. The lag time for the study group of elephant was determined by subtracting 1 up to 36 hours consecutively from all the dung data. The mean faecal stress hormone metabolite levels were then calculated for each set of hours subtracted for eight different times of day (each with its own intensity of game drive vehicle activity):

(a) 0:01 to 3:00, no game drive vehicle activity

(b) 3:01 to 6:00, no game drive vehicle activity

(c) 6:01 to 9:00, high game drive vehicle activity

(d) 9:01 to 12:00, low game drive vehicle activity

(e) 12:01 to 15:00, no game drive vehicle activity

(f) 15:01 to 18:00,high game drive vehicle activity

(g) 18:01 to 21:00, low game drive vehicle activity

(h) 21:01 to 24:00, no game drive vehicle activity

The daily changes in faecal stress hormone metabolite levels of each set of subtracted hours were then compared with the intensity of game drive vehicle activity for the chosen eight different times of day.

5.2.4 Temporal gland secretion

Data were collected over 114 sessions and a total of 38 hours throughout the study period between March 2002 and March 2003 of the amount of times that each of the nine elephant on Mabula Game Reserve secreted from their temporal glands during periods of observation. Each day the elephants were observed during either the morning, midday or afternoon for the time visible before arrival of the first game drive vehicle at the elephant sighting (first observation session in the absence of game drive vehicles) and after arrival of the first game drive vehicle at the sighting (second observation session in the presence of game drive vehicles). Any sessions that stretched over less than 10 minutes were not used for statistical analysis. When temporal gland secretion was present the time of secretion, the name of the elephant secreting and the extent of secretion were recorded for the particular elephant under observation and categorized with ranked index values as follows (Poole 1987):

(1) Temporal secretion to the lower extent of the eye. Index: 1

(2) Temporal secretion to the top part of the lower jaw. Index: 2

(3) Temporal secretion to the corner of the mouth. Index: 3

(4) Temporal secretion to the base of the lower jaw. Index: 4

For the purpose of analysis a value was calculated for each session of observation of temporal gland secretion of each elephant by multiplying the index values by the amount of times that each secretion occurred and then summing all values to obtain a total score for each session of observation. For comparison across sessions and with other elephants, because not all observation sessions stretched over the same amount of time, an index of temporal gland secretion per minute was calculated by dividing each score with the amount of time that an elephant was observed for each session. Each daily sample for each elephant consisted of a session when game drive vehicles were absent from the area of the elephant and a session when game drive vehicles were present at an elephant sighting. The affect of game drive vehicle presence on the temporal gland secretion of each elephant in general was tested using the Wilcoxon test with each observation session as a sample point.

Further data analysis of temporal gland secretion was divided according to the type of environmental factors influencing the elephants at various time intervals during each session of observation. The data for each observation session were pooled together for each environmental factor category. For example, Bull present sessions and bull absent sessions:

(a) Immediate environmental influences (univariate ANOVA):

(i) Bull presence (comparing temporal gland secretion for times when the twenty year old bull on the reserve was with the herd to times when he was not with the herd).

(ii) Time of day (comparing temporal gland secretion for morning (5:30 – 10:00), midday (10:01 – 14:30) and afternoon (14:31 – 19:00) periods).

(iii) Interval (comparing temporal gland secretion for the first ten minutes after arrival of the first game drive vehicle to the time period after ten minutes of arrival of the first game drive vehicle at an elephant sighting).

(iv) Sight control (comparing temporal gland secretion for periods when game drive vehicle activity are controlled at elephant sightings using radio communication to periods when game drive vehicles are not controlled leading to vehicles either not keeping a minimum distance of 30 m from the elephants, more than three vehicles being at an elephant sighting at a time, more than five vehicles being in the general area of the elephant at a time and vehicles approaching the elephant from more than one direction thereby blocking the direction of movement of the elephants).

(v) Distance of a disturbance from the elephants (comparing temporal gland secretion when disturbances like game drive vehicles are present at an elephant sighting between periods when the closest disturbance to the elephants is 0 to 49 m, 50 to 99 m and more than 100 m).

(b) Time of day influences (univariate ANOVA):

(i) Amount of game drive vehicles present at an elephant sighting for the entire morning, midday and afternoon periods.

(ii) Amount of game drive vehicles present in the area of the elephant for the entire morning, midday and afternoon periods.

(iii) Area or section on the reserve according to the eight sections that the reserve were divided into for the study where the elephants occurred in for most of the morning, midday and afternoon periods.

(c) Daily environmental influences

The affects of daily rainfall and average temperature on temporal gland secretion were analyzed as continuous variables using linear regression models.

H_0: $\beta_1 = 0$

Where β_1 represents the slope of the regression curve in the estimated simple linear regression equation: $\hat{y} = \beta_0 + \beta_1 x$

When data were normally distributed (Kolmogorov-Smirnov test $P > 0.05$) parametric statistics were used. When data were not normally distributed the appropriate non-parametric test were used. Data are presented as box-and-whisker plots (maximum, 75% quartile, median, 25% quartile and minimum).

5.3 Results

5.3.1 Faecal glucocorticoid metabolite levels

(1) Age of dung from deposition to collection

No significant differences occurred in stress hormone metabolite levels between the ages of dung samples (time between when the dung was sampled and the time of deposition) (Kruskal-Wallis test: $\chi^2_4 = 5.311$, N = 199, P = 0.257) (Figure 5.1).

(2) Dung consistency and appearance

Stress hormone metabolite levels differed significantly with changes in dung consistency and appearance (Kruskal-Wallis test: $\chi^2_3 = 16.805$, N = 199, P = 0.001). For softer dung samples the faecal stress hormone metabolite levels were lower than for normal samples and were higher for samples with traces of blood in them (Figure 5.2).

(3) Location of dung

Stress hormone metabolite levels for dung collected at feed supplement sites were higher than dung samples collected else where on the reserve (Mann-Whitney test: Z = -2.268, N = 199, P = 0.023) (Figure 5.3). Significant differences occurred in stress hormone metabolite levels between the different areas where dung were sampled on the reserve (according to the sections that the reserve were divided into for the purpose of the study) (Kruskal-Wallis test: $\chi^2_3 = 29.707$, N = 132, P = 0.001). Stress hormone metabolite levels were highest for dung sampled in the Modjadji area and lowest for dung sampled in the Mvubu area of Mabula Game Reserve (Figure 5.4).

(4) Variation in stress hormone metabolite levels between individual elephants

The adult male, Ngama, on Mabula Game Reserve had significantly higher levels of stress hormone metabolites in his dung compared to the four adult females on the reserve (Mann-Whitney test: Z = -2.699, N = 44, P = 0.007) (Figure 5.5). Although results revealed no significant differences in faecal stress hormone metabolite levels between elephant calves and adult elephants (P > 0.05) the adult bull on the reserve (Ngama) had significantly higher levels of faecal stress hormone metabolites compared to the two male calves on Mabula Game Reserve (Z = -2, N = 35, P = 0.046) (Figure 5.6).

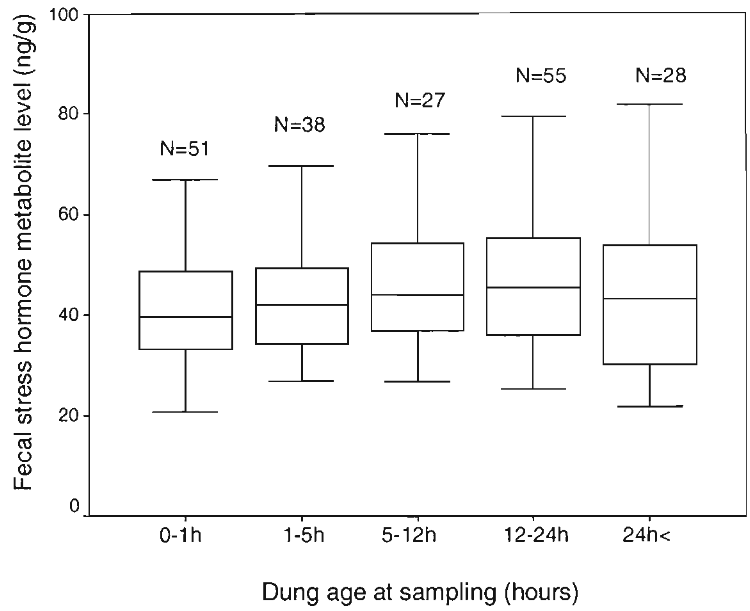


Figure 5.1: The effect of age of dung at sampling (time between sampling and deposition of dung by elephant) on faecal glucocorticoid metabolite levels of elephants ($P > 0.05$) (N = Number of samples).

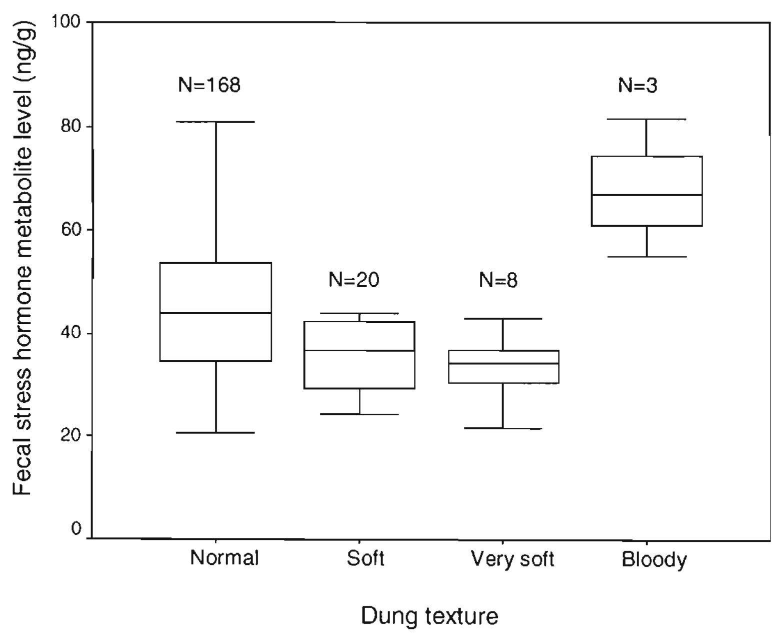


Figure 5.2: The effect of dung appearance and consistency on faecal glucocorticoid metabolite levels of elephant ($P < 0.05$) (N = Number of samples).

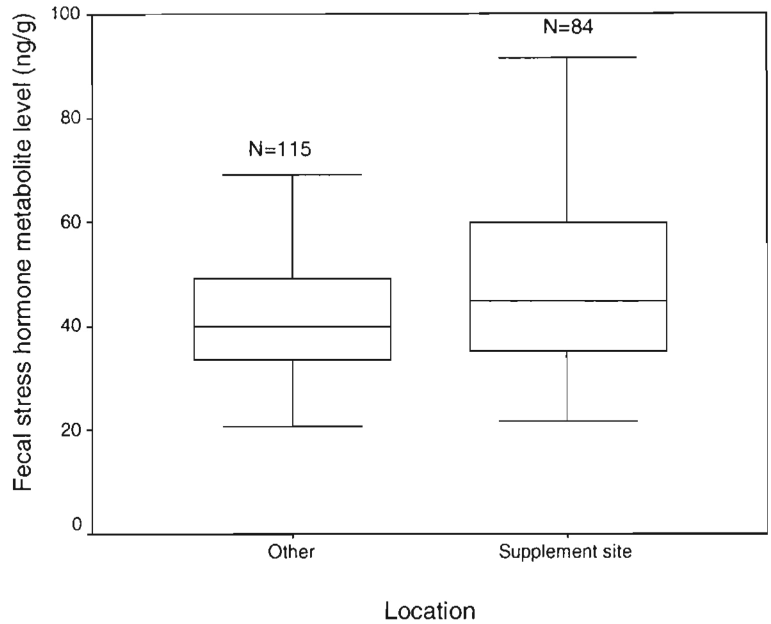


Figure 5.3: The influence of feed supplement sites for elephants on faecal glucocorticoid metabolite levels of elephant (P < 0.05) (N = Number of samples).

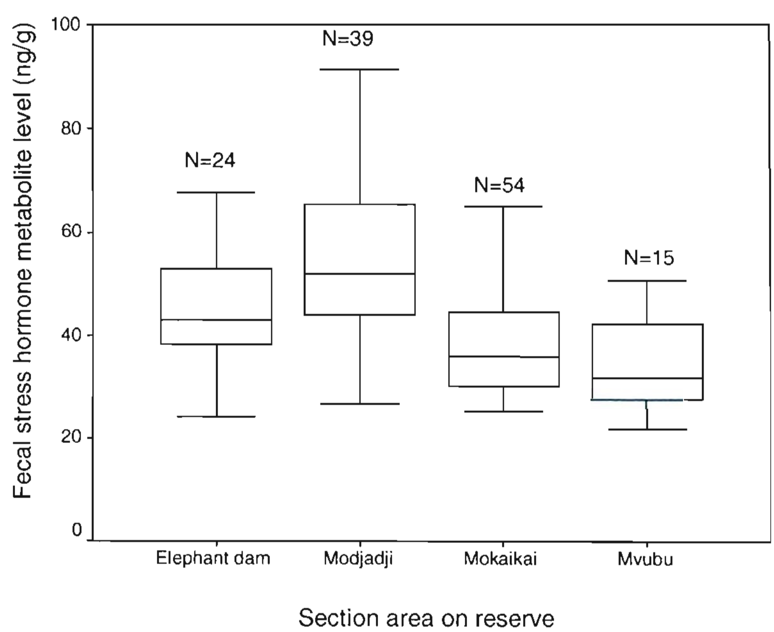


Figure 5.4: The influence of the general area (according to the eight sections that the reserve were divided into for the purpose of the study) where dung were sampled on Mabula Game Reserve on faecal glucocorticoid metabolite levels of elephant (P < 0.05) (N = Number of samples).

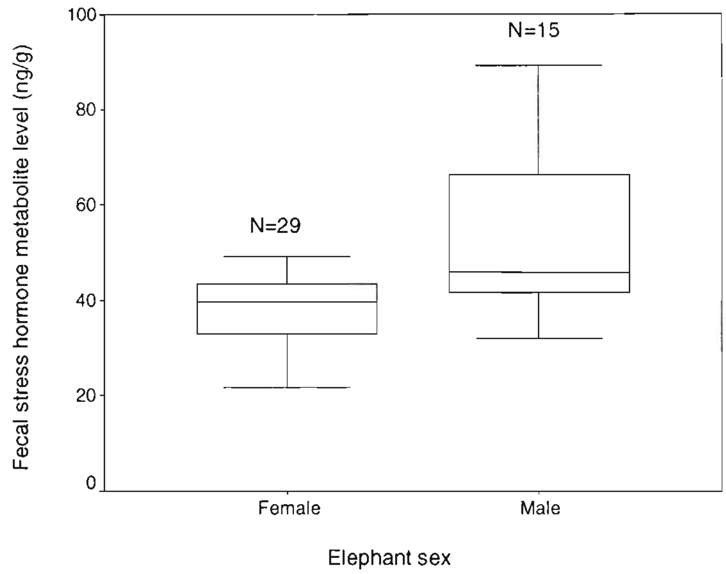


Figure 5.5: The difference between faecal glucocorticoid metabolite levels of adult female and the adult male elephant on Mabula Game Reserve (P < 0.05) (N = Number of samples).

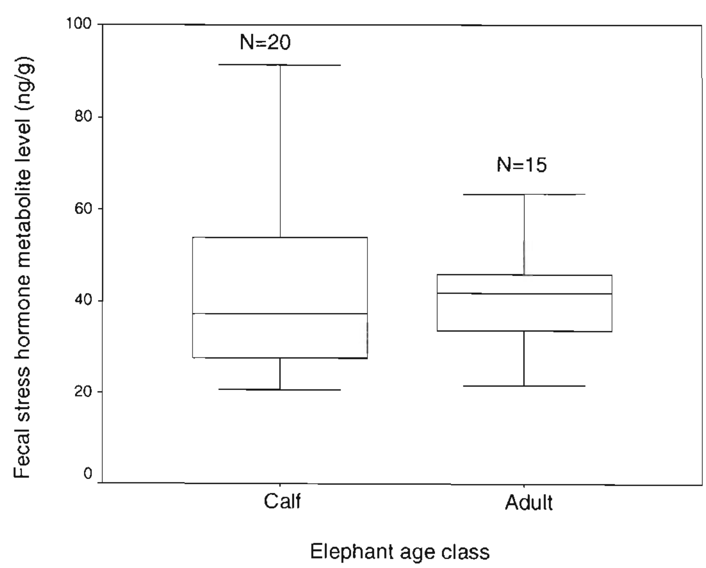


Figure 5.6: The difference between faecal glucocorticoid metabolite levels of adult elephants and calves on Mabula Game Reserve (P < 0.05) (N = Number of samples).

(5) Lag time

Stress hormone metabolite levels in the dung of elephant changed significantly with the different times of day in which the days of sampling were divided into (Kruskal-Wallis test: $\chi^2_7 = 20.03$, N = 196, P = 0.005) (Figure 7). When the estimated times of deposition of all dung samples were shifted back by 33 hours, faecal stress hormone metabolite levels showed a general daily pattern of increase during the morning period (6:01 – 9:00), decrease during the midday period (12:01 – 15:00), another increase during the afternoon period (15:01 – 18:00) after which time, stress hormone metabolite levels dropped throughout the night until the following morning. Game drive vehicle activity followed the same daily pattern, being highest during the morning (6:01 – 9:00) and afternoon period (15:01 – 18:00) and lowest for the midday (12:01 – 15:00) period (Table 5.1). Assuming a 33 hour lag-time, faecal stress hormone metabolite levels increased significantly as game drive vehicle activity increased in the vicinity of the elephant (Kruskal-Wallis test: χ^2_2 = 15.91, N = 156, P = 0.001).

(6) The effect of average daily temperature

As average daily temperature increased, faecal stress hormone metabolite levels significantly decreased ((F = 5.23, P = 0.027, $\beta_1 = -0.326$) (Figure 5.8).

5.3.2 Temporal gland secretion

Except for Bekile (female) and Ngama (male) all other adult elephants secreted from their temporal glands significantly more during periods when game drive vehicles were present at an elephant sighting compared to periods when game drive vehicles were absent (Wilcoxon test: all P < 0.05) (Figure 5.9). None of the elephant calves showed significant changes in the rate of temporal gland secretions between periods when game drive vehicles were present at an elephant sighting and periods when game drive vehicles were absent (Wilcoxon test: Botlokwa - Z = 0.000, N = 16, P = 1, Semaka - Z = 0.000, N = 16, P = 1, Tabogo - Z = -1.826, N = 17 P = 0.068, Mafuta - Z = -1.069, N = 17 P = 0.285). Temporal gland secretion to the top part of the lower jaw was the most frequent type of secretion extent (Figure 5.10)

(a) Factors present in the immediate environment of the elephant

The data on the immediate environmental influences on temporal gland secretions for adult female elephants were normally distributed (Kolomogorov-Smirnov test: N =36, P > 0.05).

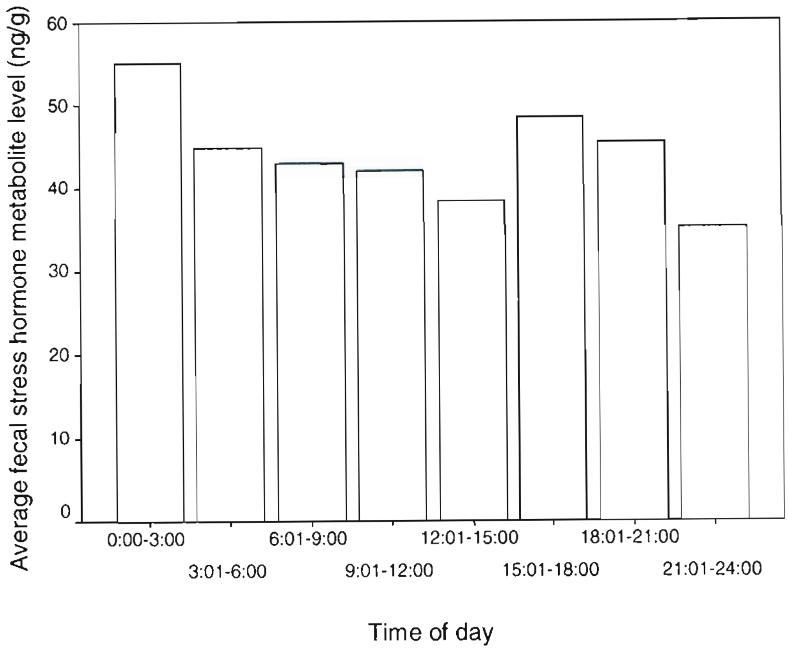
Table 5.1

The relation of the intensity of daily game drive vehicle activity in the vicinity of the elephant with average faecal stress hormone metabolite levels of elephants.

Time of day period	Game drive vehicle activity in the vicinity of elephant	Average stress hormone metabolite level at time of dung deposition (ng/g)	Average stress hormone metabolite level with a 33 hour lag time (ng/g)
0:01 – 3:00	No	55	42
3:01 – 6:00	No	45	38
6:01 – 9:00	High	43	48
9:01 – 12:00	Low	42	45
12:01 – 15:00	No	38	35
15:01 – 18:00	High	48	55
18:01 – 21:00	Low	45	45
21:01 – 24:00	No	35	43

*No – No observable game drive vehicles present in the vicinity (within a 500 m radius) of the elephant, Low – an average of five game drive vehicles present in the vicinity of the elephant, High – an average of six or more game drive vehicles present in the vicinity of the elephant.

(a)



(b)

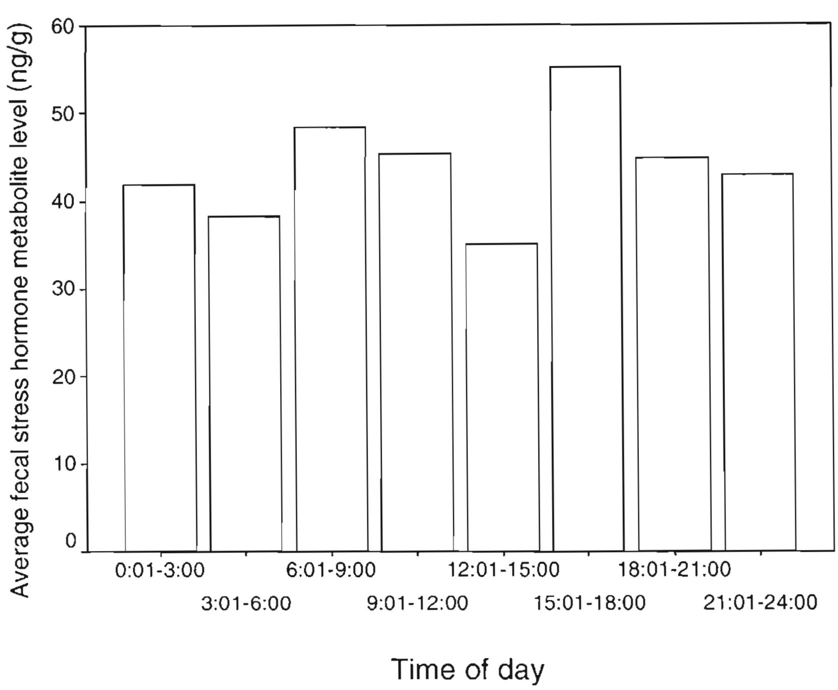


Figure 5.7: Daily patterns of average faecal stress hormone metabolite levels considering the lag-time between secretion of stress hormones after a stimuli from the environment and deposition of the stress hormone metabolites in dung (a) The average glucocorticoid metabolite levels in the dung of elephants at deposition for the different times of day, (b) The average glucocorticoid metabolite levels in the dung of elephants after 33 hours have been subtracted from the time of deposition of dung.

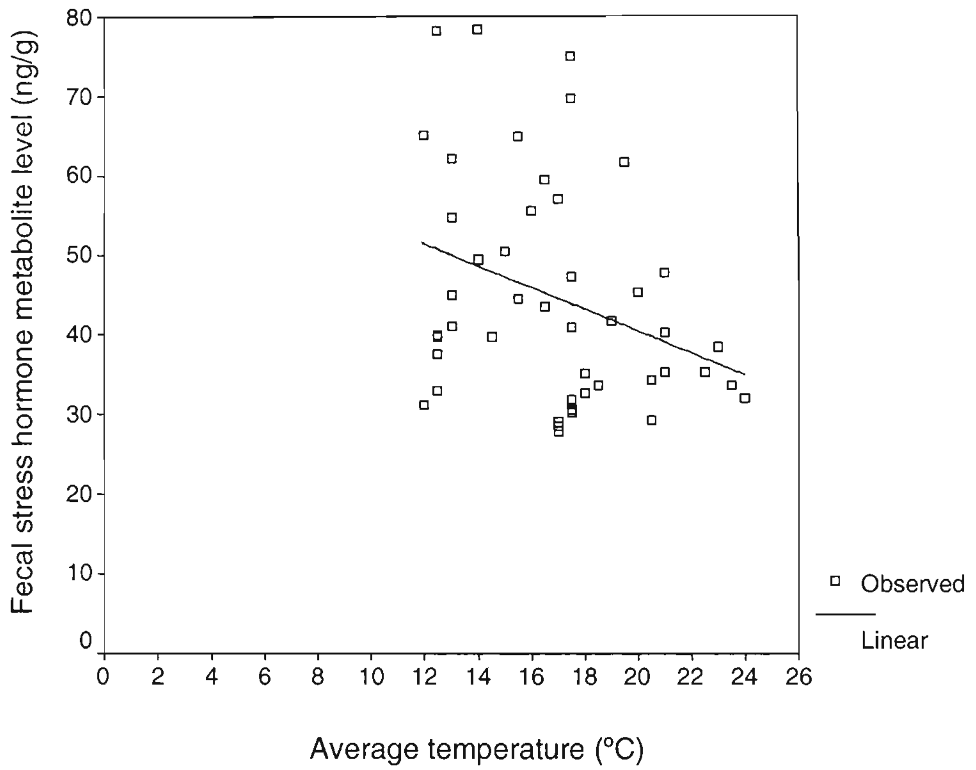


Figure 5.8: The influence of average daily temperature on faecal stress hormone metabolite levels.

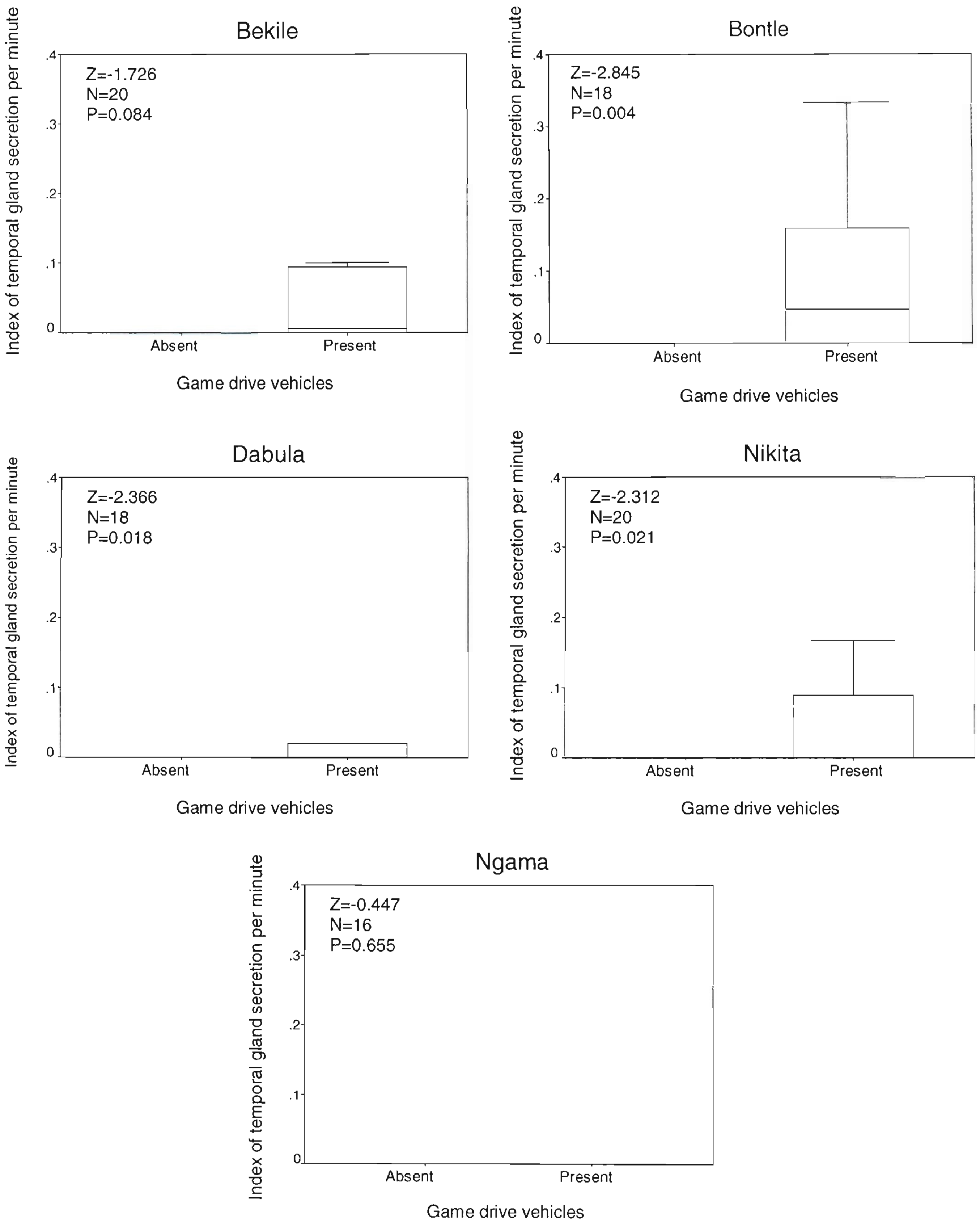


Figure 5.9: The influence of game drive vehicle presence on temporal gland secretion of adult elephant (a) Bekile (female without calf), (b) Bontle (female with calf), (c) Dabula (female with calf), (d) Nikita (female with calf), (e) Ngama (male) (outliers and extremes are not shown).

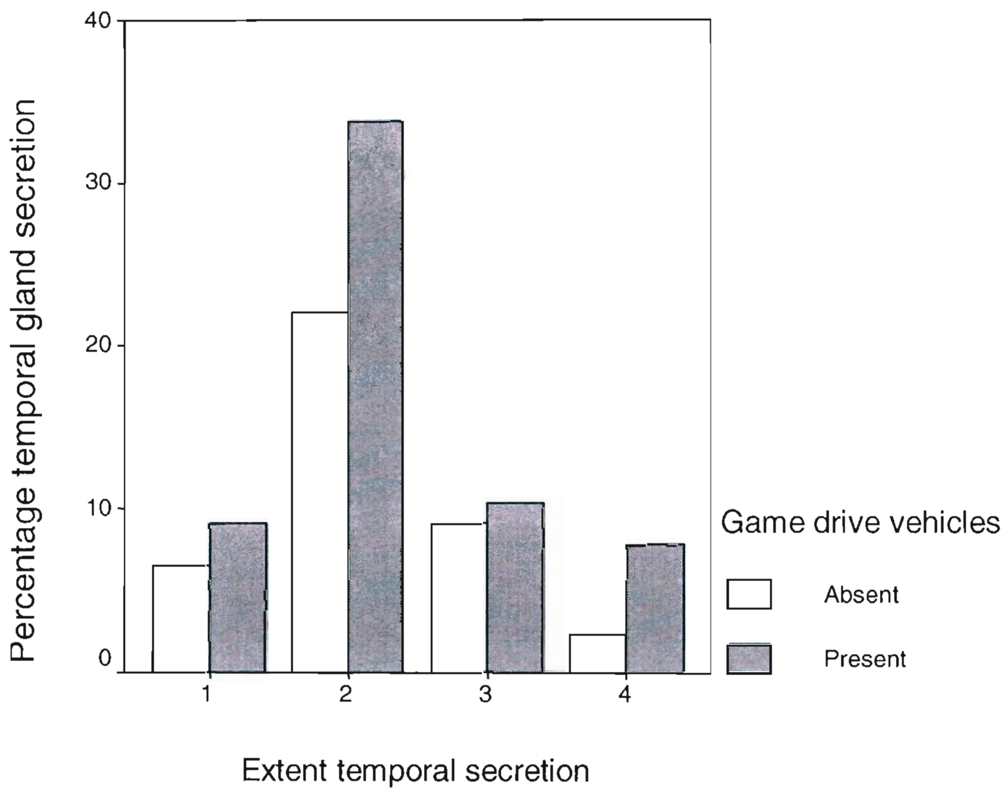


Figure 5.10: The influence of game drive vehicle presence on the extent of temporal gland secretion of the elephant (1 - temporal secretion to the lower extent of the eye, 2 - temporal secretion to the top part of the lower jaw, 3 - temporal secretion to the corner of the mouth, 4 - temporal secretion to the base of the lower jaw).

The adult female elephants on Mabula Game Reserve had significantly more temporal gland secretions for periods when game drive vehicle activity were not controlled via radio communication compared to periods when game drive vehicle activity were controlled (through limiting game drive vehicle numbers to three at an elephant sighting and not allowing any vehicles closer than 40 m from the elephants) (Mann-Whitney test: $Z = -2.129$, $N = 36$, $P < 0.05$). No significant changes in temporal gland secretion occurred for adult female elephants concerning the distance of elephants from game drive vehicles, the presence of the bull in the cowherd or the first ten minute interval of observation after arrival of the first game drive vehicle (compared to the observation period in the presence of game drive vehicles there after) (ANOVA: all $P > 0.05$) (Figure 5.11).

(b) Factors present for the different times of day (morning, midday and afternoon)

The data on the time of day influences on temporal gland secretion of female adult elephants were not normally distributed (Kolomogorov-Smirnov test: $N = 60$, $P < 0.05$) and thus parametric analysis of data was not possible. The section area where the elephants were located for periods of observation (according to the eight sections that the reserve were divided into for the purpose of the study) significantly changed the occurrence of temporal gland secretion for adult female elephants (Kruskal-Wallis test: $\chi^2_3 = 10.88$, $N = 60$, $P < 0.05$). Adult female elephants secreted more from their temporal glands in the Modjadji area of the reserve. The number of game drive vehicles at an elephant sighting, the number of game drive vehicles in the area of the elephants and other major disturbances in the elephant's environment like helicopters did not influence temporal gland secretion for female adult elephants significantly (all $P > 0.05$) (Figure 5.12).

(c) Daily factors present in the elephant's environment

According to the linear regression analysis rainfall did not influence the occurrence of temporal gland secretion for adult female elephants significantly ($F = 0.561$, $P > 0.05$, $\beta_1 = -0.106$). As daily average temperature increased, temporal gland secretion for adult female elephants decreased significantly ($F = 5.32$, $P < 0.05$, $\beta_1 = -0.313$) (Figure 5.13).

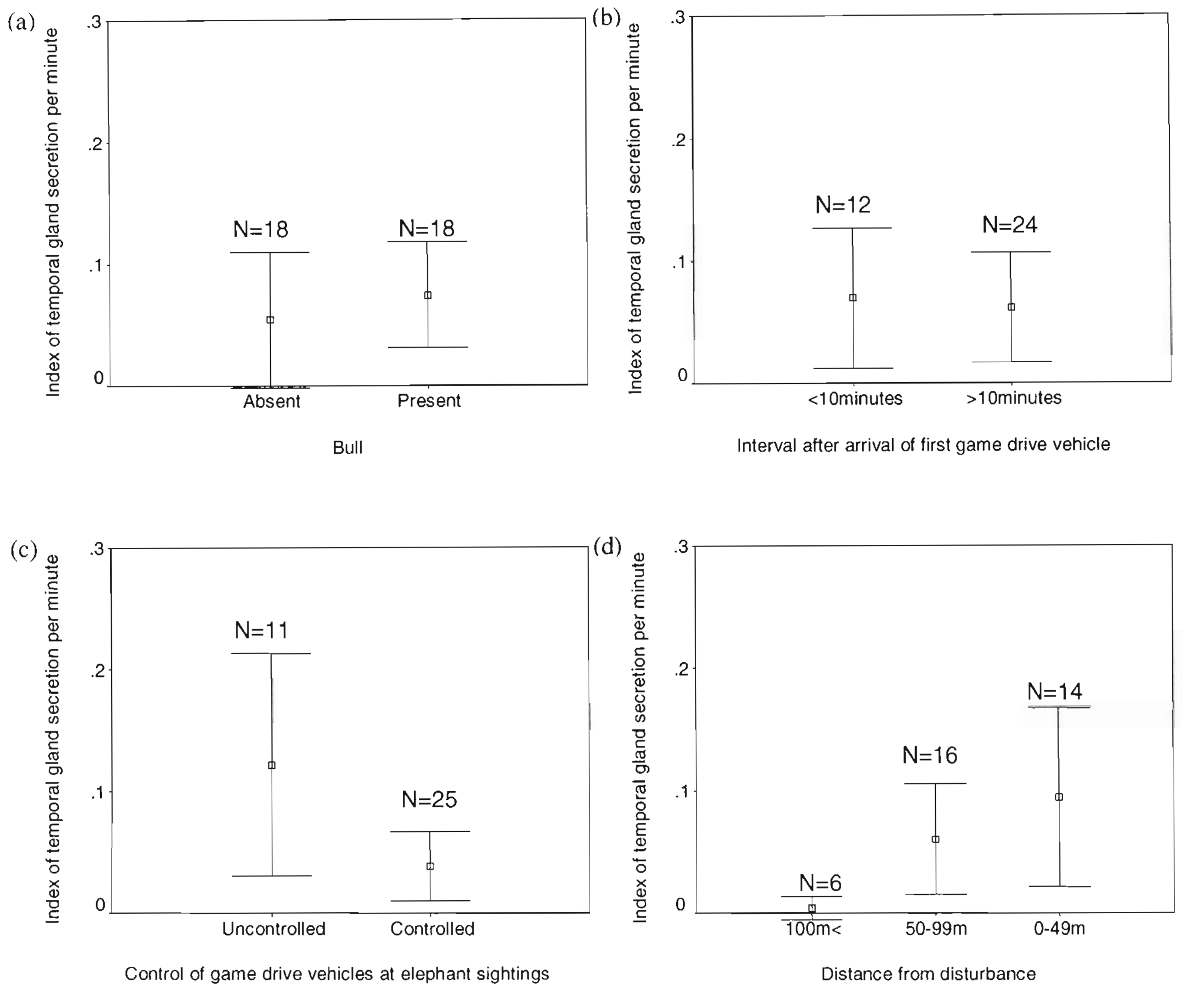


Figure 5.11: The influence of immediate factors present in the elephant's environment on temporal gland secretion. (a) the effect of bull presence in the cowherd (P = 0.205), (b) the effect of the first ten-minute interval after arrival of the first game drive vehicle compared to the following ten minutes (P = 0.747), (c) the effect of control of game drive vehicle activity at an elephant sighting (P = 0.33), (d) the effect of distance of the elephants from game drive vehicles (P = 0.102 (95% confidence interval, N = Number observation sessions, outliers and extremes are not shown).

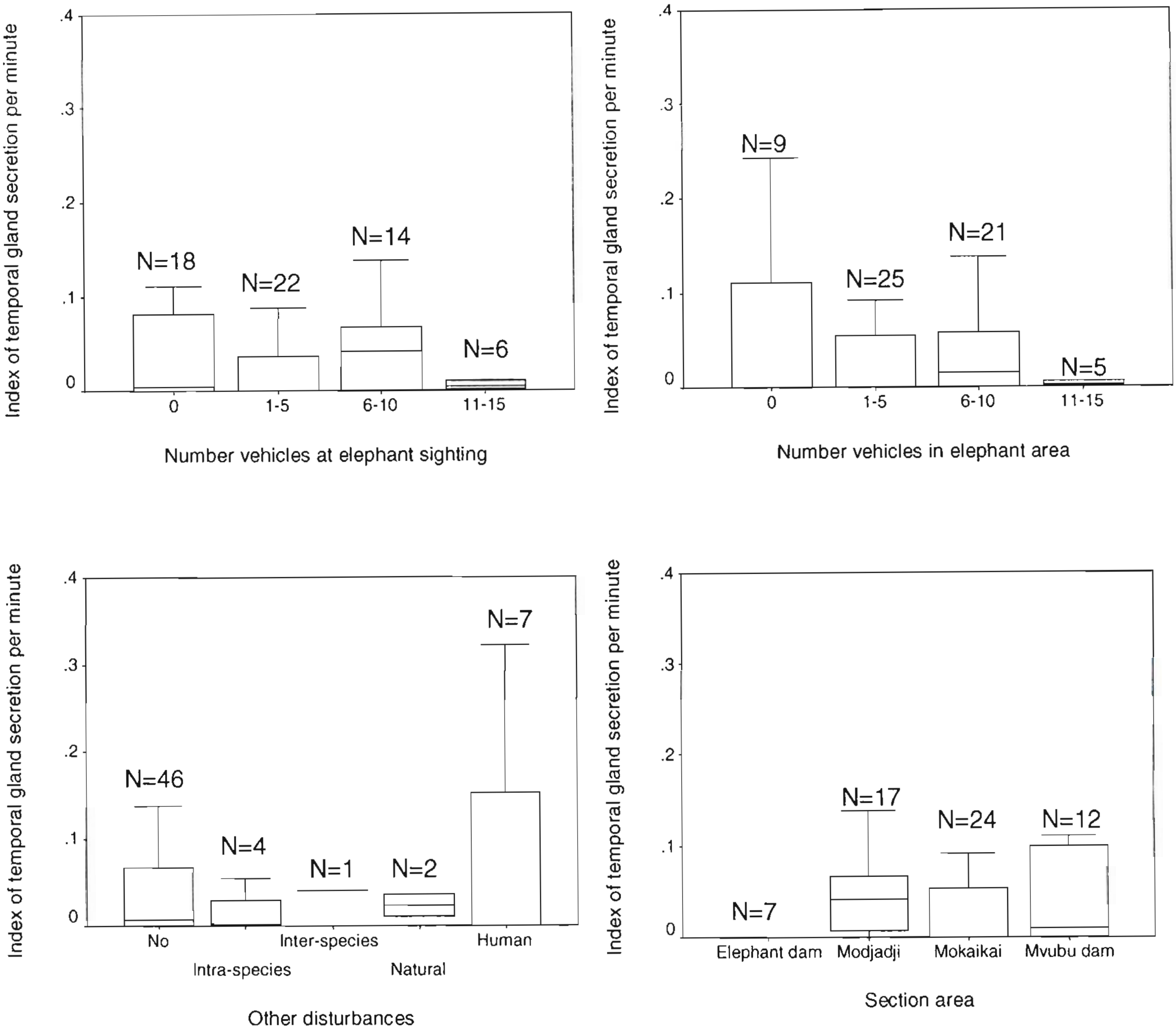


Figure 5.12: The influence of factors present in the environment for the different times of day on temporal gland secretion in elephants. (a) number of vehicles at elephant sighting, (b) number of vehicles in elephant area, (c) other major disturbances present in the elephants environment (Intra-species disturbances including estrous and mating, Inter-species disturbances including confrontations with other animals like rhinos, natural disturbances including fire, human disturbances including low flying helicopters), (d) location of the elephants on the reserve (N = number observation sessions, outliers and extremes are not shown)(see text).

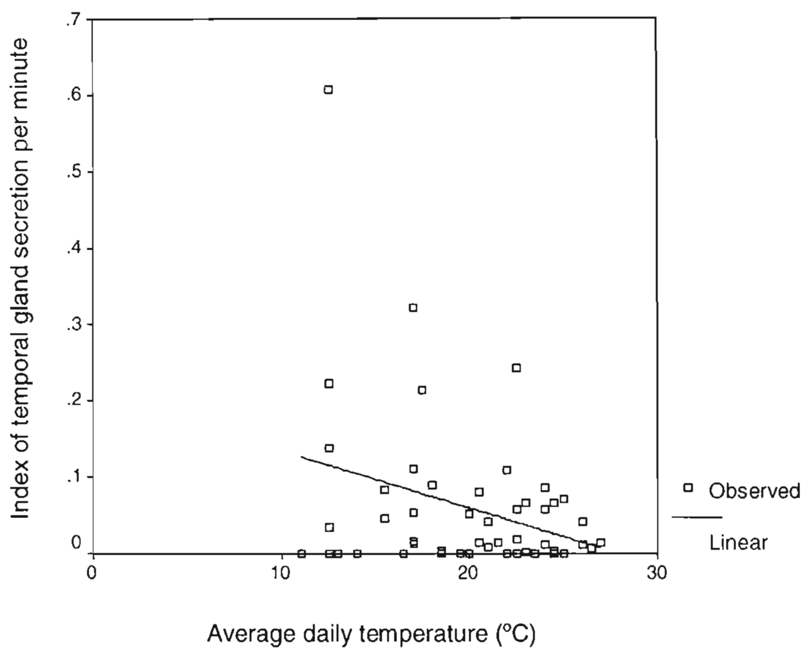


Figure 5.13: The influence of average daily temperature (°C) on temporal gland secretion of adult female elephant.

5.4 Discussion

Elephants on small reserves, except for the presence of natural stressors such as drought mainly experiences stress because of either lack of social structure due to for example absence of adult animals or because of presence of direct human disturbances in the environment. Perception of an external threat whether a social interaction with another animal or the experience of pain is dependent on the central nervous system that assesses whether a stimulus or a group of stimuli represents a significant challenge to the animal. If the stimulus is perceived as threatening and can thus be called a stressor, three types of biological responses are available: behavioural, autonomic and neuroendocrine (Moberg 1983). Previous studies on stress in animals using physiological parameters involved the measurement of faecal glucocorticoid levels for the purpose of describing stress caused by external disturbances and social stress (Wasser *et al.* 2000; Creel *et al.* 2001; Creel *et al.* 2002; Foley *et al.* 2001).

In elephants Stead, Meltzer and Palme (2000) have described the faecal monitoring of glucocorticoid metabolites by using the 11-oxoaetiocholanolone enzyme immunoassay (EIA) of Palme and Möstl (1997) that measures 11,17-dioxoandrostanes (a group of faecal cortisol metabolites). Although an elephant as a monogastric animal have a lower digestive efficiency than a ruminant and therefore a more rapid passage, retention time in the elephant can be as low as 33 hours (du Toit 2001). According to Wasser *et al.* (2000) it takes about 36 hours for a stressful event to be maximally detected in elephant faeces. Faecal glucocorticoid levels increase in areas and times of heavy snowmobile use for both wolves and elk and a variation in the number of snowmobiles was found to be parallel to day-to-day variation in faecal glucocorticoid levels of elk (Creel *et al.* 2001). For the study on Mabula Game Reserve a retention time of 33 hours for stress hormone metabolites in elephants corresponded to the daily changes in the intensity of game drive vehicle activity in the vicinity of the elephant. Faeces collected at feeding sites and in the Modjadji area of Mabula Game Reserve were significantly higher in stress hormone metabolites than faeces collected elsewhere on the reserve. The Modjadji area on Mabula Game Reserve in general had the highest intensity of human activity because it hosted two of the three time-share camps on the reserve, half of the whole owner houses and bordered the main lodge area. Temporal gland secretions for female adult elephants in the Modjadji area were also significantly higher than in other areas of Mabula Game Reserve.

Various studies indicate that secretions from the temporal gland may be related to stress (Buss, Rasmussen & Smuts 1976; Adams & Berg 1980 & Garaii 1997). Although extrinsic factors like culling operations have been reported to stimulate secretions from the temporal gland (Buss, Rasmussen & Smuts 1976) other reports indicate that intrinsic social factors seem to be the predominant reason for secretion (Weibull & Eriksson 1998). On Mabula Game Reserve temporal glands secretion for adult elephant was significantly higher in the presence of game drive vehicles.

It can be concluded from the study that both faecal stress hormone metabolite levels and temporal gland secretions for adult elephant significantly changed in the presence and absence of different environmental variables thereby qualifying both these as viable parameters for measuring stress in elephants. Social stress is difficult to identify and measure due to the constant presence of a disrupted social structure and the degree of social stress experienced will only become clear once comparative studies are done across groups of elephants with different group compositions or population structures. Only through constant monitoring over the long-term might social causes of stress become clearer for elephants on one specific reserve.

The advantages of using physiological measurements of stress to assess the status of elephants on a reserve are that:

(1) it is an objective approach which eliminates the variability in results from different observers.

(2) once an easy to use field kit are developed to measure stress hormone metabolites in faeces it will quickly identify elevations in stress levels so that focus can be placed in an early stage on identifying the causes of stress and eliminating or reducing the effects of such factors.

Human disturbance, either through game drives or infrastructure and associated usage significantly increases the stress levels of elephants. Managers need to institute mechanisms to reduce this impact in order to prevent decline in the number and quality of elephant sightings as well as possible injury or death of both tourists and elephants. Future research will require correlating behavioural measurements of stress with physiological measurements of stress in order to expand our understanding of what exactly causes stress for elephants, to what extent do different factors cause stress for elephants and how these factors can be managed and manipulated on small reserves in order to reduce stress for elephants.

Chapter 6
GENERAL DISCUSSION AND MANAGEMENT RECOMMENDATIONS

All animals have physical and psychological requirements in order to reproduce and survive including, nutrients and water, a suitable secure habitat and the correct social structure. Any changes in the environment put varying amounts of strain on the animal to which it is either adapted to cope with or not. Some of the variables present in an animal's environment are predictable to the animal and some are unpredictable (Wingfield & Ramenofsky 1999). Humans are able to control, manipulate and manage some of the variables present in an animal's environment to different degrees that can either be to the advantage or disadvantage of the animal and its environment. For example when elephant migration is no longer possible due to electrified fences elephants may have a negative impact on the vegetation. For successful management of elephants on small reserves the variables that can put strain on an elephant and that can be controlled must be identified and the methods of manipulating the effects of these variables to either benefit or reduce the disadvantage to the elephant and its environment must be determined. Results from the current study have correlated both the behavioural and physiological parameters investigated with situations that are presumed to be stressful for elephants. The next step is to now further develop these methods in order for all elephant owners and managers to incorporate them into the standard monitoring system and management plan for elephants on small reserves. By doing this problem areas can be identified and the factors causing stress can be reduced or eliminated which will not only ensure the psychological well-being of elephants but also increase tourist satisfaction. Following general observations made throughout the study period some recommendations are made based on variables identified that could possibly be controlled on Mabula Game Reserve:

(1) Social structure manipulation

After ten years since the initial re-introduction of orphan elephants onto Mabula Game Reserve the elephants social behaviour still deviated significantly from social behaviour of free-ranging elephants as described in literature in that:

(a) the bull spends most of his time with the females.
(b) there is not a single cow that always initiates change of activity and co-ordinates group movement.

The consequences of not having older experienced elephants on a reserve are still not clear. From general observations on Mabula Game Reserve and other parks with orphan elephant, this effect may in future lead to:

(a) injury or death of young elephant cows and calves due to the constant presence of young elephant bulls in the cowherds. These bulls have been observed to constantly solicit and mount young females which causes for the cowherds to move around more and not develop fixed home ranges. According to Moss (1988) older related females and an experienced matriarch will chase the young males, whom have reached puberty, away from the herd.

(b) aggression towards and possible injury of tourists. Preliminary observations on parks and reserves hosting orphan elephants reveal aggression from especially young bulls towards tourist vehicles as well as avoidance of roads and tourist activity by the cowherds.

(c) a decline in the number and quality of elephant sightings by tourists for the reasons explained above.

(d) injury or death of other species like rhinoceros. In Pilanesberg and Hluhluwe-Umfolozi Park the re-introduction of older more experienced bulls stopped the killing of rhinoceros by young orphan elephant bulls (Slotow *et al.* 2000).

(2) Habituation of elephant to humans

Mabula Game Reserve has an extensive road network with no one piece of land of 2 km^2 on the reserve without an accessible road. The reserve currently only has one group of ten elephants and a daily tourist load averaging 800 people. Because the elephant is one of Africa's big five animals the demand for elephant sightings is very high. A survey done on Mabula Game Reserve in 1999 showed elephants to be the most sought after animal to see by tourists on the reserve. All these factors lead to high game drive vehicle loads being present in the vicinity of the elephant almost constantly during main game drive times on a daily basis. If not controlled the pressures of tourism can cause increased stress for the elephants leading to the elephants health being physiologically challenged, the elephants hiding away in thickets more and the number and quality of elephant sightings for tourists decreasing. In order to prevent possible dangerous situations from developing and reducing the impact of tourism on elephant life, Mabula Game Reserve utilizes a system that control game drive vehicle activity around the area of the elephant via radio communication. In order to prevent the habituation of the elephant to too far an extent the following precautions are recommended to be added to the existing system on Mabula Game Reserve:

(a) Education and awareness programs for the general public on understanding elephant behaviour and what to do when encountering an elephant

(b) Training and assessment of all field guides or persons dealing directly with the elephants on the reserve. Although Mabula Game Reserve already has a training manual for all persons qualified to drive on the reserve which includes the elephant sight control system, an assessment and punishment policy must also be implemented for all persons not following the manual and endangering the lives of both the elephants and their guests.

(c) Preventing any close contact of humans with the elephants by:

(i) allowing only one person to get habituated to and get close to the elephant if necessary for the purpose of monitoring them continuously and providing the feed supplement

(ii) fencing off camps, buildings, public unassisted walking trails and properties where humans are active on foot away from vehicles or enclosed areas.

Any unnecessary human smells, voices and associations of humans with particular events that the elephants can be exposed to should be avoided in order to prevent gradual habituation to the point where the animals lose their fear of humans completely and become a threat to human life.

(3) Refuge areas

It is recommended that there be a zonation of the reserve, with a refuge for elephants to withdraw to where they are not harassed by people. This might be especially important during periods:

(a) when tourist activity is high, for example during long weekends

(b) just after the birth of a calf

(c) immediately after a darting operation when for example the elephant cows are darted for contraception

The fact that the study group of elephants on Mabula Game Reserve only consisted of orphan elephants may have influenced the elephants behaviour towards tourist compared to normal elephant societies. The value of the research however, lies in the development of methods to quantify stress in elephant in order to better understand what elephants require from their environment. Future studies of a similar nature needs to be conducted under varying conditions in order to determine whether the response towards tourists for the elephant on Mabula Game Reserve (as well as other small reserves with similar conditions) is influenced by an incomplete social structure or their historical association with humans.

REFERENCES

Abel, N. & P. Blaikie. 1996. Elephants, People, Parks and Development: the case of the Luangwa Valley, Zambia. *Environmental Management* 10: 735-751.

Acocks, J.P.H. 1988. *Veld types of South Africa. Memoirs of the Botanical Survey of South Africa.* 3rd edition. Botanical Research Institute, Department of Agriculture and Water Supply, South Africa.

Adams, J. & J.K. Berg. 1980. Behaviour of female African elephants (*Loxodonta africana*) in captivity. *Applied Animal Ethology* 6: 257-276.

Allaby, M. 1996. *Oxford concise dictionary of Zoology.* Oxford University Press.

Anonymous. Elephant tramples man to death. *Sapa 6 January 2003* (iafrica.com/news)

Barnes, R.F.W. 1999. Is there a future for elephants in West Africa? *Mammal Review* 29: 175-199.

Barnes, R.F.W.; G.C. Graig, H.T. Dublin; G. Overton; W. Simons & S. R. Thouless. 1999. African Elephant Database 1998. African Elephant Specialist Group, Species Survival Commission and The World Conservation Union, Gland, Switzerland and Cambridge, UK.

Bertschinger, H.J.; J.F. Kirkpatrick; R.A. Fayrer-hosken; D. Grobler; N. Lamberski; T. Ulrich & G. Honneyman. 1999. Contraceptive potential of the porcine zona pellucida vaccine in the African elephant (*Loxodonta africana*). *Theriogenology* 52: 835-846.

Bothma, J. du P. 1996. *Game ranch management.* J.L. van Schaik Publishers, Pretoria.

Brangwen-Jones, P.A. 2002. British child migrant scheme. *In: 1st National conference on the mental health aspects of persons affected by family separation.* Care Leavers of Australia Network (CLAN).

Bredenkamp, G.D. & N. van Rooyen. 1990. *Die natuurlewebestuur van Mabula.* Ekotrust B. K. Departement Plantkunde. Universiteit van Pretoria, Pretoria.

Buss, I.O.; L.E. Rasmussen & G.L. Smuts. 1976. The role of stress and individual recognition in the function of the African elephant's temporal gland. *Mammalia* 40: 437-451.

Colescott, J.H. & M.P. Gillingham. 1998. Reaction of moose (*Alces alces*) to snowmobile traffic in the Greys River Valley, Wyoming. *Alces* 34: 120-125.

Creel, S. 2001. Social dominance and stress hormones. *Ecology and Evolution* 16: 491-497.

Creel, S.; J.E. Fox; A. Hardy; J. Sands; B. Garrott & R.O. Peterson. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. *Conservation Biology* 16: 809-814.

De Bruin, D.J. 1995. *The ecology and behaviour of reintroduced African elephant on Mabula Game Reserve, Northern Province, South Africa.* MSc (Wildlife management) thesis, University of Pretoria, Pretoria.

De Villiers, P.A. & O.B. Kok. 1997. Home range, association and related aspects of elephants in the eastern Transvaal Lowveld. *African Journal of Ecology* 35: 224-236.

Douglas-Hamilton, I. 1972. *On the ecology and behaviour of the African elephant.* D.Phil. Dissertation. University of Oxford, Oxford, England.

Du Toit, J.G. 2001. *Veterinary Care of African Elephants.* The South African Veterinary Foundation/Novartis Wildlife Fund, Republic of South Africa.

Ebedes, H.; C. Vernon & I. Grundling. 1991. Past, present and future distribution of elephant in southern Africa. *Proceedings of a symposium on the African elephant as a game ranch animal.* Wildlife Group of the South African Veterinary Association, Onderstepoort.

Eltringham, S.K. 1977. The numbers and distribution of elephant *Loxodonta africana* in the Rwenzori National Park and Chambura Game Reserve, Uganda. *East African Wildlife Journal* 15: 19-39.

Estes, R.D. 1991. *The Behavior Guide to African Mammals, Including Hoofed Mammals, Carnivores, Primates.* University of California Press, Berkeley.

Foley, C.A.H.; S. Papageorge & S.K. Wasser. 2001. Noninvasive stress and reproductive measures of social and ecological pressures in free-ranging African elephants. *Conservation Biology* 15: 1134-1142.

Frandson, R.D & T.L. Spurgeon. 1992. *Anatomy and Physiology of Farm Animals.* Fifth edition. Lea & Febiger, Philadelphia.

Garaï, M.E. 1997. *The development of social behaviour in translocated juvenile African elephants* Loxodonta africana. PhD thesis, University of Pretoria, Pretoria.

Gowans, J. 2000. Fury of the elephants. *Sunday Tribune News, 13 February 2000.*

Grotjan, H.E. & B.A.Keel. 1996. Data interpretation and quality control, p. 51-93 *In:* **E.P. Diamandis & T.K. Christopoulus [eds.]**, *Immunoassay.* Academic Press, New York.

Guy, P.R. 1976. Diurnal activity patterns of elephant in the Swenga Area, Rhodesia. *East African Wildlife Journal* 14: 285-295.

Hoare, R. 2000. African elephants and humans in conflict: the outlook for co-existence. *Oryx* 34: 34-38.

Jeffcoate, S.L. 1981. *Efficiency and effectiveness in the endocrinology laboratory.* Academic Press, New York.

Kalemera, M.C. 1987. Dry season diurnal activity of elephants in Lake Manyara National Park, Tanzania. *African Journal of Ecology* 25: 255-263.

Kerley, G.I.H.; B.G.S. Geach & C. Vial. 2003. Jumbos or bust: do tourists' perceptions lead to an under-appreciation of biodiversity? *South African Journal of Wildlife Research* 33: 13-21.

Kriel, A. 2000. Geologie van Mabula Wild Reservaat. Universiteit van Pretoria, Pretoria.

Langbauer, W.R. 2000. Elephant communication. *Zoo Biology* 19: 425-445.

Lawley, L. 1994. *The world of elephants.* Friedman/Fairfax Publishers.

Laws, R.M. & I.S.C. Parker. 1968. Recent studies of elephant populations in East Africa. *Symposia of the Zoological Society London* 21: 319-359.

Lee, P.C. 1997. *In*: **Eltringham, S.K.** *The Illustrated Encyclopedia of Elephants.* Salamander Books Limited, London.

Low, A.M. & A.G. Rebelo. 1996. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs & Tourism, Pretoria.

Lott, D.F. 1995. Asian rhinos *Rhinoceros unicornis* on the run? Impact of tourist visits on one population. *Biological Conservation* 73: 23-26.

MacKenzie, P. 1998. http://elephant.elehost.com

Martin, P. & P. Bateson. 1993. *Measuring behaviour: An introductory guide.* 2nd edition. Cambridge University Press, Cambridge.

Meredith, M. 2001. *Africa's elephant, a biography.* Hodder and Stoughton, London.

Millspaugh, J.J.; R.J. Woods; K. Hunt; K.J. Raedeke; B.E. Washburn; G.C. Brundige & S.K. Wasser. 2001. Using fecal glucocorticoids to quantify the physiological stress response of free-ranging elk. *Wildlife Society Bulletin* 29: 899-907.

Moberg, G.P. 1983. Biological response to stress: Key to assessment of animal well-being? p. 27-49. *In:* **S.R. Geuger.** *Stress physiology in animals.* American Physiological Society, California.

Moss, C. 1988. *Elephant memories.* William Marrow & Company, Inc., New York.

O'Fegan, P.O. 2000. Validation, p. 211-238. *In:* **J.P. Gosling [ed.]**, *Immunoassays.* Oxford University Press, New York.

Palme, R. & E. Möstl. 1997. Measurements of cortisol metabolites in faeces of sheep as a parameter of cortisol concentration in blood. *International Journal of Mammalian Biology* 62: 192-19.

Palmer, D. 2002. Youth detention and the Qld Forde inquiry. *In: 1st National conference on the mental health aspects of persons affected by family separation.* Care Leavers of Australia Network (CLAN).

Poole, J.H. & C.J. Moss. 1981. Musth in the African elephant, *Loxodonta africana. Nature* 292: 830-831.

Poole, J.H. 1987. Rutting behavior in African elephants: the phenomena of musth. *Behavior* 102: 283-316.

Poole, J.H. 1989a. Announcing intent: the aggressive state of musth in African elephants. *Animal Behavior* 37:140-152.

Poole, J.H. 1989b. Mate guarding, reproductive success and female choice in African elephants. *Animal Behavior* 37: 842-849.

Poole, J.H. 1997. *Elephants.* Voygeur Press, Stillwater, United States of America.

Pretorius, Y. 2001. The effect of feed supplementation on the African elephant of Mabula Game Reserve. Honours (Wildlife management), University of Pretoria, Pretoria.

Price, E.O. 1983. Evolutionary and ontogenetic determinants of animal suffering and well-being. p. 15-26.*In:***S.R. Geuger.** *Animal stress.* American Physiological Society, California.

Roe, D.; N. Leader-Williams & B. Dalal-Clayton. 1997. *Take only photographs, leave only footprints: The environmental impacts of wildlife tourism.* International Institute for Environment and Development, London, United Kingdom.

Saller, M. & K. Gröning. 1999. *Elephants, a cultural and natural history.* Könemann, Mohn-media, Gütrsloh, Germany.

Schwarzenberger, F.; E. Möstl; E. Bamberg; J. Pammer & O. Schmehlik. 1991. Concentrations of progestagens and oestrogens in the faeces of pregnant Lipizzan, trotter and thoroughbred mares. *Journal of Reproduction and Fertility Supplement* 44: 489-499.

Seliers, S.J. 1998. An ecological study of the adaptations and behaviour of the reintroduced African elephant on Mabula Game Reserve. BSc(Hons) Wildlife Management. Centre for Wildlife Management, University of Pretoria, Pretoria.

Sengendo, J. & J. Nambi. 1997. The psychological effect of orphanhood: a study of orphans in Rakai district. *Health Transition Review, Supplement* 7: 105-124.

Skinner, J.D. & R.H.N. Smithers. 1990. *The mammals of Southern Africa Subregion.* University of Pretoria, Pretoria.

Slotow.R; G. van Dyk; J. Poole; B. Page & A. Klocke. 2000. Older bull elephants control young males. *Nature* 408: 425-426.

Slotow.R; D. Balfour & O. Howison. 2001. Killing of black and white rhinoceros by African elephants in Hluhluwe-Umfolozi Park, South Africa. *Pachyderm* 31: 14-20.

Smith, A.K.K.; E. de Merode; A. Nicholas; B. Bulls & A. Ndey. 1995. Factors affecting elephant distribution at Garamba National Park and surrounding reserves, Zaire, with a focus on human-elephant conflict. *Pachyderm* 19: 39-48.

Sokal, R.R. & F.J. Rohlf. 2001. *Biometry: The principles and practice of statistics in biological research.* 3rd edition. W.H. Freeman and Company, New York.

Stead, S.K., D.G.A. Meltzer & R. Palme. 2000. The measurement of glucocorticoid concentrations in the serum and faeces of captive African elephants (*Loxodonta africana*) after ACTH stimulation. *Tydskrif Suid Afrikaanse vetenêre Vereniging.* 71: 192-196.

Stephan, E. 1992. Scientific methodology and criteria for assessment of well-being. *In:* **Seamer, J.H. & F.W. Quimby. 1992.** *Proceedings of the Animal Welfare Sessions XXIV World Veterinary Congress, Rio de Janeiro, 1991. World Veterinary Association.* Published by the Animal Welfare Committee of the World Veterinary Association, London.

Sukumar, R. 1991. The management of large mammals in relation to male strategies and conflict with people. *Biological Conservation.* 55: 93-102.

Tyler, N.C. 1991. Short-term behavioural responses of Svalbard reindeer *Rangifer tarandus* to direct provocation by a snowmobile. *Biological Conservation* 56: 179-194.

Verlinden, A. & I.K.N. Gavor. 1998. Satellite tracking of elephants in northern Botswana. *African Journal of Ecology* 36: 105-116.

Wasser, S.K.; K.E. Hunt; J.L. Brown; K. Cooper; C.M. Crockett; U. Bechert; J.J. Millspaugh; S. Larson and S.L. Monfort. 2000. A generalized fecal glucocorticoid assay for use in a diverse array of non-domestic mammalian and avian species. *General and Comparative Endocrinology* 120: 260-275.

Weibull, A.C. & H. Eriksson. 1998. Short-term gland secretion in the African elephant: tourist disturbance or social interactions as source for secretion? *African Journal of Ecology* 36: 360-367.

Westermarck, H. 1992. Degrees of stress in animals. *In:* **Seamer, J.H. & F.W. Quimby. 1992.** *Proceedings of the Animal Welfare Sessions XXIV World Veterinary Congress, Rio de Janeiro, 1991.World Veterinary Association.* Published by the Animal Welfare Committee of the World Veterinary Association, London.

Whyte, I; R.J. van Aarde & S.L. Pimm. 1998. Managing the elephants of Kruger National Park. *Animal Conservation* 1: 77-83.

Wickler, W. & U. Seibt. 1997. Aimed object-throwing by a wild African elephant in an interspecific encounter. *Ethology* 103: 365-368.

Wing, L.G. & I.O. Buss. 1970. Elephants and forests. *Wildlife Monogastrics*. 19: 1-92.

Wingfield, J.C. & M. Ramenofsky. 1999. Hormones and the behavioural ecology of stress. *In:* **Balm, P.H.M.** *Stress Physiology in Animals.* Sheffield Academic Press, England.

World Wildlife Fund. 1997. Conserving Africa's Elephants. **http://www.panda.org.html**

Wyatt, J.R. & S.K. Eltringham. 1974. The daily activity of the elephant in the Rwenzori National Park, Uganda. *East African Wildlife Journal* 12: 273-289.

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I dedicate this thesis with love first of all to God almighty without who's strength and love I could not have completed the study and secondly to Jock McMillan and the elephants of Mabula Game Reserve who was willing to share a brief moment in time of truth with me in a world often filled with pretence.

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Appendix A
MABULA GAME RESERVE ELEPHANT IDENTIFICATION GUIDE

NGAMA

A 20-year-old bull that spends most of his time with the cows and calves (the only adult bull elephant on Mabula). In the presence of vehicles he will often stop and 'bite' on his trunk or touch his temporal gland as if to think what to do next before moving on. He often charges vehicles without warning coming from the side. He likes playing with anything he can find and seeks competition therefore requiring more space from game drive vehicles than the cows. Further he has short tusks a broad trunk and forehead with an overall bulky and masculine appearance. He is the most dominant elephant currently on the reserve.

Front (October 2000)

Left side (July 2002)

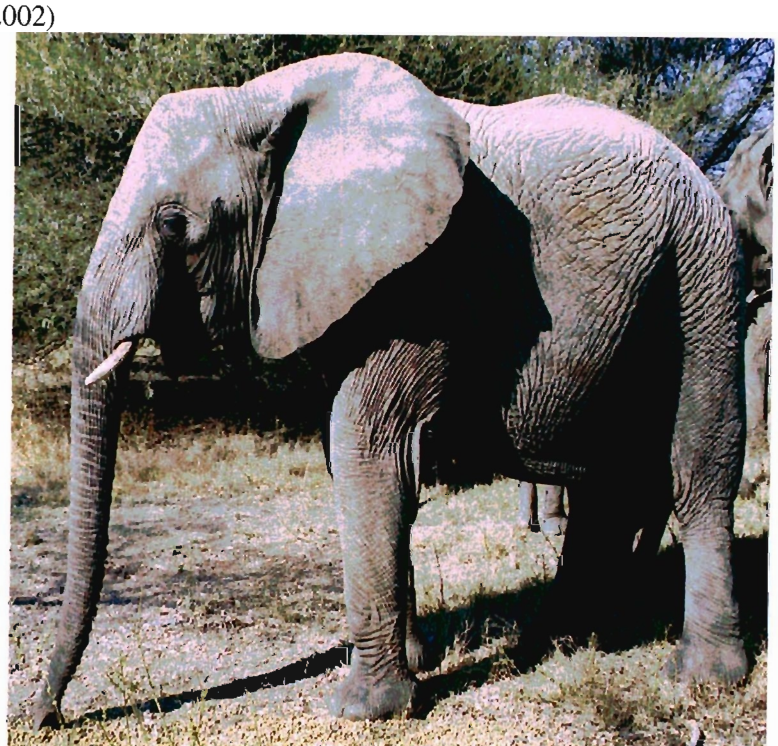
Right side (September 2002)

DABULA

A 19-year-old cow with two calves (Mafuta and Semaka). She is the cow that assumes the matriarch role most often. She is dominant over all the other cows and has a big slit through the top right part of her right ear.

Right ear (September 2002)

Left side (July 2002)

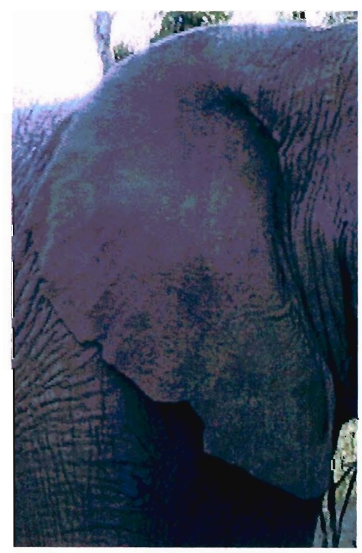


BEKILE

An 18-year-old female without a calf. She is the biggest among the cows with the longest tusks but only second in the dominance hierarchy among the cows after Dabula. Her left tusk is slightly longer than the right. She is an allo-mother to the other cow's calves and allows the younger calves to suckle from her. She secretes relatively easy from her temporal glands and often assesses her environment via smelling with her trunk.

Left ear (October 2002)

Right ear (October 2002)

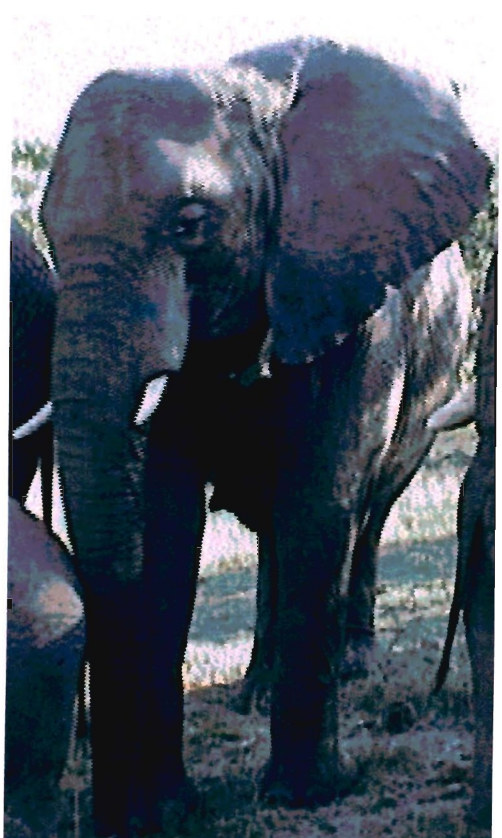


Front (July 2002)

BONTLE

A 17-year-old cow with two male calves (Tabogo and Fejane born at the end of the study period in February 2003). She is second lowest in hierarchy among the cows and often moves off with her calf up to 400 m from the rest of the group. She quickly gets irritated with game drive vehicles and often move closer displaying her irritation by growling, pulling her face and secreting heavily from her temporal glands. Her right tusk is longer than the left and she is collared.

Front (September 2002)



Right side (October 2002)

NIKITA

A 16-year-old cow with one female calf (Botlokwa). She is smaller than all the other cows and has the shortest tusks. She is lowest in the hierarchy and is constantly pushed around by the others. In the presence of game drive vehicles she will often shake her head and sometimes secrete from her temporal glands.

Front (February 2002)

Left ear (October 2002)

MAFUTA

Dabula's oldest male calf born on the 20th of July 1999. He often moves around with Bekile and tests his strength and spars against her, Nikita and Tabogo. He is the biggest of the calves and likes mock charging vehicles.

Left side (July 2002)

Right side (September 2002)

TABOGO

Bontle's eldest male calf born on the 13th of November 2000. He is the second biggest calf and often moves away from the group with his mother or on his own. He has a small slit on top of his left ear and although he is quiet and calm most of the time he likes playing with the other calves.

Right side (July 2002)

Left ear (November 2002)

SEMAKA

Dabula's youngest female calf born on the 8th of January 2002. She is bigger, bulkier and less active than Botlokwa (the other female calf in the group of the same age). She often walks with and suckles from Bekile.

BOTLOKWA

Nikita's female calf born on the 4th of February 2002. She is the smallest and youngest female calf. She is very active and often wonders around quite a distance from her mother exploring new things and bothering the other calves. She often suckles from and stays with Bekile.

Front (August 2002)

Appendix B

SOCIAL ASSOCIATIONS OF THE ELEPHANTS ON MABULA GAME RESERVE

Focal Elephant	Nearest Neighbour	Average Nearest Neighbour Distance (m)	[a] Nearest Neighbour Association
Bekile	Botlokwa	0.8	0.156
Bekile	Bontle	0.9	0.207
Bekile	Ngama	0.9	0.255
Bekile	Tabogo	1.0	0.076
Bekile	Semaka	1.2	0.138
Bekile	Mafuta	2.0	0.164
Bekile	Nikita	2.0	0.175
Bekile	Dabula	2.4	0.213
Bontle	Ngama	1.7	0.124
Bontle	Nikita	3.1	0.223
Bontle	Botlokwa	5.0	0.058
Bontle	Mafuta	7.2	0.083
Bontle	Semaka	10.0	0.041
Bontle	Bekile	15.4	0.207
Bontle	Dabula		0.147
Dabula	Bekile	2.0	0.213
Dabula	Nikita	2.0	0.077
Dabula	Ngama	2.1	0.204
Dabula	Bontle	2.6	0.147
Dabula	Botlokwa		0
Dabula	Mafuta		0.068
Dabula	Tabogo		0.031
Botlokwa	Semaka	0.7	0.394
Botlokwa	Bekile	1.6	0.156
Botlokwa	Ngama	2.0	0.057
Botlokwa	Tabogo	3.2	0.233
Botlokwa	Mafuta	5.0	0.012
Botlokwa	Bontle	6.4	0.058
Botlokwa	Dabula		0
Mafuta	Bontle	1.0	0.083
Mafuta	Dabula	1.0	0.068
Mafuta	Semaka	1.0	0.105
Mafuta	Tabogo	1.0	0.03
Mafuta	Ngama	1.1	0.253
Mafuta	Bekile	1.1	0.164
Mafuta	Botlokwa		0.012

Mafuta	Nikita		0.102
Ngama	Semaka	0.3	0.228
Ngama	Botlokwa	1.5	0.057
Ngama	Mafuta	5.6	0.253
Ngama	Bekile	7.4	0.255
Ngama	Nikita	19.5	0.192
Ngama	Dabula	29.2	0.204
Ngama	Bontle	60.4	0.124
Ngama	Tabogo	108.3	0.092
Nikita	Dabula	2.2	0.077
Nikita	Tabogo	2.3	0.04
Nikita	Mafuta	2.7	0.102
Nikita	Semaka	3.7	0.069
Nikita	Bekile	7.1	0.175
Nikita	Bontle	7.8	0.223
Nikita	Ngama	10.5	0.192
Semaka	Bekile	0.4	0.138
Semaka	Botlokwa	0.5	0.349
Semaka	Mafuta	1.5	0.105
Semaka	Ngama	2.0	0.228
Semaka	Tabogo	2.0	0.162
Semaka	Nikita	2.8	0.069
Semaka	Bontle	3.0	0.041
Tabogo	Semaka	0.8	0.162
Tabogo	Botlokwa	0.9	0.233
Tabogo	Bekile	1.7	0.076
Tabogo	Nikita	2.0	0.04
Tabogo	Ngama	4.3	0.092
Tabogo	Dabula		0.031
Tabogo	Mafuta		0.03

[a] Index of association = $N_{AB}/ (N_A + N_B + N_{AB})$

Where N_{AB} is the number of occasions A and B are seen together; N_A is the number of occasions A is seen without B; and N_B is the number of occasions B is seen without A. Index 0 = no association, index 1 = complete association.

Appendix C
STRESS BEHAVIOUR RESPONSE

1. Disturbed behaviour
   a. Abrupt termination of current action while lifting head and ears slightly and listening for sounds from possible disturbances before continuing with the previous action (for example feeding) (atc).

   b. Coiling, uncoiling and twitching trunk (ct).

c. Front foot swung not directed towards a disturbance (fsn).

(i)

(ii)

(iii)

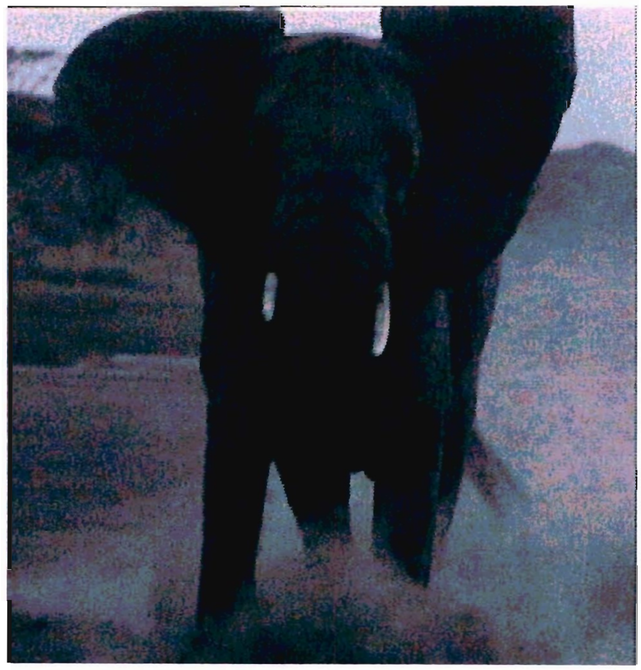
(iv)

d. Smelling disturbance with trunk lifted towards disturbance (smd).

e. Touching temporal gland with trunk (ttg).

2. Threatened behaviour

a. Charge towards a disturbance (c) (Künkel 1998).



b. Flapping ears directed towards a disturbance (fe).

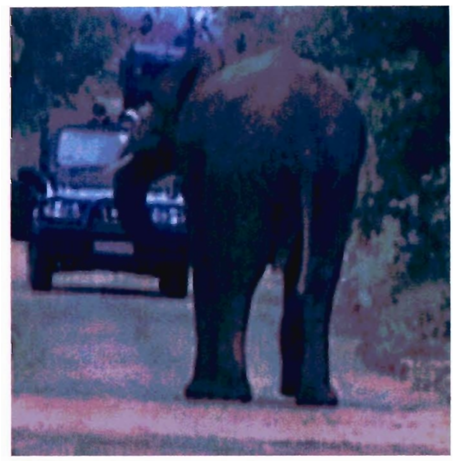
(i)

(ii)

c. Head shake or head jerk directed towards a disturbance (hs).

(i)

(ii)



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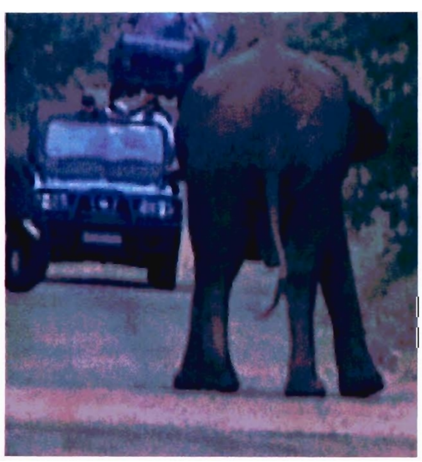

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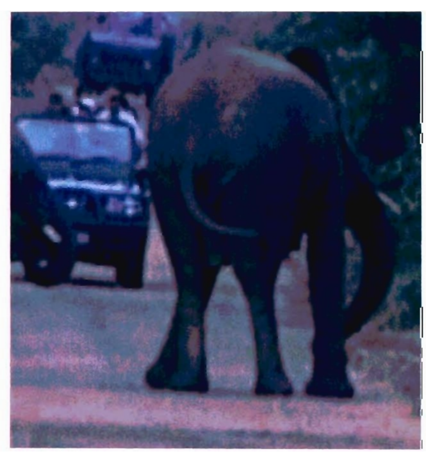
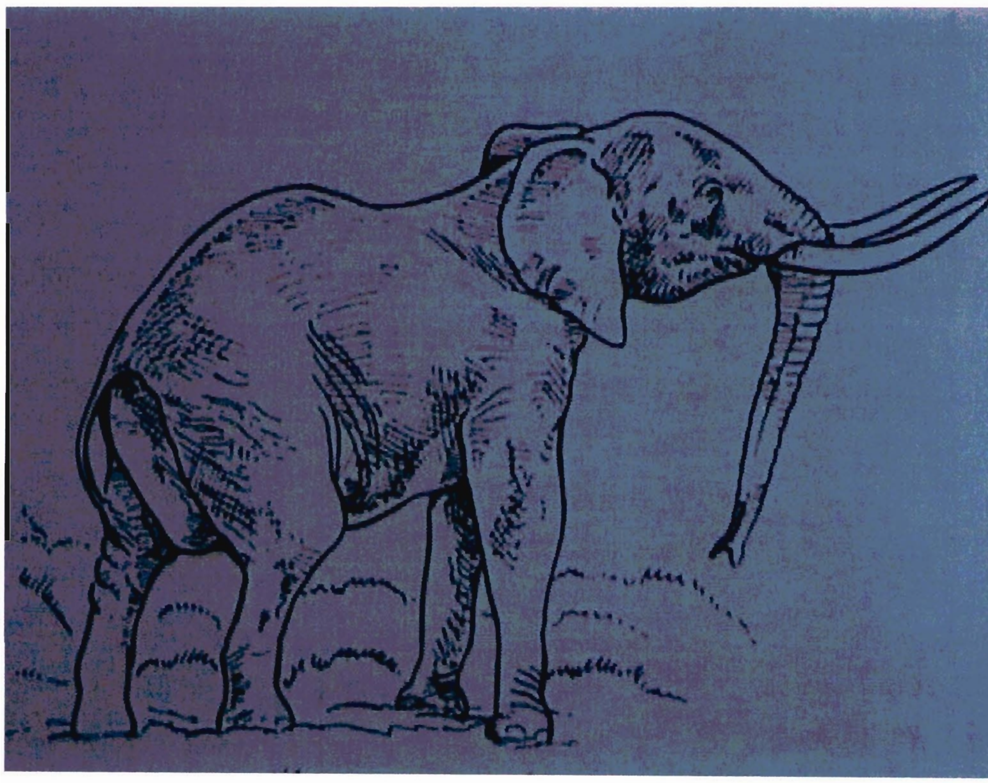


(v)

(vi)

d. Standing tall (head raised high, elephant peering over tusks, ears cocked and trunk hanging at an acute angle) (st) (Estes 1991).

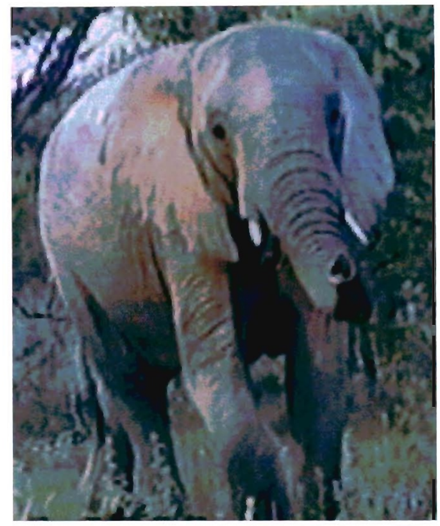


e. Turning towards a disturbance with ears spread (tt).

f. Forward trunk swish (ts).

(i)

(ii)



3. Distressed behaviour
    a. Ears tilted up and back (eub).
    b. Tail held up and straight while moving around cautiously or moving away fast (tsu).

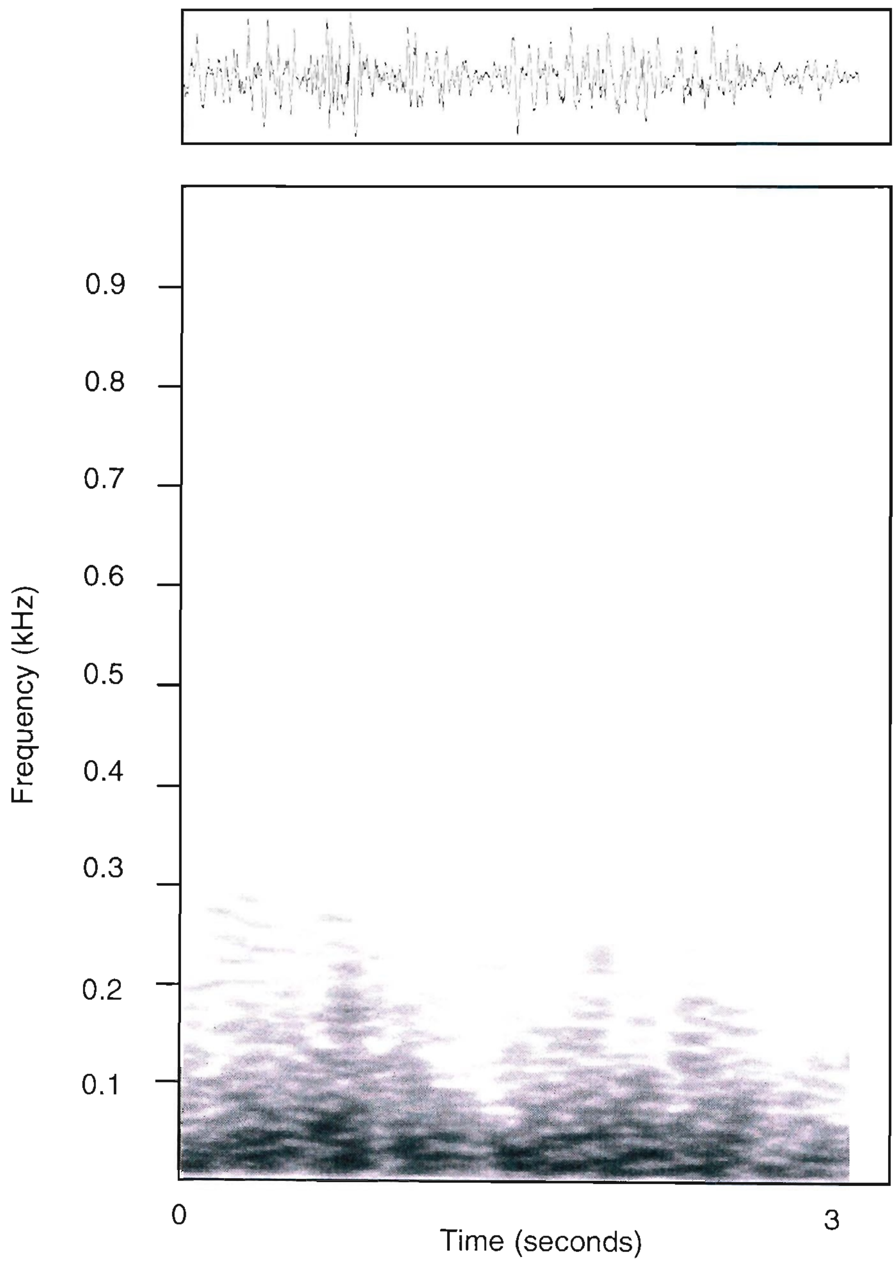
(i)

(ii)

(iii)

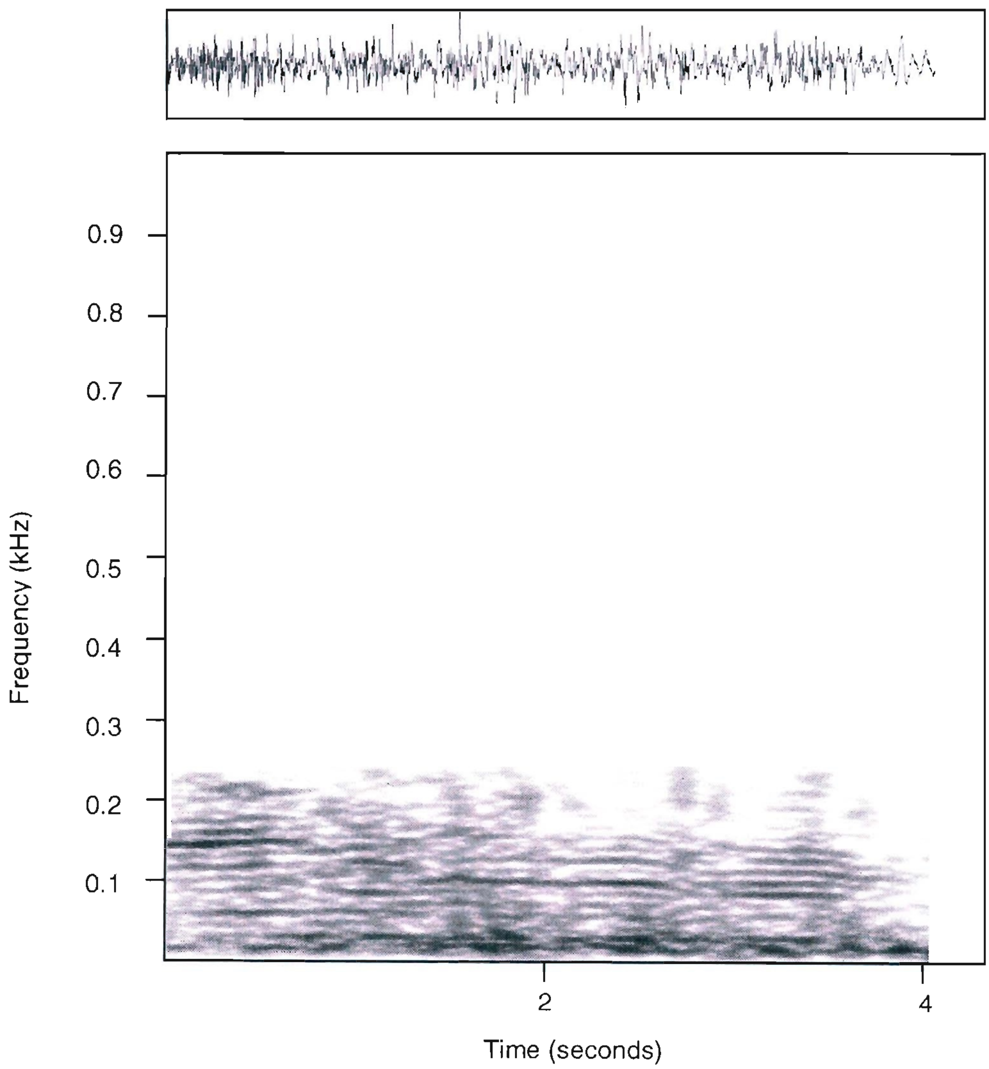
Appendix D
ELEPHANT VOCALIZATION DESCRIPTION

a. Waveform and spectrogram of a calf moan.



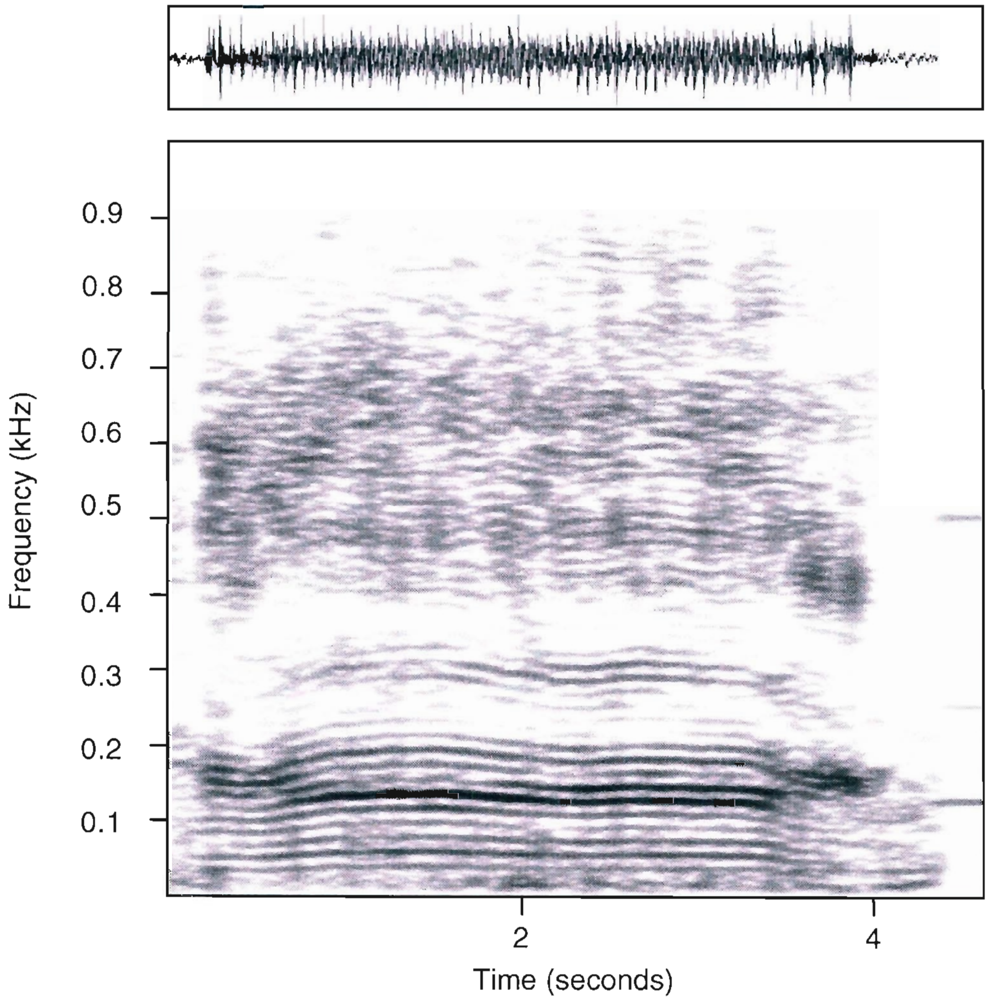
(Frequency bandwidth: 5 Hz; Resolution: 1 Hz; FFT size: 1024 points; Frame: 50 %; Window: Hamming; Overlap: 98.43 %)

b. Waveform and spectrogram of an adult female elephant rumble.



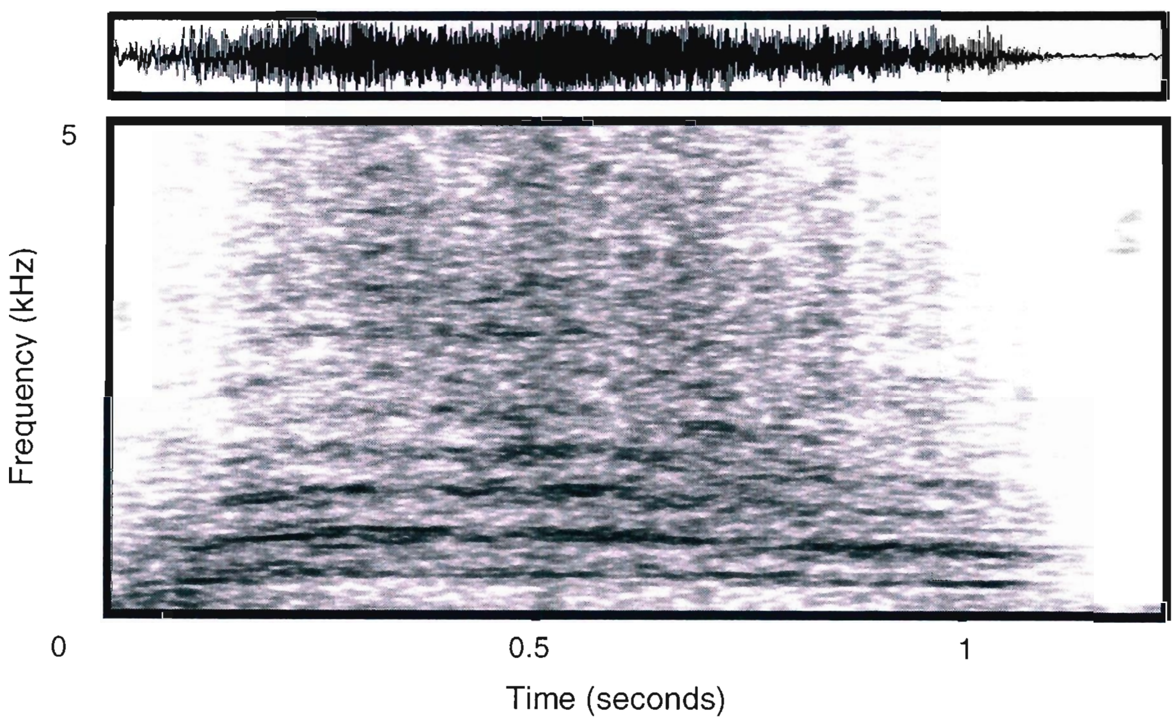
(Frequency bandwidth: 5 Hz; Resolution: 1 Hz; FFT size: 1024 points; Frame: 50 %; Window: Hamming; Overlap: 98.43 %)

d. Waveform and spectrogram of an elephant growl.



(Frequency bandwidth: 5 Hz; Resolution: 1 Hz; FFT size: 1024 points; Frame: 50 %; Window: Hamming; Overlap: 98.43 %)

c. Waveform and spectrogram of an elephant trumpet.



(Frequency bandwidth: 30 Hz; Resolution: 11 Hz; FFT size: 1024 points; Frame: 50 %; Window: Hamming; Overlap: 98.43 %)

Appendix E
ELEPHANT FAECAL SAMPLE COLLECTION

As described by Joshua Millspaugh, School of Natural Resources, Department of Fisheries and Wildlife Sciences, University of Missouri, 302 Anheuser-Busch Natural Resources Bldg., Columbia, MO 65211-7240:

"Because the stress hormones may be unevenly distributed in the faeces, please collect a small portion of faecal material from various parts of the entire faecal mass. If the faecal mass was deposited in several separate pieces, please collect a small portion of faecal material from the inner core of each separate piece. Please attempt to minimize dirt and other debris in the sample. Then combine all sub-sampled material into one composite sample. The total size of the sample should be no larger than a golf ball.

To collect the faecal material, we generally invert the freezer bag over our hand and use it as a glove. It eliminates the need for latex gloves or other sampling gear in the field. Please be sure that the combined faecal material is from the same known animal. It is very important that we do not combine faecal material from more than one animal. Use of known individuals will also greatly improve our inference by allowing us to develop individual animal stress profiles.

The entire sample must be mixed thoroughly prior to storage. Please mix and mash the entire faecal sample to a similar consistency prior to freezing. Please label the outside of the freezer bag with the following information: Date of collection, Time of collection, Age of sample (time from deposition to time placed in freezer bag), Animal ID, and Location of Collection.

After collecting and mixing the sample, and labelling the bag, please freeze the sample as soon as possible at –20°C. If the time from collection to storage is greater than 5 hours, please consider placing samples in a cooler to keep them cold. We are conducting a separate study looking at the effects of environmental degradation on faecal steroid stability to determine the maximum amount of time samples may be left unfrozen.

Sample Treatment

1. Thaw out the frozen faecal samples to be treated.

2. Mix the thawed faecal sample thoroughly. This is important in case hormones are unevenly distributed throughout the entire faecal mass.

3. Transfer each faecal sample into a plastic 22 mL scintillation vial. The vial should be approximately 3/4 full with faeces.

4. Label the vial with pertinent identification on 2 sides of the vial and on the bottom of the vial using a permanent marker. The acetic acid may remove the writing.

5. Dilute acetic acid to 2% solution by mixing distilled white vinegar 50:50 (by volume) with distilled or deionized water. Please do not use tap water as it may contain chlorine which could significantly influence hormone concentrations. Vinegar should contain 4% acetic acid; please check.

6. Fill each vial with enough 2% acetic acid solution to cover the faeces (basically fill the vial).

7. Cap the vial and shake it to ensure good contact between the faeces and the acetic acid (so it all gets sterilized).

8. Let the capped vial sit for 30 minutes.

9. Cut cheesecloth into 3" x 3" squares.

10. Uncap the vial and place a piece of cheesecloth (folded over once or twice) over the open end of the vial. Holding on tightly to the cheesecloth and vial, invert the vial over a waster container and drain out as much as the liquid as possible. If the cheesecloth soaks up a lot of liquid, it may be necessary to repeat with a fresh piece. The liquid will be of a dark colour, but the majority of the solid faeces should remain in the vial. A small amount of liquid will likely remain with the solid faeces.

11. Recap the vial and wipe it dry with a paper towel. Please make sure the sample identification on 2 sides and the bottom is legible.

12. Freeze the vial for 48 hours. The samples are now ready for transport.

Packing samples for shipment

When the samples have been treated and are ready for shipping, we recommend the following procedure to keep the samples frozen during transport:

1. Place the plastic sample vials into the sample trays. If the tray is not completely full, it is best to place the sample vials toward the centre.

2. Line the bottom of the cooler or shipping box with a thick layer of newspaper.

3. Place a layer of frozen ice-packs on top of the newspaper.

4. Place the boxes of sample vials in the centre of the cooler or shipping box directly on top of the ice packs. The ideal situation is to get the samples tight together on the innermost part of the cooler or shipping box, surrounded by a layer of ice-packs.

5. Place ice-packs on all sides of the sample trays and stuff newspaper into any crevices and spaces.

6. Place a layer of ice-packs on top of the sample trays and a thick layer of newspaper on top of the ice-packs to fill the cooler or shipping box. The ideal situation is to get the samples tight together on the innermost part of the cooler or shipping box, surrounded by a layer of ice-packs which is further insulated by the newspaper.

7. Close the cooler or shipping box and tape it completely shut with shipping or duct tape. Seal the box tightly with enough tape to deter any air exchange with the cooler or shipping box.

8. The samples are now ready for shipping!

9. Please ship to:

Joshua Millspaugh, School of Natural Resources, Department of Fisheries and Wildlife Sciences, University of Missouri, 302 Anheuser-Busch Natural Resources Bldg., Columbia, MO 65211-7240, Phone: 573-882-9423, Fax: 573-884-5070

E-mail: MillspaughJ@missouri.edu

A United States Department of Agriculture permit must also be included.

Analysis of faecal samples

Frozen faecal samples are thawed and an ~10-g subsample is placed in a lyophilizer (Freeze-dry Specialties, Inc., Osseo, MN, USA) for 24 hours. Once freeze-dried, samples are ground, sifted through a stainless steel mesh to remove large particles, and thoroughly mixed. Freeze-drying and grinding preserve feacal glucocorticoids, control for dietary changes in steroid excretion (Wasser et al. 1994), and allow for thorough mixing of the sample prior to extraction (Wasser et al. 1996). Glucocorticoids are extracted from faeces using a modification of Schwarzenberger et al. (1991). Dried faeces (~0.2 g) are placed in a test tube with 2.0 mL of 90% methanol and vortexed at high speed in a multi-tube vortexer for 30 min. Samples are then centrifuged at 2,200 rpm for 20 min, and the supernatant is saved and stored at -84o C until assayed.

I125 corticosterone radioimmunoassay (RIA) kits (ICN #07-120103, ICN Biomedicals, Costa Mesa, CA, USA) are used to quantify elephant faecal glucocorticoid metabolite concentrations as well as the ICN protocol for the I125 corticosterone RIA, except that the volume of all reagents is halved."