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Anthropogenic Influences on the Spatio-Temporal Displacement of Elephants (*Loxodonta africana*) in Olifants West Nature Reserve landscape, South Africa

MASTER'S THESIS

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Co-supervisor: Paul Allin, Transfrontier Africa

Declaration

I hereby declare that I have done this thesis entitled "Anthropogenic Influences on the Spatio-Temporal Displacement of Elephants (*Loxodonta africana*) in Olifants West Nature Reserve landscape, South Africa" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, the 15th May 2020

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Romana Kremláčková

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Ethics Statement

The study has been done using standard approved techniques for surveying large mammals. During the research no animal was handled, and no ethical approval was required.

The research was done with the cooperation of the Balule research team and data processing expertise of the Czech University of Life Sciences Prague, Czech Republic.

Abstract

Human population and eco-tourism have been growing. As a result of such growth, people and wild animals share the land and often come into intensive contact. Areas with anthropogenic features such as roads, human settlements, fences, and other physical objects that are often connected to human activity, pose threats and disturbance for animals and can lead to a change of their behaviour. To avoid these potential disturbances, animals may have to adjust their spatio-temporal activities. This includes using the areas with less disturbing anthropogenic features or shifting their active times to the night. In this study, a combination of line transects and satellite data from collared elephants were used to evaluate the effects of anthropogenic features of the landscape. These features were namely the intensity of use of buildings, roads, and waterholes by humans on the spatio-temporal displacement of elephants (*Loxodonta africana*) in Balule Nature reserve (BNR) focused on Olifants West, part of BNR. Ground-based data were collected for two months in the dry season and were further tested in Statistica software. Two years of satellite data was provided by Elephants Alive and was further processed with ArcGIS (ESRI). A relative abundance and density of elephant dung and tree damage was used as a proxy for time spent at the unit are by elephants. Satellite data were used to determine the elephants' home range and various degrees of avoidance near anthropogenic features on the landscape. It was found that elephants did not show significant avoidance towards anthropogenic features, but they generally spent more time in the areas with low human activity or further away from the potential disturbance. Additionally, male elephants showed to be less sensitive towards disturbance and potential threats than females, which was shown in their differing home range and a females' clear avoidance of the areas with high density with human settlements. This study further suggests the need for further investigation of elephants' diurnal and seasonal activity patterns around anthropogenic features.

Key words: animal behaviour, elephants, anthropogenic features, disturbance, drivers, human-wildlife conflict, South Africa

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APNR - Associated Private Nature Reserves

BNR - Balule Nature Reserve

ETD – Elliptical Time Density

GLM – General linear model

GPS - Global Positioning Coordinates

HEC – Human elephant conflict

NGO- Non-government organization

OWNR - Olifants West Nature Reserve

1. Introduction and Literature Review

The use of private lands in the biodiversity conservation becomes important in maintaining a balance between animals and humans. Humans are cohabiting the same land with animals, and this is especially the case of the land we share – nature reserve, and the supporting infrastructure which follows high population growth (Carter et al. 2012; Selemani & Sangeda 2019).

Therefore, understanding human-wildlife interactions and their impacts are important for monitoring and assessing human activities for preserving natural resources and wildlife (Songhurst et al. 2016).

Human activities in different forms and intensities significantly affect wildlife at different spatio-temporal scales. Starting from the short-term changes of wild animal behaviour and local to global extinction of populations (Festa 2019). Carter et al. (2012) argue that large wildlife species, such as ungulates and large carnivores, cannot steadily share the same location, thus cannot coexist with humans at fine spatial scale, especially elephants, which are forced to adapt their behaviour to human conditions (Songhurst et al. 2016).

Due to these barriers and conditions, some wildlife species cannot share the same area on the landscape and there is an urgent need to provide some rationales between conservation management and their programs for biodiversity sustainability and protection (Wittemyer et al. 2016).

Previous studies showed that protected areas are an essential strategy for wildlife protection. This is well documented in the study of Gray et al. (2016) who argue that the protected areas are most effective when human-dominated land use is minimized.

Although protected areas are nowadays key factor for biodiversity conservation and their goal is to minimize the human impact, a number of them are slowly changing from natural to ‘human-modified’ landscape and are under the markable threats from anthropogenic activities (Farfán et al. 2019; Gray et al. 2016) such as high touristic pressure, high vehicular activity or high density of physical objects. These anthropogenic disturbances may have negative effects on wildlife protection as well as on their survival, reproductive success, or behaviour (Pirotta et al. 2019).

To better understand the impact of anthropogenic features as disturbance and its effect on animals, elephants are ideal to examine when investigating how human activity influences their spatio-temporal displacement and behaviour. They have flexible activity patterns, home ranges, propensity for exploitation of anthropogenic features, and learning ability (Botettiger et al. 2011; Gaynor et al. 2018). Thus, this study investigates the spatio-temporal displacement of African elephants (*Loxodonta africana*), classified as vulnerable species (Blanc 2008), and their coexistence in the landscape with anthropogenic features as well as humans.

1.1. Animal spatio-temporal displacement patterns and behaviour

The movement of animals in general, based on their behaviour is a complex association of factors including external or internal conditions. Although, direct studies about internal state are scarce (Jachowski et al. 2013), spatio-temporal phenomenon is widely exploited and brings new insights (Kays et al. 2015). Spatio-temporal data give information related to time and space, involving point objects moving over time (Gudmundsson et al. 2008; Kays et al. 2015) passively, in response to some stimulus, some behaviour of any kind (González et al. 2017), or interaction between an animal and its environmental conditions (Avgar et al. 2012).

Displacement and movement of animals, specifically of the most mammal species, are crucial for understanding their life history, their ecology, and the impact of changes in the environment. Animal displacement and movement is behavioural response to the environmental and physiological conditions, such as migration, reproduction, memory of previous experiences, and others (González et al. 2017). Animal movement patterns, together with its relationship to surrounding conditions are in many cases scale-dependent, which means that the response of animals might be at specific spatial scales and can be distinguished only at different temporal resolutions (Avgar et al. 2012; Kays et al. 2015).

The reason of movement and migration of animals across the landscape does not depend only on life-history traits and evolutionary processes (Kays et al. 2015), but other drivers, such as landscape dynamics, distribution of resources (González et al. 2017) or habitat selection (Thaker et al. 2019). Critical and mechanical understanding of the pattern of different types of drivers of animals’ movement is a crucial component in the predicting of population spreading, might be helpful for conservations and managements (Avgar et al. 2012; González et al. 2017; Boettiger et al. 2011; Songhurst et al. 2016) and offers information for wildlife protection, planning, managing invasive species, mitigation human-wildlife conflict, (Wittemyer et al. 2019) and human-elephant conflict (Jachowski et al. 2013).

There have been using different types of technological advances (Wittemyer et al. 2019). Global positioning system (GPS) is one of the tools that contribute to the animal movement researches for studying and monitoring of animals. GPS can provide detailed movement and spatio-temporal information about target animal species in the wild (González et al. 2017), and with the help of other technological advances it can even discern behavioural response to human-driven landscape changes (Wittemyer et al. 2019). This allows us to have insight into the questions of why and how animals move, and thus gives the information why animals visit different areas and can predict their behaviour and movement (Kays et al. 2015). Recording of the elephant abundance and habitat use also fall into the direct observations, where elephants themselves are counted either from the ground or from the air. Another method of surveys is indirect observation consisting of recording of tracks, dung-piles or feeding signs to access elephant presence (CITES n.d.). A combination of those was beneficial for this study and provided insight into the use of landscape with anthropogenic features.

1.2. Elephant spatio-temporal displacement and behaviour

Elephants are key and important species for the African savanna ecosystem (Nasseri et al. 2010; Carrigy n.d.), by altering and creating habitats (MacFadyen et al. 2019). They are often seen as a main base of conservations across the variety of their natural habitats (Evans et al. 2020), as they consume different types of vegetative resources on the landscape (MacFadyen et al. 2019).

Elephants do not require a special type of habitat, because they are rather foraging generalists, nonselective herbivores (Jachowski et al. 2013; Forrer 2017; Wittemyer et al 2007). Furthermore, activity and movement of elephants depends on the distribution of all features across the landscape (Boettiger et al. 2011; Wittemyer et al. 2016; Wittemyer et al 2007). Boettiger et al. (2011) also noted that elephants' spatial displacement is influenced by several reasons, such as foraging resources recognized or the availability of water sources, mainly in the dry season (Wall et al. 2013; Jachowski et al. 2013). During the dry season, elephants utilize vegetation and forage that is available and are rather concentrated around water sources on the landscape. They also shift their diet mainly to woody browse (Nasseri et al. 2010; Carrigy n.d.), which helps them to cope with drought (Wato et al. 2016). Elephants' browsing strategies vary according to their terms of the time of the utilization, including for instance breaking of branches, debarking, trees uprooting (Nasseri et al. 2010), or pushing them over Carrigy n.d.) which are the events that engineering ecosystem.

Due to their role in the ecosystem, in the form of shaping the structure of habitats and their function, the topic about the thriving of elephants is relevant, especially in different regions or countries where elephants are abundant, because each part of the country or Africa can face distinct levels of threats (MacFadyen et al. 2019).

First, human activities and its components are one of them and are a dominant driver for the spatio-temporal displacement of elephants on the landscape, with the roads classified as a barrier for the animals' movement (Boettiger et al. 2011). Wittemyer et al. (2016) in his study that focused on spatio-temporal features that influence rest locations of elephants at human-dominated locations found that elephants' resting pattern was higher during the day and further away from the permanent water sources in areas with high human density, outside the protected area. This result implies that elephants adjust their resting behaviour to the areas with low risk of human interactions (Wittemyer et al. 2016). Moreover, it was found that elephants are active during the day as well as during the night (Thaker et al. 2019) and thus their movements can be also temporal and vary according to the time of the day, season, or time spent at any location (Songhurst et al. 2016).

In addition, elephants are usually less active in the heat during the day, as they try to avoid hot peaks of the day (Thaker et al. 2019; Dunkin et al. 2013), which can shift their activity more to the cool hours or to the night. It was also stated that elephants use water at night to limit encounters with humans and generally shifted their movement to minimize direct contact with people (Gaynor et al. 2018; Thaker et al. 2019).

Another type of threat that elephants face, is for example habitat loss or conflicts with humans. As the human population grows, populations of elephants are forced to live in smaller areas (Archie & Chiyo 2011). Sharing the lands of elephants and humans has been increasing and elephants are often forced to use corridors between protected areas, which arises their physiological stress and movement pattern response (Jachowski et al. 2013). Therefore, it is important to know when and where elephants are displaced (Wall et al. 2013).

Besides the levels and types of threats, it is important to note that males and female elephants have distinct habitat use and social cues. Due to this fact, they might also have different responses to the potential disturbances and therefore their spatial displacement may be different (MacFadyen et al. 2019). According to the reproductive strategy hypothesis, females select habitats to provide safety and protection of the offspring, while males risk more and are less sensitive towards some form of disturbance or potential danger and rather select the habitat depending on the forage ability to maximize their body fitness to increase the reproduction success (Shannon et al. 2008). The study that was done on African elephants and their response to wildlife tourism showed, that performing conspecific-directed aggression when tourist pressure was high, was more likely seen in males (**S**zott et al. 2019). Generally, males have lower mean stress levels than females, even towards anthropogenic disturbances, which might be due to the physiology of those two sexes (Hunninck et al. 2017). Therefore, the response of different sexes may differ, as well as the drivers that cause the spatio-temporal movements.

Research about the movement of animals due to environmental factors has increased, as it is important to understand various ecological or evolutionary processes that cause spatiotemporal movements (Avgar et al. 2012).

Movement rates may decrease in profitable and favourable areas, for example in areas rich for food resources. Terrain and some physical obstacles like dense and thick vegetation, might be also a reason that movement slows down (Avgar et al. 2012). Elephants have a big impact on vegetation and there is a question about the strong influence of their use of landscape raised (Dunkin et al. 2013). Chamaillé-Jammes et al. (2009) adds that the impact of elephants on the vegetation is higher in the proximity of water source, however, also depending on the woody cover at the landscape. On the other hand, areas that are not profitable and have unfavourable local conditions, for example low forage availability may increase movement rates (Avgar et al. 2012).

This situation is typical for seasonal changes when vegetation and forage abundance and quality vary and fluctuates and therefore determines the migratory movement of elephants to search for other valuable types of the forage or browse or water source (Selemani & Sangeda 2019).

Source of water has the potential to be a critical driver for elephants (Dunkin et al.2013) and promotes physiological and behavioural thermoregulation that other animals need to cope with. Elephants use water for both purposes; drinking and wallowing to cool down (Thaker et al. 2019). For the animals that live in hot arid and semi-arid areas, temperature is a key environmental factor that dictates the time and frequency of water accessibility (Thaker et al. 2019).

Elephants have a wide range of thermoregulatory strategies e.g. loosing heat via trunk or flapping their ears. At the spatio-temporal scale, they try to avoid thermal stress by choosing their activity peaks to the times of the day with lower temperature or landscapes with no big temperature variations. Elephants are water-dependent species (Dunkin et al. 2013; Forrer 2017), and therefore the influence of rainfall, distribution of water sources including the river (MacFadyen et al. 2019) and temperature on the landscape are more likely to be important drivers of elephants' distribution and movement for their periodic visits of water sources (Thaker et al. 2019; Dunkin et al. 2013).

1.3. Possible causes and consequences of anthropogenic factors on animal spatio-temporal displacement and behaviour

Through the studies on wildlife and human coexistence, it was found, that human encroachment into the wildlife landscape is one of the key drivers of human-wildlife conflict (Songhurst et al. 2016). Selemani & Sangeda (2019) and Forrer (2017) agree that anthropogenic activities (e.g. urbanization or infrastructure development) are key drivers for the movement of animals. From the other human activities need to be mentioned poaching, hunting or wildlife conflict activities (Songhurst et al. 2016; Gaynor et al. 2018) as another threat and a reason for the spatio-temporal displacement. The study of Danquah

(2016), confirms that poaching activity, concretely hunting with guns, plays an important role that influences elephant displacement. The statement of Forrer (2017), that human-elephant conflict (referred hereafter as HEC), poaching, habitat loss, and fragmentation are the main threats that affect elephant abundance and their survival, support the previous findings too. Selemani & Sangeda (2019) also agree that HEC in many forms and poaching are drivers for migration from protected areas.

According to Jachowski et al. (2013), the distribution of elephants can be highly influenced by human disturbance, which can disrupt their movement behaviour in response to natural elements on the landscape, such as forage, vegetation, and water availability. The possibility of increased movement of animals from the land that is not favourable, can be also caused by physical modifications on the landscape. These modifications (anthropogenic features), such as waterholes, roads, or human settlements increase habitat avoidance (Avgar et al. 2012). Moreover, similar studies also showed, that elephants are more likely to move away from the areas with an increasing number of vehicles (Szott et al. 2019; Gaynor et al. 2018).

Songhurst et al. (2016); Jachowski et al. (2013); Boettiger et al. (2011) agree that anthropogenic activities and features e.g. roads or protection boundaries like fences, have a significant effect on the movement of elephants. Moreover, the study of Danquah (2016) showed that roads and human settlements, although outside the protected areas, had a significant negative impact on elephants resulting in strong avoidance, presumably because of the possibility of higher hunting activity.

There are areas where human-made features like buildings and another infrastructure overlap with the home ranges of elephants, which leads to the adaptation of elephant behaviour and avoiding to human disturbance (Songhurst et al. 2016).

The drivers for spatio-temporal movement of elephants are influenced by natural as well as social factors (González et al. 2017; Songhurst et al. 2016; Avgar et al. 2012; MacFadyen et al. 2019), as was mentioned in the previous subchapter. Therefore, proper planning of human land use is advocated as a requirement for protection of animal pathways in order to avoid any form of HEC, which can result in many forms of elephant behaviour (Jachowski et al. 2013), and since natural factors cannot be changed (Songhurst et al. 2016).

The physiological state is likely to play a crucial role in the spatial behaviour of elephants. When disturbance event occurs, elephants respond in stress hormone and they are likely to refuge away from the disturbance events (Jachowski et al. 2013). Therefore, it is crucial to understand the responses of elephants, their movement, and avoidance of anthropogenic disturbances at the finer spatio-temporal scale.

Findings showed that animals deal with the behavioural adaptation to the human disturbances in different ways; for example, elephants move faster in areas with higher human density and habitation and are more likely to travel in the dark to avoid these areas (Songhurst et al. 2016).

Human-altered landscape and disturbing features can further cause restriction of connectivity of elephant populations, use of habitat, and in the next stage show aggressive behaviour towards humans (Jachowski et al. 2013). With the population grow, eco-tourism and human-wildlife interaction are also on the rise (Szott et al. 2019). All the mentioned anthropogenic drivers and factors may lead to aggression, attentiveness and increasing stress, which can cause that elephants' home-range will be restricted (Thaker et al. 2019) or it will affect physiological functions which in the long-term can lead to a fitness and reproduction reduction (Hunninck et al. 2017).

However, the information and investigation studies on wildlife observation are scarce (Szott et al. 2019). The result of variation of environmental and anthropogenic boundaries may result in leaving protected areas by elephants, when they can face other threats, and increased HEC (Danquah 2016; Gaynor et al. 2018).

1.4. Elephants in the Balule reserve in South Africa

Elephants are the main attraction for tourists and residents and are often seen as the main base of conservations (Evans et al. 2020). They are also stated as an iconic wildlife species and are provide economic benefits for conservation management and countries (Evans et al. 2020). Therefore, for this study, elephants were the centre of the study research to better understand if the anthropogenic features affect their displacement or whether elephants became habituated. The research took place in Olifants West Nature Reserve (OWNR), part of the Balule Nature Reserve (BNR).

As the OWNR offers rich sight on different types of species of animals and attracts tourists, infrastructural developments to increase accessibility have been made, for example roads, waterholes, fences, and buildings, which can be classified as anthropogenic influences. It was assumed by a local research team, that elephants use these anthropogenic features like roads and waterholes considerably. This observation was confirmed by damaged trees and dung around anthropogenic features found. What was not known was, how much time they spend utilising these anthropogenic features and if elephants use them mainly at night to avoid them, or they use them during the day as well. Specifically, areas, which are highly visited by tourists associated with vehicular activity, busy roads, and areas with high human concentration.

Most of the waterholes are artificial with high road density around (Figure 3), which means that waterholes are easily accessible for tourists and elephants. However, waterhole has two potential factors for elephants, where the first one serves as a "leisure" place, where elephants spend more time drinking, wallowing, or feeding (Thaker et al. 2019). Or, a second factor could be anthropogenic influence, which is expected to not be too comfortable for elephants to spend much time there as they will come as a necessity for drinking therefore, they spend less time. It was also unknown, how elephants use roads, if they use it as an object to cross or utilising them as a path.

A high density of roads, different types of buildings, and other possible features can cause changing behaviour (Szott et al. 2019; Songhurst et al. 2016). That means, that elephants will be more likely to move away from the areas that have a high density of vehicles or people in general or simply will try to avoid trafficked roads during the game drives.

There is a risk of decline in tourism in OWNR, if there are fewer animals to see in the reserve. As elephants are threatened from different spheres, on one side, tourism can be a form of protection of animals due to income from tourism serving for conservation and management purposes. On the other side, anthropogenic influences and disturbance from high human activity should be balanced and ensured with elephants and their natural habits in the area. Hence, there was a call for the new study of anthropogenic aspects which may influence the distribution of elephants and their activities in the reserve.

2. Aims of the thesis

The study aimed identify if, and how anthropogenic features of the landscape, namely the intensity of use of buildings, roads, and water holes by humans, affect the spatio-temporal displacement of elephants in Balule Nature reserve (BNR) focused on Olifants West part of BNR. The objectives of the research were to determine:

1) relative abundance and density of elephant dung and tree damage as a proxy for time spent at a unit by elephants, and
2) home range of elephants towards anthropogenic features on the landscape, including avoidance of specific areas.

To verify the hypothesis, the prediction was that relative abundance of elephants was going to be higher in the areas with low intensity of anthropogenic features and their relative abundance was going to be lower in areas with high intensity of disturbance related to human activity, and elephants were going to avoid the areas with increased human disturbance.

3. Methods

3.1. Study area

Balule Nature Reserve (BNR) is a private nature reserve and covers approx. 56,000 ha (Allin, pers.comm.) in the Limpopo Province in South Africa. BNR is part of Greater Kruger and covers the area between South Africa, Zimbabwe, and Mozambique (South Africa 2019). It is part of the Associated Private Nature Reserves (APNR) including Olifants West Nature Reserve (OWNR) (Elliot 2018) and shares an unfenced border with Kruger National Park (Figure 1). BNR is home to a wide range of species including around 94 mammal species and over 200 bird species. The reserve is recognized as a “big five” area which means lions, buffalos, elephants, rhinos, and leopards, the most dangers animals to hunt, are present and can roam freely across the reserve. Active conservation takes place in BNR and largely within the place of the study, Olifants West. The activities in OWNR are led by Transfrontier Africa, a conservation management non-government organization (NGO) and the region’s warden, Craig Spencer.

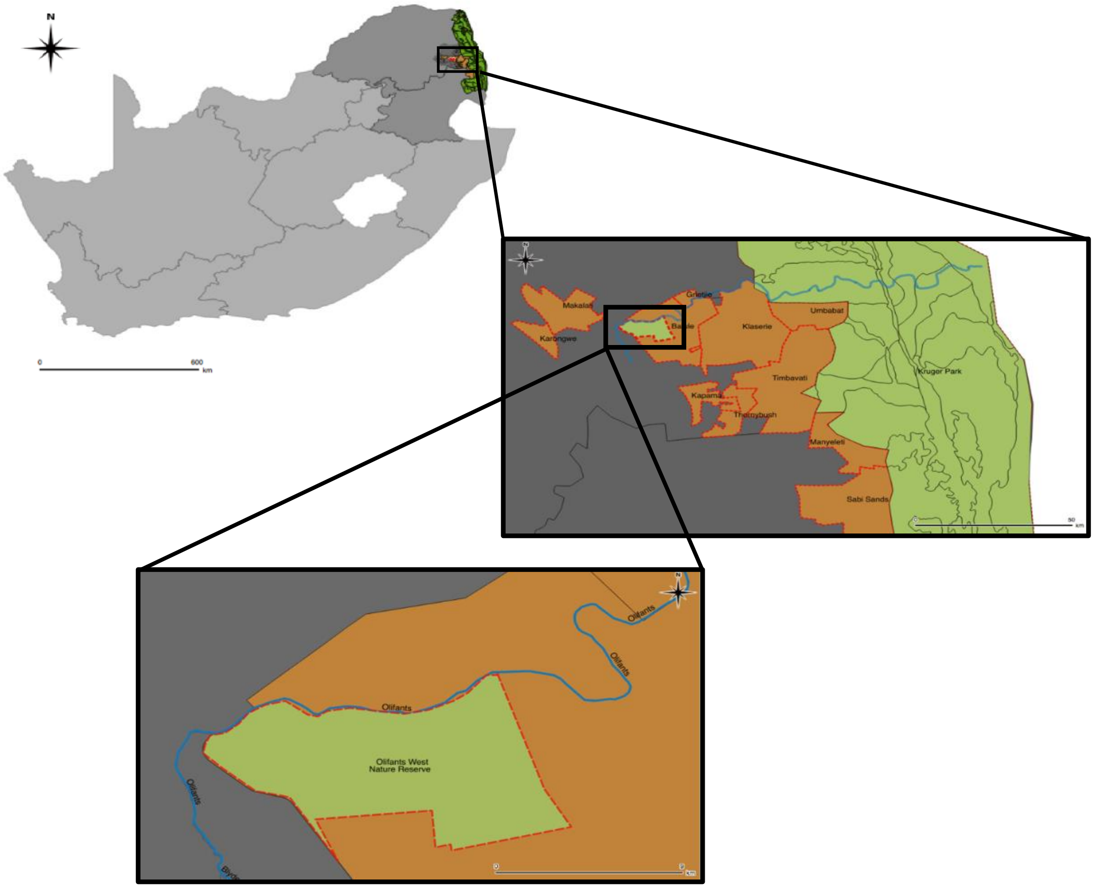

Figure 1. The location of Olifants West Nature Reserve within the Associated Nature Private Reserves in South Africa (Elliot 2018).

OWNR (24° 11' S, 30° 54' E; 86 km^2 =8,600 ha) is classified within the savanna biome with lowveld vegetation communities. Low precipitation is common in this type of biome (Clark 2013). The average total rainfall for the last 35 few years was 421.46 mm per year (OWNR 2020). The wet season usually begins in October and generally lasts for 5-7 months. Summers are hot with temperatures ranging from 18-45°C and from 8-23 °C in winters (Clark 2013).

Fauna and flora

OWNR conserve a large diversity of animal species that include more than 40 mammals with range from woodland mouse to the biggest terrestrial animal elephant, and more than 200 recorded bird species (Olifants West 2013).

Vegetation in OWNR is a highly variable savanna biome with flora/plants ranging from trees to bushvelds. The most common tree species in Greater Kruger National Park, another savanna biome is *Acacia* species, Marula trees, *Combretum* species etc. (Naidoo et al. 2012). *Combretum* spp. are one of the most abundant trees within the OWNR (Elliot 2018) and are one of the elephants' favourite plants to browse. Elephants strip the bark, break branches, uproot the tree, and forage on new growth (Harvey 2019). Since the tree are of varying sizes (Masupa & Rampho 2011), elephants of all ages can utilize them. *C. apiculatum* tree is the most widely spread tree species across the reserve, making it a focus for this study (Allin, pers.comm.) therefore it was the target species for the research.

Red bushwillow

Red bushwillow (*Combretum apiculatum*) belongs to the family Combretaceae. This small to medium-sized tree occurs in savanna regions with conditions ranging from medium rainfall to semi-arid. They are usually found in rocky areas of altitude around 1,400 to 1,500 m a.s.1 (Masupa & Rampho 2011). Furthermore, *Combretum* species, including *C. apiculatum*, are classified as one of the eight common savanna tree species that are found in the Greater Kruger National Park in South Africa (Naidoo et al. 2012). Besides others, it is also abundantly located in the Limpopo area (Masupa & Rampho 2011).

Red bushwillow can have a single or multiple stem (Figure 2) and its height can reach from 3 to 10 metres. The trunk is often curved and short and spreads irregular canopy. Its secondary branches hang down and are typically long and slender. The colour of the bark on the stem ranges from grey to brownish grey, depending on the age (Masupa & Rampho 2011).

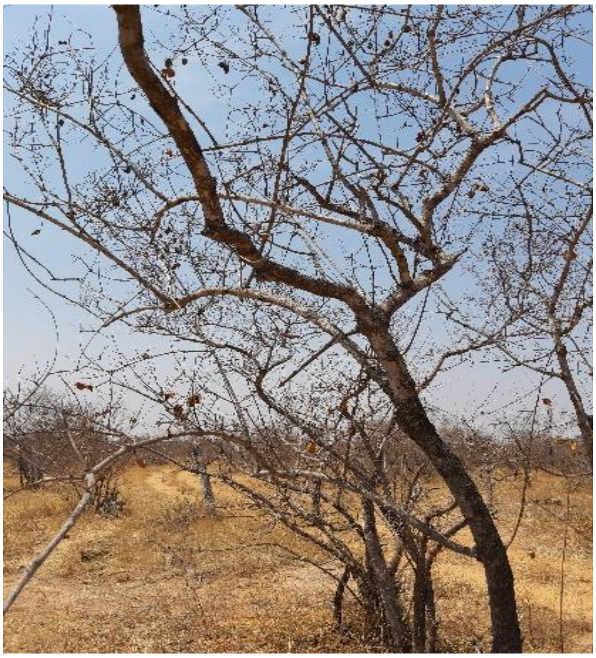

Figure 2. Red bushwillow. Photo taken during the fieldwork by R. Kremláčková.

Red bushwillow can also be recognized by its yellow-green leaves (during the wet season), that have sharp, twisted tips with a roundish outline base. The flowering is seasonal, usually from September to February. It is a valuable fodder tree that serves for browse of variety animals such as kudu, giraffe and elephants (Masupa & Rampho 2011).

Infrastructure in the reserve

Within OWNR, there are 54 water sources, mainly man-made and associated with roads. Moreover, 15 of water sources are associated with some building or lodge. There are, in total, 111 buildings with varying usage/purpose. Within them there are 11 commercial lodges, that vary in size and nature and offer a variety of eco-tourism walking and vehicular safaris or rarely visited or uninhabited buildings. These buildings and lands belong to approx. 50 private landowners.

3.2. Identifying and categorising anthropogenic disturbance features

The main sources of anthropogenic features within OWNR are buildings associated with human activity, fences, waterholes, and roads associated with the activity of vehicles and possible other modifications. To test the effects of intensity of human activities and anthropogenic features on elephant displacement, there have been selected buildings, roads, and waterholes as anthropogenic features based on the dung and tree damage density analysis. These features were further subdivided into low and high intensity.

The intensity of all features was chosen based on the knowledge and expertise of the management of OWNR and the distribution of the features within the reserve. The general description of categories for designation of the intensity (human activity) is described and locations of sites are shown in Figure 3. Information that are displayed on this map are based on the data that belong to Transfrontiers Africa. Data are displayed using geographical information system software, ArcGIS (ArcGIS, Esri, Version 10.7.1.).

In total 20 sites of different intensities were chosen for data collection on transects and density counts. Half the number of each group (buildings, waterholes, roads) was divided into low and high intensity categories. This final design and selection of sites were chosen with the expert advice of Craig Spencer and Paul Allin and actual logistic and time options (constraints) in the reserve during the field work. The number of sites was chosen to be representative for the statistical results.

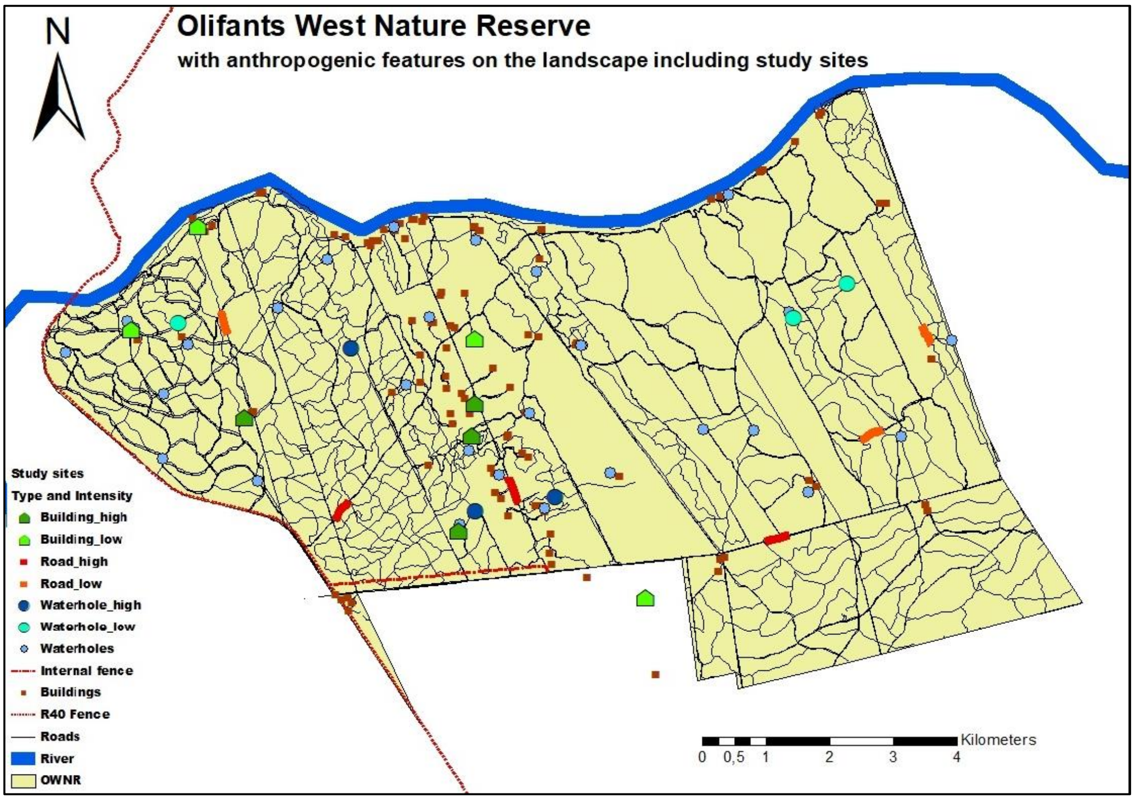

Figure 3. Olifants West Nature Reserve map with chosen sites of different intensity for the survey. Buildings representing light green colour are referred as low intensity buildings, and dark green is representing high intensity buildings. Waterholes with light blue colour are representing low intensity waterholes and dark blue is representing high intensity waterholes. The sections of studied roads of orange are representing low intensity road sections and red colour is representing high intensity roads.

- **Buildings**

Eight out of total 111 buildings in the OWNR were chosen and divided into two categories as follows:

1) "Low intensity buildings" indicate sites in the proximity of buildings that were uninhabited or occasionally visited by guests with low vehicular activity and were rather far away from the area in the "busy polygon" of the reserve; area with a high density of buildings. Studied buildings are displayed in Figure 3 and two of those were bounded by the electrical fence and two of them are unfenced.
2) "High intensity buildings" are categorized as buildings with permanent residence or commercial lodge that operates most of the year. Vehicular activity is higher there and the noise during the day and evenings is also higher as providing cultural evening and different types of entertainment. An electric fence is guided around

the building. One of the selected buildings (research and volunteer camp) is unfenced.

- **Waterholes**

Six out of 54 waterholes within OWNR were chosen and split into the following categories:

1) "Low intensity waterholes" were chosen according to the distance from the high density of buildings, it means those more than 1 km, low or rare visits by tourists connected to low vehicular activity and far from the high intensity road.
2) "High intensity waterholes" were chosen according to the known high number of tourists that visit the waterhole. Favourite touristic itineraries and popular drink stops for quests or similar tourist attractions were considered.

- **Roads**

  Six roads in total were chosen according to the traffic and divided into the following categories:

  1) "Low intensity roads" belonged to the roads that were used mainly during the game drive hours (5:30 – 10:00 and 15:00 – 20:00) mainly by commercial lodges. These roads were used rarely.
  2) "High intensity roads" can be characterized by high numbers of vehicles per day. These roads were highly frequented during the game drives used by visitors, staff, residents, or deliveries and used during the night for antipoaching patrols.

3.3. Data collection

To complete the aims, two types of data were used.

The first type of data was ground-based data collected from the field using line transects. As it is difficult to observe elephants directly, an indirect method based on the density of dung and tree damage was used, slightly like the study of Songhurst et al. (2016) who used also indirect method, however based on examination of footprints.

The second type of the data was the satellite data from the collared elephants for better view of spatial displacement of elephants on the landscape.

3.3.1. Dung and tree damage count on the line transects

Data on dung and tree damage densities were collected during the fieldwork from the 30th of August until the 7th of October 2019. This period corresponded to the dry winter season.

Indirect survey methods that are linked to particular animal signs (tree damage and dung-piles in this case) are usually more useful when identifying animal presence and density or abundance than observing animals themselves. Hence, they use a wide range of habitat (Hedges 2012), especially in this case when elephants can walk long trails up to 195 km per day (the average is 25 km per day) (Elephants for Africa 2016). Therefore, the walk line transect method was used for ecological sampling (Manly & Navarro 2015).

The dung of elephants and tree damage density were counted without revisiting studied areas within 4 × 100 m plots spaced perpendicularly depending on the terrain in waterholes and buildings as it is graphically represented in Figure 4 and Figure 5, and in 100 m between roads (Figure 6). This method did not require repeated visits and allowed visiting more sites and do more transects for increasing the sampling rate.

Every elephant sign on the transects was recorded to the database containing information such as location, type of the dung or tree damage, or an age (Appendix 1). Through the multiple transects within 20 sites, the spatial distribution of species according to the testing of the density of tree damage and elephant dung was accessed.

3.3.2. Design of data collection on transects

For the ground data collection, the data sheet and Avenza application was used. Using Avenza application is an efficient method for sight monitoring which serves as GPS to track or plot locations, shows distance and time travelled (Avenza systems INC 2020). The data sheet was customized for the collection of data for dung piles and tree damage to show the mean density.

Transects covered the same distance of anthropogenic influence – 4 × 100 m. The distance of 100 m from the starting point of the transect was assumed to be representative for the testing of density of dung and tree damage and was chosen according to the time and logistic limitations. The following schematic diagrams represent the presumed transects with the knowledge that the lines could lead the direction which was the most suitable; walked path, not many objects (trees, bush, stones...) on the line.

The idea of line transect was to move along the transect line and observe the items or target signs within the defined plots. By this method density of signs could be found or even density or abundance of target animals (Navarro & Gamboa 2015). If the obstacle on the line needed to be avoided, the line followed a walking path, and 2 m either side did continue the walking path as the original path. Field tape measure was used for the transects with the length of 100 m and a long stick of 2 m was another tool that helped to recognize the width from the line. For minimizing possible chances of missing the dung piles, a team of minimum 3 observes searched the entire with and length of each plot.

Each recorded dung pile, trees, and tree damages were assigned to one of its categories (Subchapter 3.3.3.) and a GPS location was marked. Only one field personnel conducted dung pile counts and tree damage estimations, to minimize any observer bias.

The planned number of walked transects was 116 and the total area covered was planned to be 4.62 ha. For the more accurate results, it was planned to increase the number of sites at the end, which was finally not possible due to time and logistical constraints, thus was increased number of transects that could not be finally constant in all the sites again due to time and logistical constraints. Therefore, the final total number of transects was 126 at all types of infrastructure and intensity together and the total covered area was 50,400 m^2 = 5.04 ha.

Waterholes

The sites were established for 2 categories of waterholes (low intensity waterholes, high intensity waterhole) with 4 waterholes in each category. Plots for transects were 100 m long and 4 m wide. Observing and counting the dung balls and tree damage 2 m at the right and 2 m at the left side of observer walk. There were 4 transects at each waterhole with the beginning at the border of the waterhole radially outwards, seen on representing Figure 4. The number of planned walked transects was 12 for low intensity waterholes and 12 for high intensity waterholes, and the total area for all studied waterholes was planned to be 9,600 m^2 for both categories. After increasing number of transects, the final number of transects was 14 for low intensity waterholes and 12 for high intensity waterholes. Therefore, the total area covered for waterholes of both categories was 10,400 m^2.

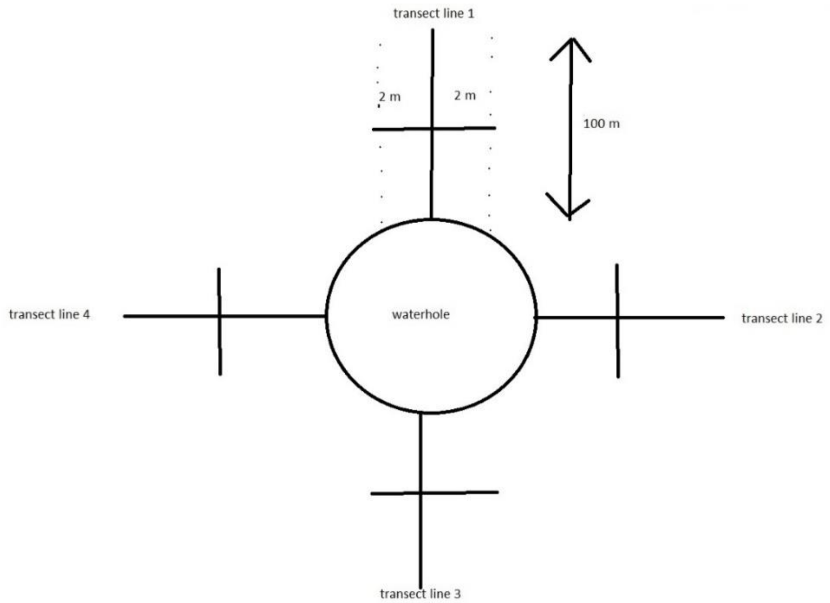

Figure 4. Schematic diagram of waterhole for transects.

Buildings

The sites were initially established for 4 categories of buildings (low intensity buildings with the fence, high intensity buildings with a fence, low intensity buildings without fence, high intensity buildings without fence), however, it finally was counted only with 2 categories regardless the fence with 4 buildings in each category. Plots for transects were 100 m long and 4 m wide, observing and counting the dung balls and tree damage 2 m at the right and 2 m at the left side of observer walk. There were 4 transects at each building with the beginning at the border of the building or building with the fence radially outwards, seen on representing Figure 5. The number of planned walked transects was 16 for low intensity building and 16 for high intensity building, and the total area for all studied buildings was planned to be 12,800 m^2 for both categories. After increasing the number of transects, the final number of transects was 20 for low intensity building and 18 for high intensity building. Therefore, the total area covered for buildings of both categories was 15,200 m^2.

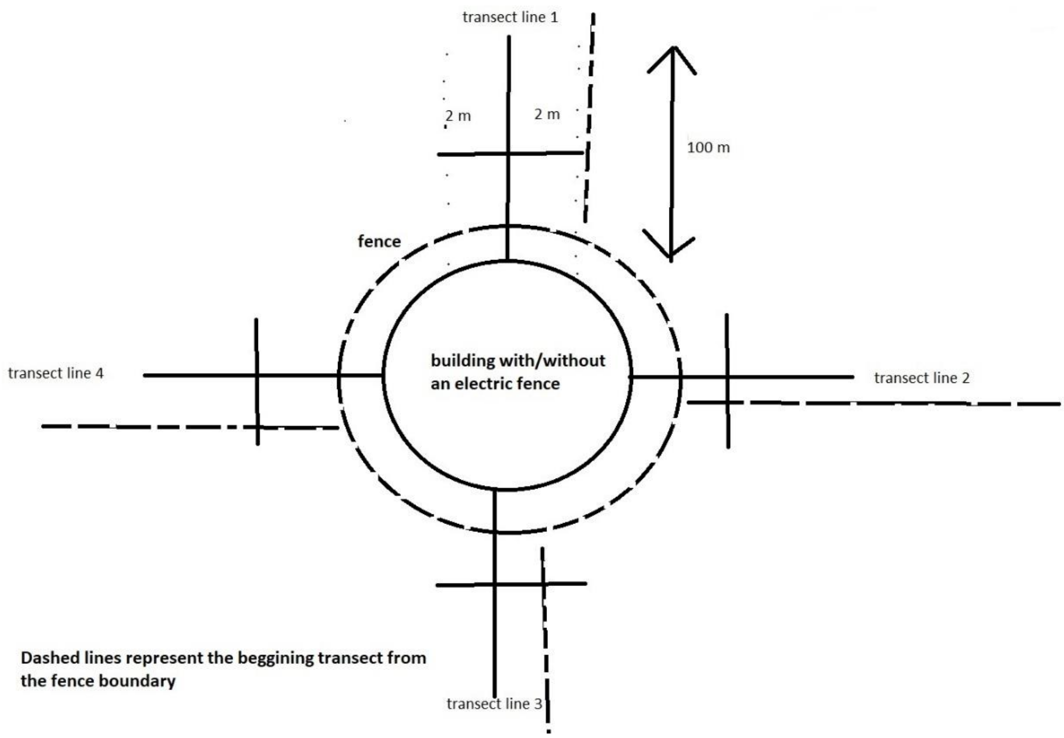

Figure 5. Schematic diagram of building for transects.

Roads

The sites established for roads were also divided into 2 categories (low intensity roads, high intensity roads), with 3 roads in each category. Plots for transects were 100 m long and 4 m wide, observing and counting the dung balls and tree damage 2 m at the right and 2 m at the left side of observer walk. To cover assumed representative area and according to the logistical possibilities there were 10 transects from roads, 5 transects at each side of the road with the spacing of 100 m from the transects which will make 420 m of 1 side (Figure 6). The number of planned walked transects was 30 for low intensity roads and 30 for high intensity roads, and the total area for all studied roads was planned to be 24,000 m^2 for both categories. After increasing the number of transects, the final number of transects was 30 for low intensity roads and 32 for high intensity roads. Therefore, the total area covered for roads of both categories was 24,800 m^2.

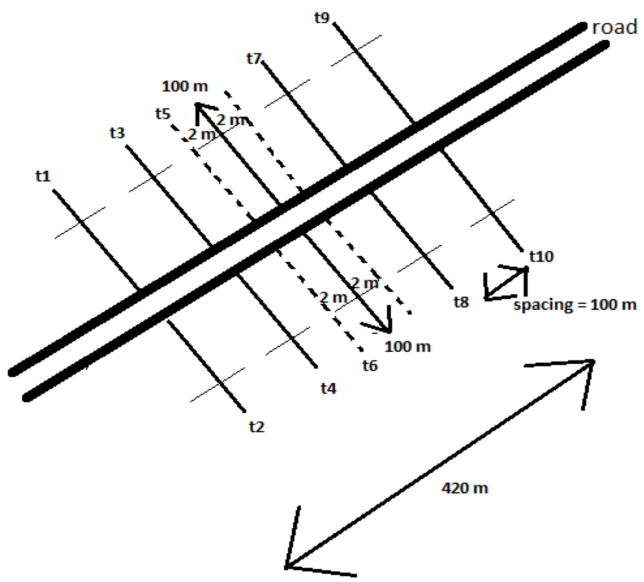

Figure 6. Schematic diagram of road for transects.

3.3.3. Data collection and classification

A sheet with different columns (Appendix 1) was used for recording of the dung piles and tree damage.

3.3.3.1. Dung counts

When counting the signs, it was necessary to decide which sign in the form of dung or tree was included in the counts. Representation of the dung counts is graphically shown in Figure 7. Counts included piles within the 2 m border at each side, which means, the dung “lying” on the line of 2 m border were included in the counts. The piles of dung beyond the border were not counted.

The distance of each dung pile on the line, within 2 width was recorded from the start of the line to the “middle” of the pile, regardless of the amount of dung balls (Figure 7).

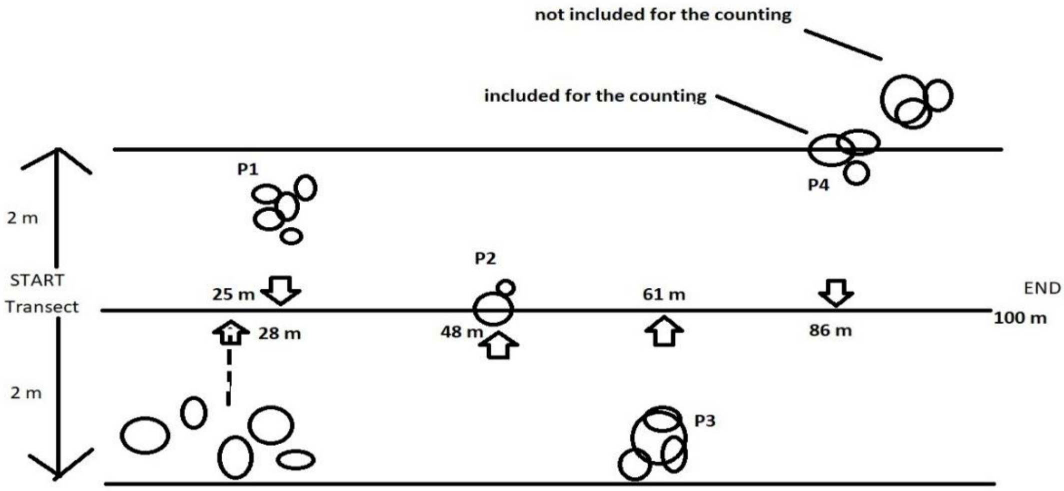

Figure 7. Representation of dung counts.

Most of the information are self-explanatory. However, the classification of some points is clarified below:

- **Estimated size of a dung pile**

Three categories of recording of the size of a dung pile were established. The category of small (1) did represent a dung pile which consisted of 1 dung ball, medium category (2) counted 2 – 4 dung balls per a pile and category large (3), recorded 5 or more dung balls per a pile.

The following images represent how numbers of dung balls were distinguished and estimated. Therefore, there was done estimation of size, and the dung piles were categorized. These categories were further converted to actual numbers for statistical analysing. This step is explained in Subchapter 3.3.5.1.

The first option of calculating was from a clear sight, where the number of dung balls were countable. This was identified by the shape and the volume, which is coherent (does not break-up) and could be handled without any significant crumbling. According to the Figure 8(a), the amount was estimated to 4 and the dung pile was classified in category 2. Clear numbers of dung balls were counted normally, and the rest of the dung was estimated. Figure 8(b) assumed that the dung ball was just broken, and the number was estimated as 1 and classified as a group 1. When the identification of the dung pile was not clear, the amount was assumed by the observer. An example 8(c) was assumed as 4 marked in category 2. The group of dung that was not included into the counting is represented in the Figure 8(d).

Figure 8. Examples of different types of number of dung balls showing clear number of dung balls of 4, marked in category 2 (a), estimated dung ball of 1 marked in category 1 (b), not clear number of dung balls estimated to number 4 marked in category 2 (c), dung pile encountered that was not enumerated (d). Photo by: R.Kremláčková.

When the size of the dung pile or tree damage was not clear, the photo and the note was taken, and estimation was done later. The column "other notes" also served as a comment related to the sign.

- **Estimated age of the dung**:

In the category "less than 24h" (1) were included noticeably fresh balls of dung which were characterized by the layer of slime, moisture inside, steam, by observation of elephant defecating etc.

The category “less than a week” old (2) referred to a dung that displayed some activity from insect, termites, there were some dry parts and a dung started to lose the moisture, but it was not completely without activity or not completely dry.

The last category “more than a week” (3), included the dung piles that did not show any activity of insect, were completely dry, were found with mould inside, and a grass growing around.

- **Type of the elephant social group**

Sex of the elephant was difficult to estimate. Ty social group was estimated by the size of the dung ball or by assuming according to the visual density of dung balls. This means, if there was found a single pile of a large dung ball, it was assumed to be a single adult (1). If there were more large piles around, they were assessed as a bachelor group (2). When more dung piles with different sizes were found within a respective distance (i.e. within 3 m^2), a social group was assumed to be a herd with calves (3). However, it was expected to mark most of the cases as unknown (4). This part was just indicative estimation and was not taken as a key or reliable factor.

3.3.3.2. Tree damage counts

The same rules, as for the recording of the dung, were applied for the recording of tree damage. Counting included trees within the 2 m border or on the line of the 2 m border. Branches lying or interfering with the study zone were not counted. The measurement of damaged trees was also taken from the beginning of the transect line. Various classifications of tree damages were recorded in the fitting columns (Appendix 1).

Classification of studied points:

- **Type of tree damage**

To estimate the damage of a trees and asses time spent utilizing the tree categories of damage were established and are listed in Table 1.

If one tree showed different types of damage and damage at different ages, the information was recorded separately as different damage. However, it could have been marked in the same row in data sheet. When data were transferred to the excel sheet, each damage represents its row. If the stems could not be distinguished as main and secondary because they had the same sizes, they were assumed as main trunks. Estimation of very old crumbling stems of grey to black colour were not counted in the damage scale.

Activities in 4, 5, 6 group are usually more time consuming, therefore it is assumed that elephants spend more time at the spot.

Table 1. Group numbers and types of tree damages

Classification group	Type of tree damage
0	No damage
1	Small and secondary branches broken
2	Primary branches broken
3	Secondary trunk debarked or broken
4	Main trunk debarked or broken
5	Trunks pushed over
6	Uprooted or kicked out

- **The age of tree damage**

The age was assessed by looking at the colour of the damaged area on the tree (broken branch, strain) and estimating dryness.

The signs for a classification of fresh (1) had green or reddish/brown colouration with signs of moisture inside, middle old (2) fading colours and impact marked as old (3) was damage visually old, with grey/black colour.

3.3.4. Satellite data from collared elephants

The second type of data were satellite data with GPS locations of elephants, as it can provide detailed movement and spatio-temporal information about target animal species in the wild (González et al. 2017).

For this study the approach of Elliptical Time Density (ETD) was used. The satellite data from the collared elephants employed in this study were collected and prepared by Elephants Alive organisation. Data were calculated to 50 % (core home range) and 90 % ETD Home Range of elephants to determine site occupancy using data extracted from 3 females and 7 males' location points. This type of home range (i.e. ETD) quantifies "*the amount of time spent by an elephant per unit area providing more fine-*

scaled insight of elephants' spatial and temporal use across a landscape" (Wall et al. 2014). The data were delivered in the vector form of the shapefile and were collected and clipped for OWNR within the time spent per unit area for two years, from 01/012018 until 01/01/2020. The collars of 1 male and 1 female elephant were set hourly, the rest of elephants (i.e. 2 females and 6 males) were set to four hourly downloads. Elephants were collared according to the standard operation procedures approved by the South African National Parks Animal Use and Care Committee (SANParks 2011). The satellite collars were sourced from Africa Wildlife Tracking and Savannah Tracking.

Data were filtered for erroneous GPS fixes based on a biologically defined upper movement limit of 7 km/h (Wall et al. 2013). All spatial data were projected to the Universal Transverse Mercator (UTM) WGS_1984 reference system (Zone36 S).

ETD is an animal space-use model for which discrete-time tracking data are used for movement studies of wild animals. It provides a non-parametric approach based on the trajectory for animal displacement. The parameters are derived from the movement behaviour of the animals. ETD model approach helps to better estimate the utilization displacement of elephants since the data are derived straight away from the tracking data, are interpretable, can be adapted to different temporal regimes, preserves the connection of the landscape and utilization (Wall et al. 2014).

3.3.5. Data processing and analyses

3.3.5.1. Calculation of dung and tree damage density

The density for dung was calculated as the number of dung (n) on transect divided by the area of transect per ha. Density was counted for each category "estimated size of a dung pile" separately. Groups in these categories were further converted into basic numbers to be able to count the density and use it for statistical tests. The group 1 (dung of 1 dung ball) was converted to number 1, group 2 (dung of 2-4 balls) was converted to number 3, and group 3 (dung of 5 and more balls) was converted to number 6. The number of piles and density of dung did indicate how long an elephant stayed in the particular spot and showed the density and possible influence in different zones on the transect line from the anthropogenic features.

For some groups of signs were counted proportions in percentage, from which the statistical analyses were made. The relative proportion in % gave a better image among the groups of signs. It was the case of a general overview for all the categories and signs, as an additional review of ages of dung and elephant social groups. Counting of mean percentage according to the elephant group is just informative and indicative.

With the percentage proportions was also counted in case of tree variety of damages and its age. Calculation of tree damage density was counted for each transect separately (same as for the dung counts), and the density and percentage of all damages were counted for the relativity.

3.3.5.2. Dung and tree damage density analyses

Both, dung and tree damage density were tested to evaluate the differences among the three anthropogenic features and two intensities of human activities.

First, the data were tested by the Kolmogorov-Smirnov test of normality. Data of dung density were not normally distributed; therefore, the data were log-transformed to meet the assumptions to apply parametric tests. The tree damage data were normally distributed (tested by Kolmogorov-Smirnov test, $p>0.05$).

To test the differences in the density of dung and density of tree damage among anthropogenic features and between intensities of human activity, the general linear model (GLM) was applied, for each separately. Tested independent variables (predictors) were the anthropogenic feature (waterhole, road, building), level of intensity of human activities (low x high), and interaction of these predictors. For significant effects in the GLM, the post-hoc HSD Tukey tests were applied. In addition, the differences in dung density between low and high intensity of human activity were tested separately for each anthropogenic feature using Student's t-test (log-transformed dung density as the dependent variable).

Next, the density of different aged dung (old, middle old, fresh) were tested for differences among anthropogenic features and intensity of human activity. GLM was used for repeated measures with data on dung density of different age in two forms as dependent variable repeated at the same transect, i.e. log-transformed dung density of each age and dung density of each age as proportions. Features, intensity, and their interactions entered these two models as predictors. For significant effects in the GLM, the post-hoc HSD Tukey tests were applied.

For the density of trees among the features GLM was used and for significant effects in the GLM, the post-hoc HSD Tukey tests were applied.

The differences of relative occurrence of tree damage (i.e. % out of all trees per plot) according to the damage severity (7 levels of severity) at the same transect were tested, using GLM for repeated measures. Features, intensity, and their interactions were used as predictors. For significant effects in the GLM, the post-hoc HSD Tukey tests were applied.

The calculation of proportions in % of some categories in the study, was relative. All the analyses were performed in the STATISTICA software package (Tibco, USA).

3.3.5.3. Processing and analyses of satellite data

to visualise the home range, of male and female elephants and their occupancy at different landscape utilisations, the data were transferred to the ArcGIS (ArcGIS, Esri, Version 10.7.1.) software.

The area of home ranges was calculated for all four categories and both elephant sexes to see the proportion from the total area. An overlap was made of all elephants and their home ranges were calculated and visualized to see, which landscape units were the most occupied by females, males, and all elephants by intersecting of layers. Furthermore, to see any interaction and overlap of all elephants and their home ranges and anthropogenic features as a disturbance, buildings were chosen to conduct a “disturbance zone” to see any interaction and the overlapping area. This disturbance zone was created as a 500 m buffer zone from all the buildings. This zone was firstly clipped for OWNR to exclude the extra area behind the OWNR borders and dissolved to avoid counting of overlaying zones from the buildings. Afterwards, all layers, one by one, and together, according to the need, were intersected with this buffer zone.

The overlapping area was also recalculated for all elephant categories and home ranges as an area from the total area and proportion within the disturbance zone.

Since there was a high density of roads and they could not be classification into the intensities and waterholes do not have this classification either and their purpose is different, the buffer zone was created only for buildings, regardless of the intensity or classification. Buildings were taken as a human-made object, and a majority of them with the potential disturbance of an electrical fence.

4. Results

The final number of studied sites was 20 with a total number of 126 transects, covering the area of a total of 5.04 ha area. This represents the sampling effort 0.059 % on the total 8,600 ha of OWNR. A total of 784 dung samples were found counting 2,955 dung balls. 761 trees were recorded in total, with 1,467 of tree damage records. 18 trees (2.4 %) from all 761 trees were found with no damage.

4.1. Elephant dung density in the reserve

The overall mean density of dung per hectare in the reserve was 591 (± 518 SD). There was recorded 208 fresh dung representing 7 % of total records, 1,073 medium aged representing 36 % and the last group of old dung with 1,674 records of 57 % out of all the records.

Indicative results of proportions of elephant social group showed that 420 dung counts belong to the individual elephants which is 14 % of all the counts. It was recorded of 518 dung per ha (18 %) belonging to a bachelor group of elephants, breeding herd type had 701 dung counts representing 24 % of total records, and there were 1,316 dung per ha (44 %) of total records that were placed in the unknown group.

4.1.1. Differences and effects of intensity among anthropogenic features

The elephant dung density (n/ha) was higher around waterholes 1,063 dung per ha (± 769 SD) in comparison to roads and buildings (Figure 9), while the dung density around buildings (440 dung per ha ± 380 SD) was similar to dung density around roads (484 dung per ha ± 310 SD) ($F=10$, $df=2$, $P<0.001$).

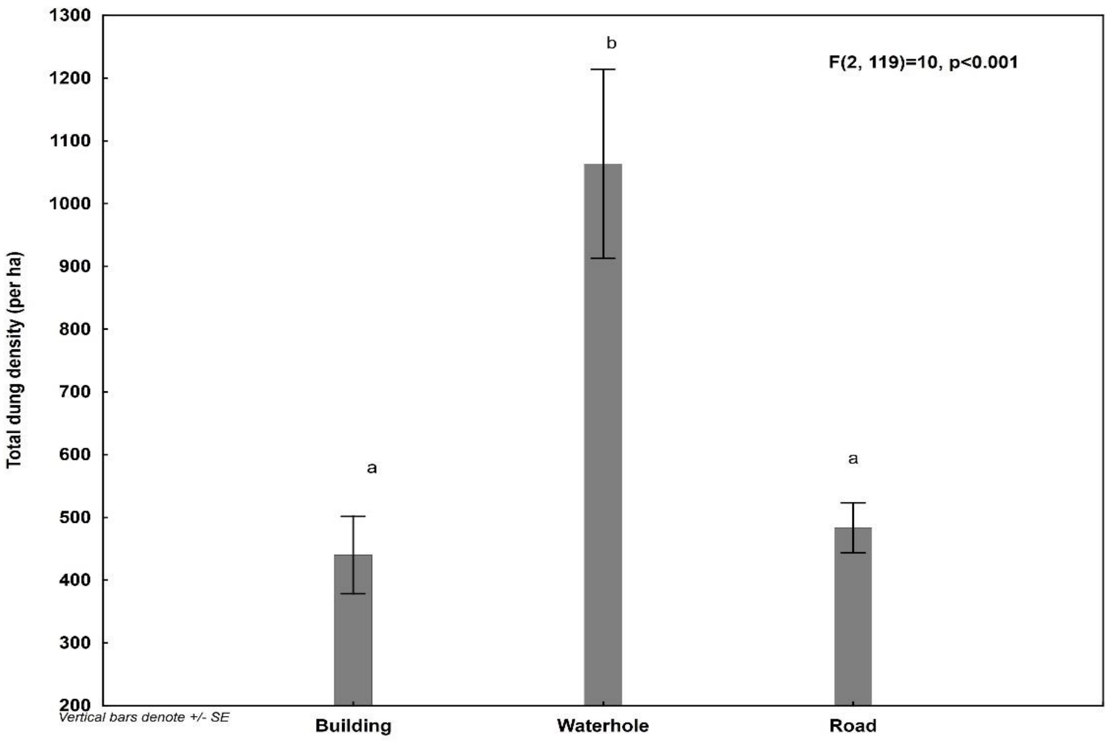

Figure 9. Total density of elephant dung per ha in proximity of anthropogenic features

The density of the dung was higher for waterholes and roads with low intensity sites in contrast to buildings, where the dung density was higher at building sites with high intensity (Table 2). There were no significant differences between low and high intensity of buildings and waterholes, however, there was a significant difference between low and high intensity at road sites (Figure 10).

Table 2. Overall dung density per 1 ha comparing intensities of studied anthropogenic features

Anthropogenic features	Intensity	N of transects	Mean	Median	Std.Dev.
Building	Low	20	419	175	432
	High	18	464	388	322
Waterhole	Low	14	1230	1100	919
	High	12	869	1025	518
Road	Low	30	579	538	355
	High	31	391	400	229

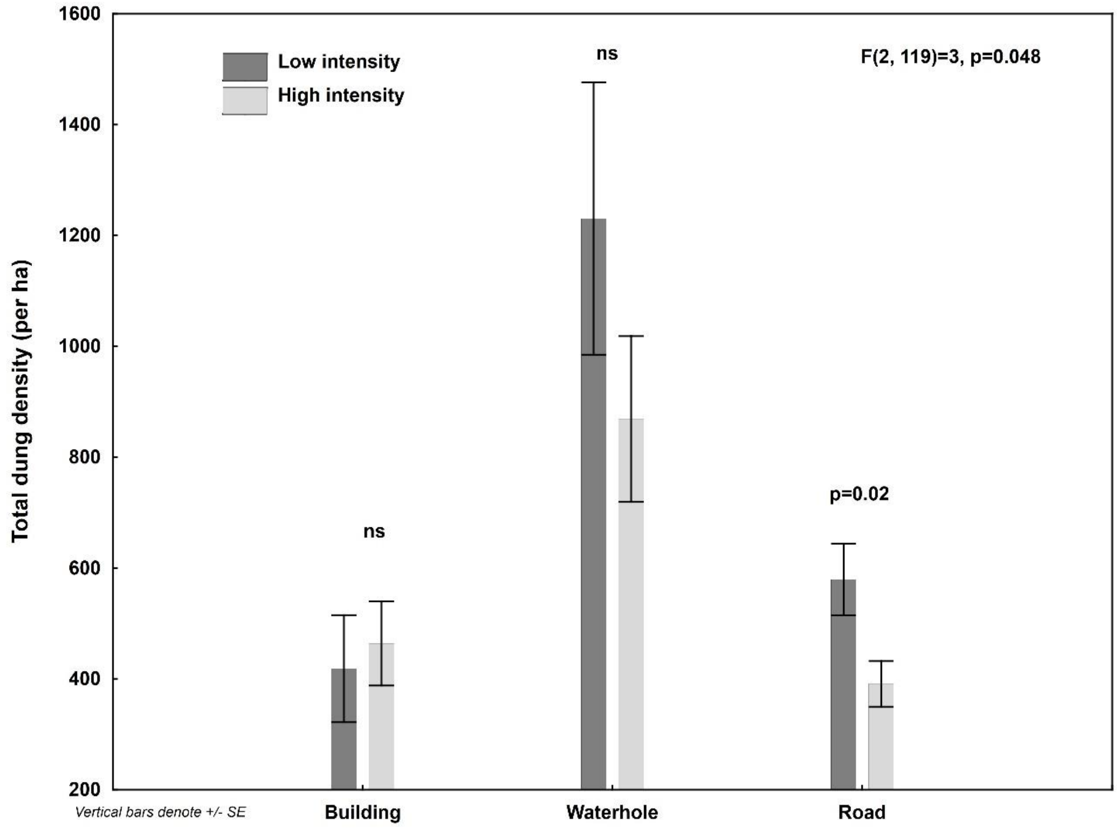

Figure 10. Total dung density per ha comparing three studied anthropogenic features and its intensity

The overall mean density of fresh elephant dung was 36 per ha± 22 SD and was significantly lower than that middle-aged (76 per ha ± 67 SD) and old elephant dung (108 ± 86 SD) ($F=3.5$, $df=2$, $p=0.041$). However, these densities did not differ among types of sites/ anthropogenic features, neither intensities nor their interactions ($p>0.05$ for all these factors, Figure 11).

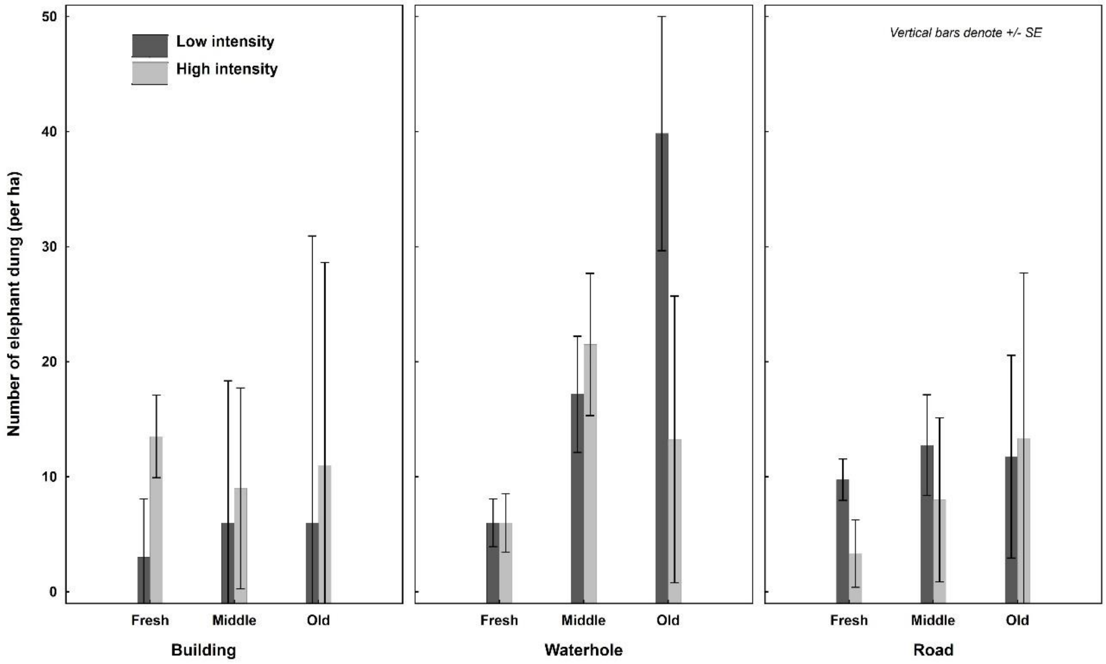

Figure 11. Density of elephant dung according to the age of dung at three anthropogenic features.

In the occurrence of various aged dung proportions, the fresh dung was the least represented (mean 5.5% ±14 SD), followed by middle aged dung (mean 30%±30 SD), and the old dung was the most represented (60%±34 SD) ($F=71$, $df = 2$, $p<0.001$). There were, however, no differences in proportions among sites, neither between low nor high intensities ($p>0.05$ for all these factors, Figure 12).

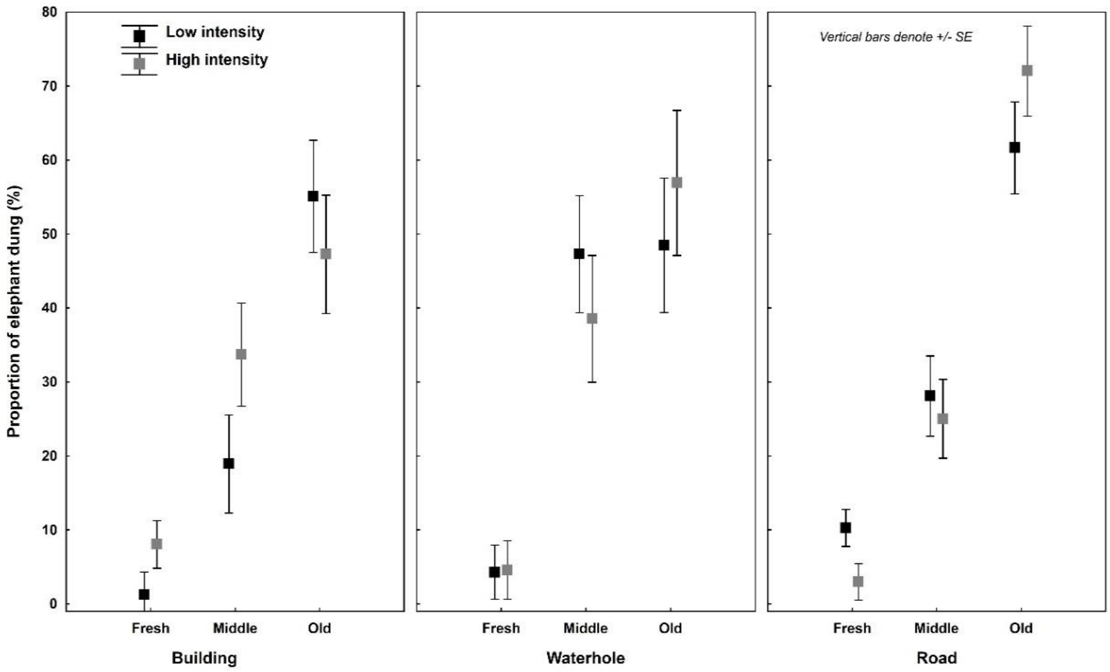

Figure 12. Proportions of elephant dung according to the age of dung at three anthropogenic features.

Proportions of elephant dung according to the social group

There were more individual elephants present at all the low intensity anthropogenic features, bachelor group of elephants had higher representation at a high intensity of buildings, slightly higher at roads but higher presence at low intensity waterhole. Breeding herds had higher percentage of dung counts at high intensities of buildings and waterholes compared to roads where there was higher representation at low intensity roads (Table 3).

Table 3. Relative proportions of elephant dung (in %) according to its social group comparing between intensity of anthropogenic features.

Anthropogenic feature	Individual elephant	Bachelor group	Breeding herd	Unknown
building	**7.8**	**15.8**	**27.1**	**49.3**
high	23.1	56.6	57.5	47.9
low	76.9	43.4	42.5	52.1
road	**21.7**	**18.4**	**23.5**	**36.4**
high	37.1	50.2	24.9	49.3
low	62.9	49.8	75.1	50.7
waterhole	**10.1**	**17.6**	**22.0**	**50.3**
high	43.8	41.5	53.1	28.4
low	56.3	58.5	46.9	71.6

4.2. Elephant tree damage density in the reserve

The overall mean density of trees

The overall mean density of trees per hectare in the reserve was 175 (± 116 SD). Tree mean density of trees (n/ha) in the proximity of roads was 211 (± 122 SD) which was higher in comparison to waterholes and buildings. The mean tree density around waterholes was 150 trees per ha (± 122 SD) and was higher to the mean tree density around buildings which was 118 trees per ha (± 70 SD).

There was a statistical significance between the mean density of trees in proximity or roads and buildings (F= 7.8, df= 2, p= 0.0006). There was no statistical significance between the intensities nor their interactions (for both tests p>0.05).

The mean density of trees was the same for both intensities of buildings, the low intensity of intensity of waterholes had a higher mean density of trees, and high density roads had higher mean density of trees compared to low intensity of roads (Table 4).

Table 4. The density of trees among anthropogenic features and its intensity.

Anthropogenic features	Intensity	Mean	Std.Dev.
Building	Low	118	76
	High	118	68
Waterhole	Low	163	136
	High	125	94
Road	Low	203	142
	High	219	103

The overall mean density of tree damages

The mean density of tree damages in the proximity of buildings was 243 per ha± 135 SD which was significantly lower than the mean density of tree damages in proximity of roads (390 per ha ± 210 SD). The mean density of tree damages around waterholes was 315 per ha ± 271 SD and was similar to both other anthropogenic features (F=5.3, df=2, p=0.006). There were no differences in tree damages in relation to the intensity (low/high) of anthropogenic features (Figure 13).

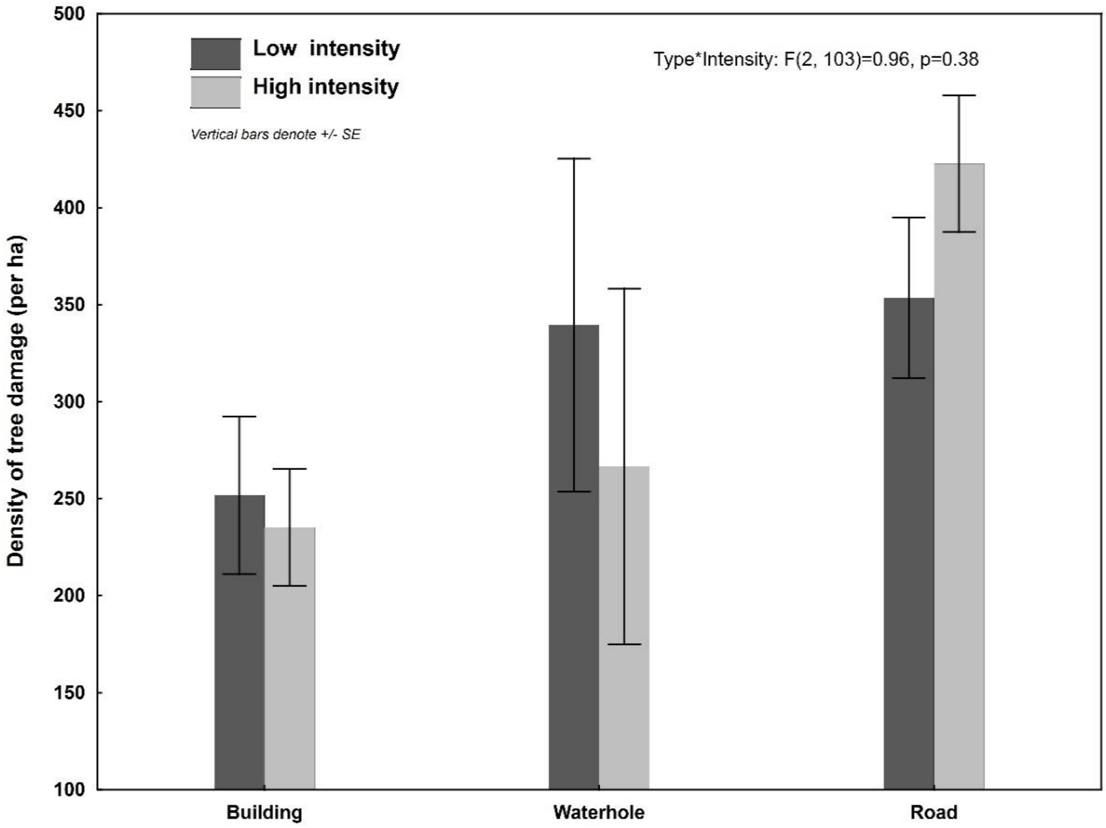

Figure 13. Density of tree damage per ha comparing three studied anthropogenic features and its intensity.

The pattern of relative proportions of tree damage severity was very similar for all three types of anthropogenic features (interaction 'type of damage*type of anthropogenic features': F=1.3, df=12, p=0.25), specifically, there were only a few trees with no damage, damage 1 and 2 were represented the most, and damage 3 to 6 were similar with slightly higher representantion of damage 6 at waterholes (Figure 14).

There were no significant differences between the intensities of anthropogenic features and types of damages with damage 0, the proportion of damage 1 was higher at high intensity at buildings and waterholes, the proportion of damage 2 was similar at all intensities, the proportion of damage 3 was significantly higher in low intensity of buildings, compared to intensities of waterholes and roads, the proportion of damage 4 was also higher at low intensity of buildings and waterholes, while higher at a high intensity of roads, the proportion of damage 5 was very similar to intensities of waterholes and roads and slightly higher at low intensity of buildings, and finally, the proportion of damage 6 did not show a significant difference between intensities of buildings and roads, however there was a significant difference at waterhole, where the higher proportion was at low intennsity of anthropogenic feature (Figure 14).

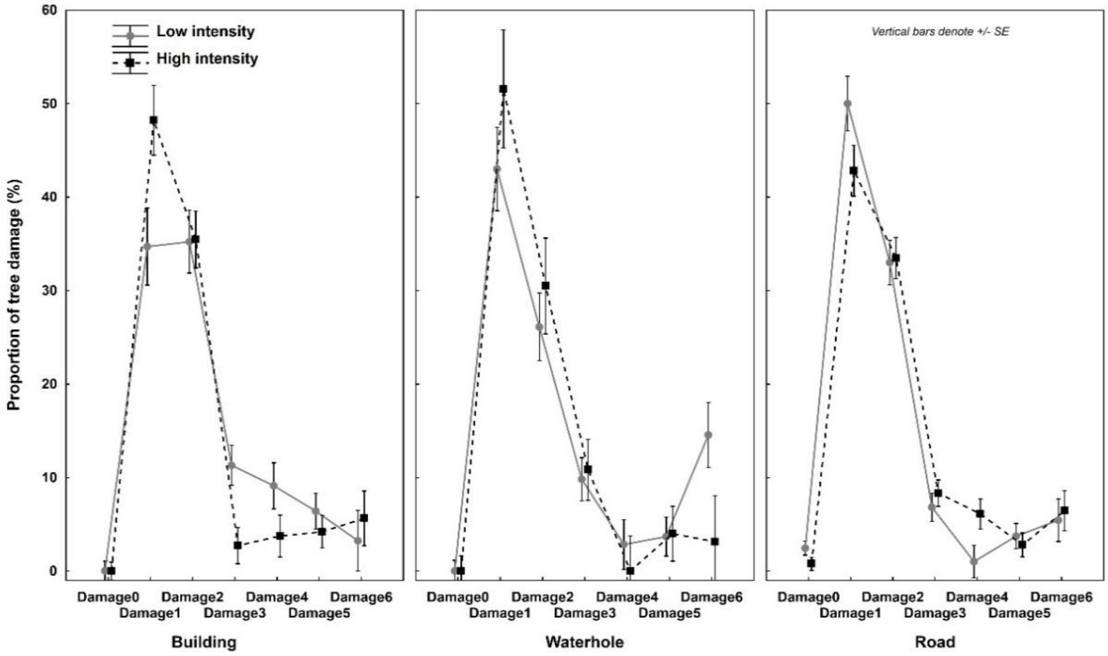

Figure 14. Relative proportion of tree damage according to the type of damage at three anthropogenic features and its intensity.

Proportions of tree damage according to the age

An overall frequency of old tree damages was 82 %, middle age tree damage of 12 % and the least frequency of tree damage were fresh tree damages (6 %). The least frequency of fresh tree damage was recorded among all anthropogenic features, which was followed by middle old tree damage, and the most tree damages recorded were old (Table 5).

Table 5. Frequency of tree damages among anthropogenic features.

Anthropogenic feature	Age	N damages	%
Building	Fresh	24	8.1
	Middle old	46	15.4
	Old	228	76.5
Waterhole	Fresh	18	7.9
	Middle old	40	17.6
	Old	169	74.5
Road	Fresh	50	5.3
	Middle old	90	9.6
	Old	797	85.1

Proportion of fresh tree damage

The highest proportion of fresh damage was at roads (54 %), the fresh tree damage around buildings counted 26 % and around waterholes 20 %.

The highest number of all fresh records (n= 92) was with the type of damage 6 followed by type of damage 1 with half of the records. The overall records of the rest of the types of damages were similar to each other (Figure 15).

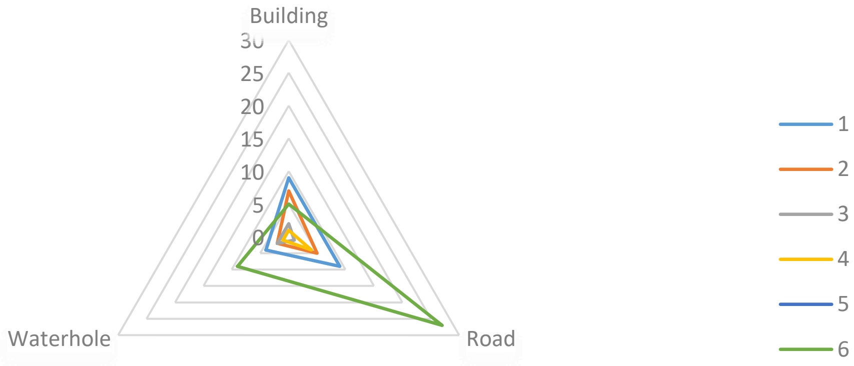

Figure 15. Total number of records of fresh tree damage according to the type of damage between anthropogenic features, (1-6 stands for type of tree damage).

The proportion of fresh damage 1 and 2 was higher at a high intensity of all anthropogenic features apart of buildings, where the type of damage 2 was higher at low intensity building, type of damage 3 and 4 had also higher proportion of a high intensity of anthropogenic features, unlike waterhole and damage 4, where the higher proportion was at low intensity, type of fresh damage 5 did not occur at buildings and waterholes and had higher representation at low intensity of roads, and type of damage 6 had a higher proportion of damage at low intensity of all anthropogenic features, furthermore, there was a considerable difference at buildings and waterholes in case of the intensity (Table 6) however, not statistically tested.

Table 6. Proportions of fresh tree damage (in %) according to the type of damage between intensity of anthropogenic features.

Anthropogenic feature	**Type of damage and proportion in %**						**N of fresh damage**
	1	**2**	**3**	**4**	**5**	**6**	
Building	**37.5**	**29.2**	**8.3**	**4.2**	**0**	**20.8**	**24**
High	40.9	27.3	9.1	4.5	0	18.2	22
Low	0	50.0	0	0	0	50.0	2
Road	**18.0**	**10.0**	**2.0**	**8.0**	**8.0**	**54.0**	**50**
High	20.0	13.3	3.3	10.0	3.3	50.0	30
Low	15.0	5.00	0	5.0	15.0	60.0	20
Waterhole	**22.2**	**11.1**	**11.1**	**5.6**	**0**	**50.0**	**18**
High	37.5	25.0	12.5	0	0	25.0	8
Low	10.0	0	10.0	10.0	0	70.0	10
Total N	**22**	**14**	**5**	**6**	**4**	**42**	**92**

4.3. Elephant spatial distribution in the reserve

Female elephant activities, in the core home range of their 50 % time scale were concentrated mainly in the areas with lower road density and the areas outside of the higher intensity and density of buildings (Figure 16). This area covers 23.17 km^2 of the total area (Table 7). 90 % of female elephants home range shows the same avoidance of the buildings in the area with high intensity buildings. This area covers approx. 68 % from the whole study area (Table 7).

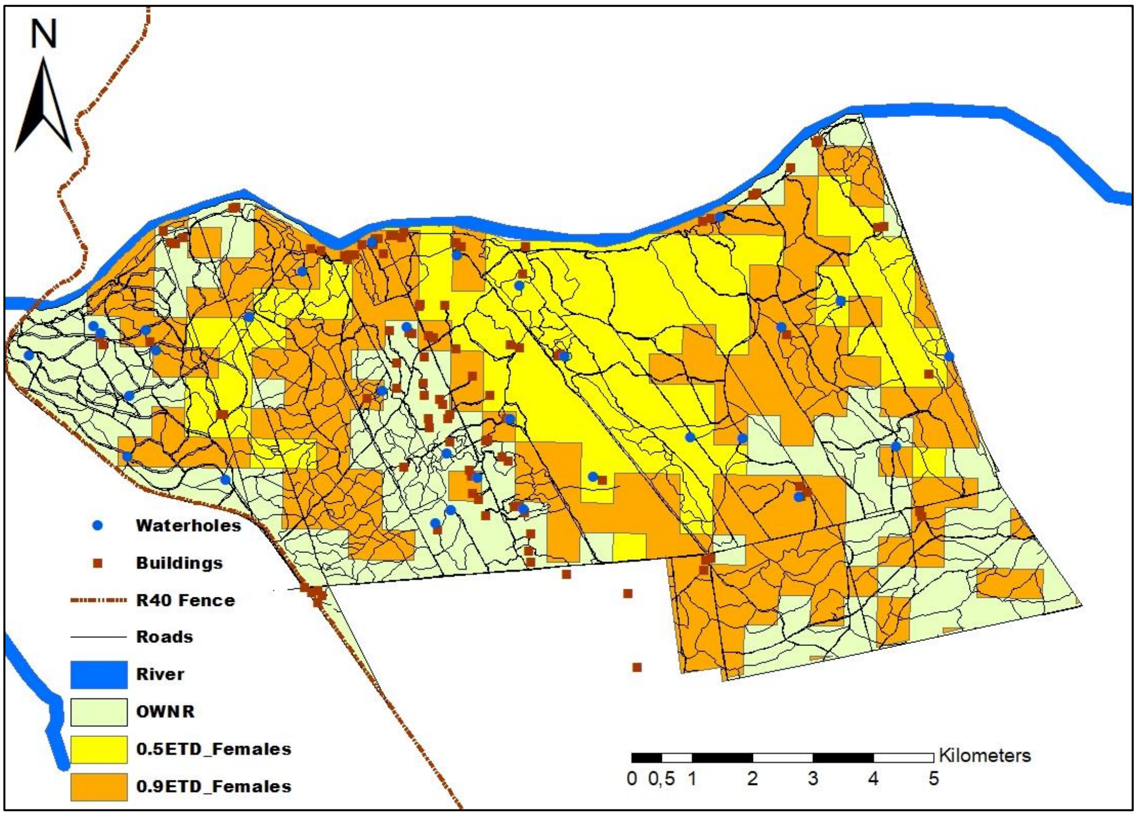

Figure 16. Elliptical Time Density Home Range of female elephants. The yellow polygonal zones represent the area where elephants spent 50 % of their time (core home range) and orange represent (together with yellow area) overal 90 % of home range during the 2 years (January 2018 - January 2020).

Table 7. Areas of different types of home ranges of both sexes of elephants over the area of 86 km^2 of the Olifants West Nature reserve.

Elliptical time density home range of elephants	Area		Representation from the total area (in %)
	km^2	ha	
Females 0.5	23.17	2 316.94	26.94
Females 0.9	58.44	5 843.79	67.95
Males 0.5	24.56	2 455.51	28.55
Males 0.9	79.42	7 942.16	92.35
Overlap of all elephants within OWNR	4.20	419.69	4.88

Male elephant activities, in the core home range of their 50 % time scale were concentrated mainly at the west section of the OWNR covering 24.56 km^2 of the total area, similar as in females (Table 7). The area of the 90 % of male elephant's home range covers almost the whole reserve with only a few spots on the reserve, where was found no activity (Figure 17).

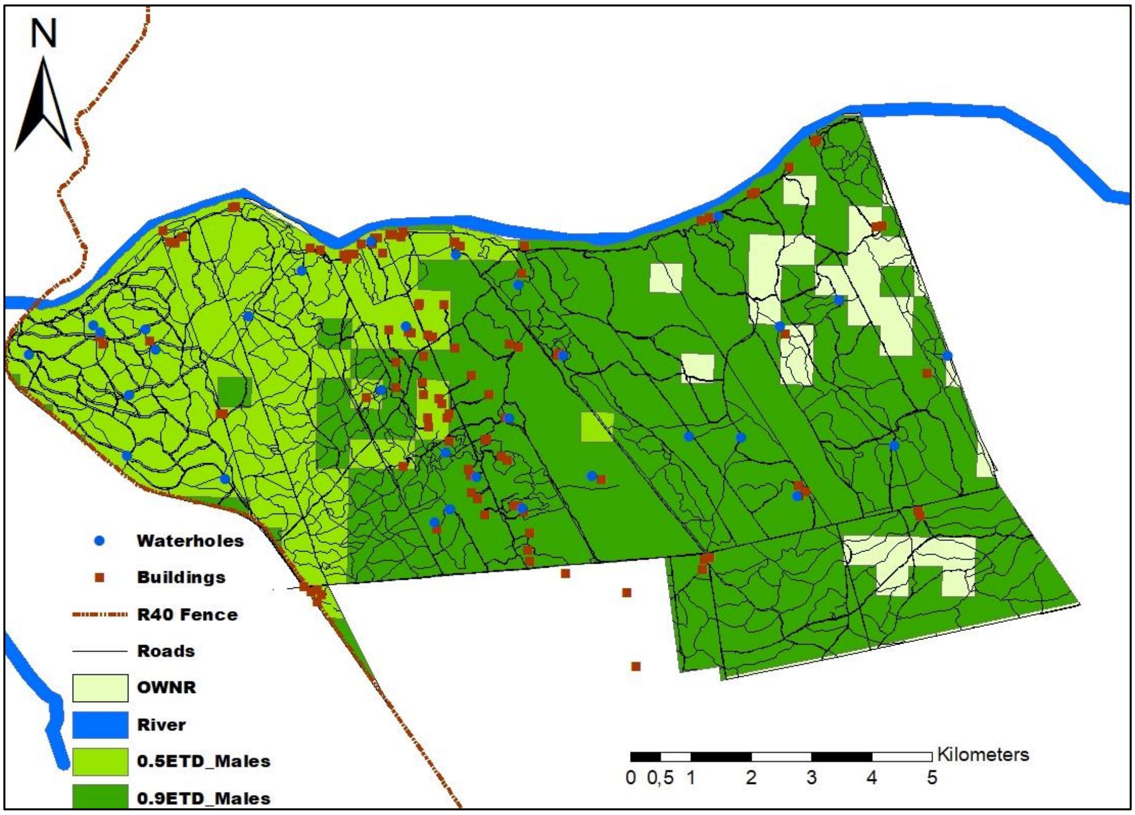

Figure 17. Elliptical Time Density Home Range of male elephants. The distinctive green polygonal zones are representing the area where elephants spent 50 % of their time (core home range) and dark green represent overal 90 % of home range during the 2 years (January 2018 - January 2020).

The common utilization displacement area of all elephants and their home ranges covers approx. 5 % of the whole area (Figure 18).

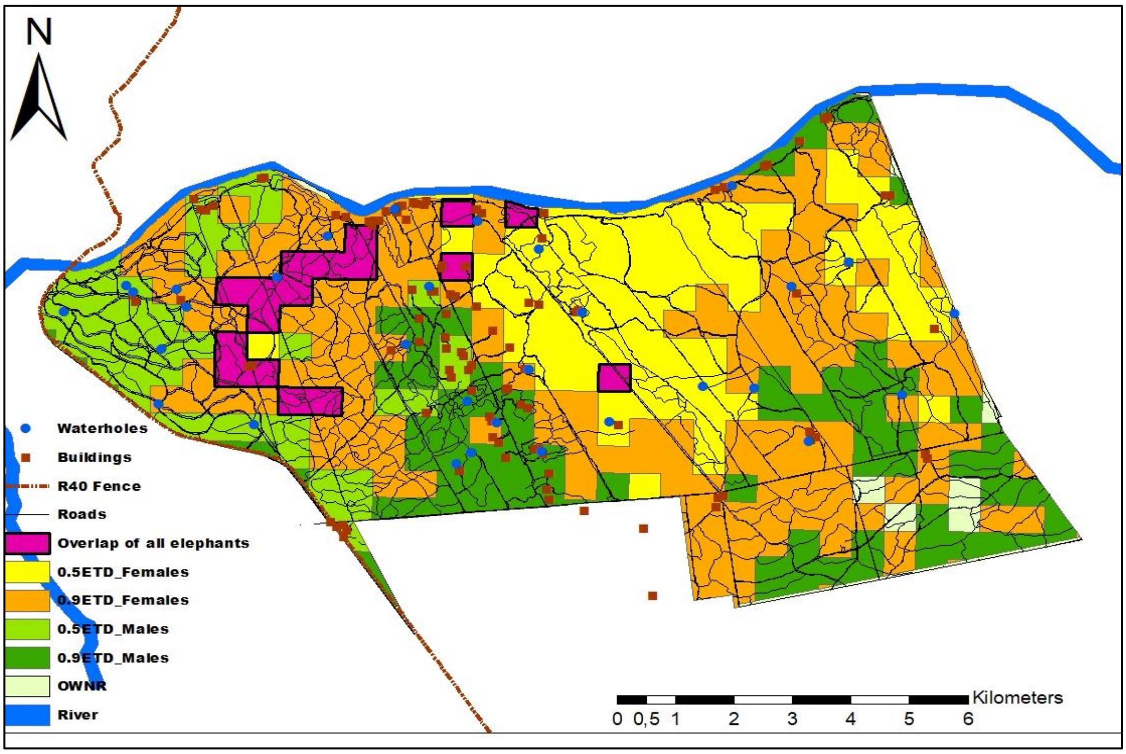

Figure 18. Overlapping area (representing pink colour), of all elephants and their home ranges within Olifants West Nature reserve for two years.

The created zone (area that is 500 m from all the buildings) has 28.15 km^2 of the total area.

The area of 27 % was overlapping with the 50 % female home range and buffer zone, where 65 % of the area did overlap with 90 % of home range of females. This intersection covers approx. 21 % from the total area (Table 8). See Figure 19 for a visual representation of the overlap for all females.

Table 8. Overlapping area of elephant home ranges within buffer zone of buildings (500 m) and the area from the total study area.

Overlap of elephant home range with the buffer zone	Area		Representation from the total area (in %)	Representation from the buffer zone (in %)
	km^2	ha		
Females 0.5	7.52	751.74	8.74	26.85
Females 0.9	18.14	1 813.78	21.09	64.78
Males 0.5	8.70	869.51	10.11	31.05
Males 0.9	26.38	2 637.89	30.67	94.21
All elephants	1.48	147.61	1.72	5.27
Buffer zone	28.15	2 815	32.73	X

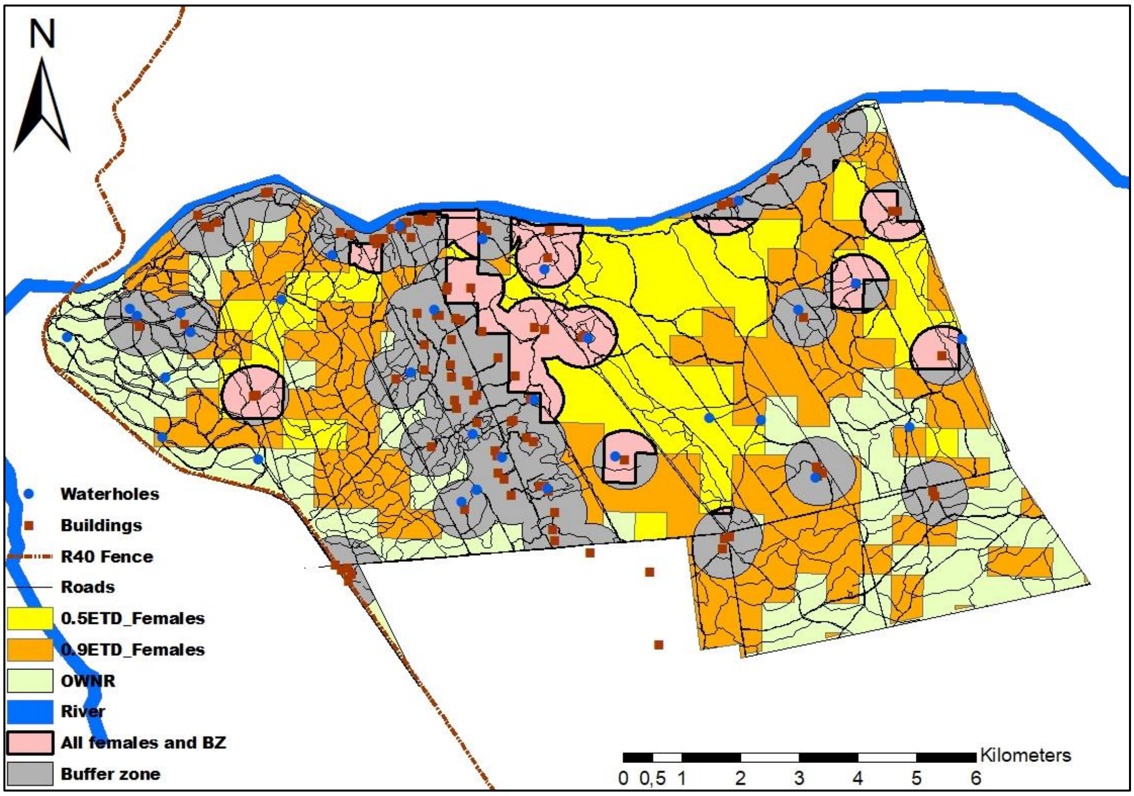

Figure 19. Overlap of all females and the area within the proximity of 500 m from the buildings (represented by grey colour).

The area of 31 % was overlapping with the 50 % male home range and buffer zone, where almost the whole area (94 %) of the area did overlap with 90 % of home range of males. This intersection covers approx. 31 % from the total area (Table 8). See Figure 20 for visual representation of the overlap for all males.

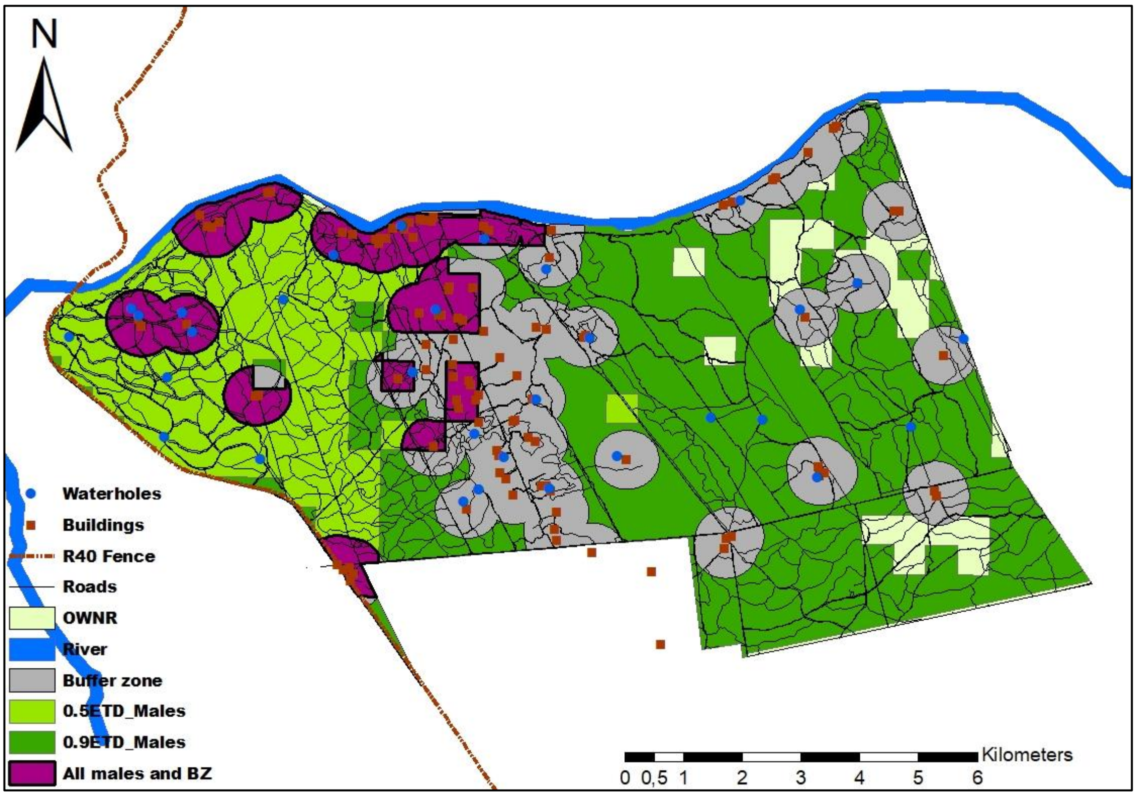

Figure 20. Overlap of all males and the area within the proximity of 500 m from the buildings.

The overlap of all elephants and the buffer zone covers 1.5 km^2 from the total area, which is 5.3 %, and 1.8 % from the whole buffer zone (Table 8; Figure 21).

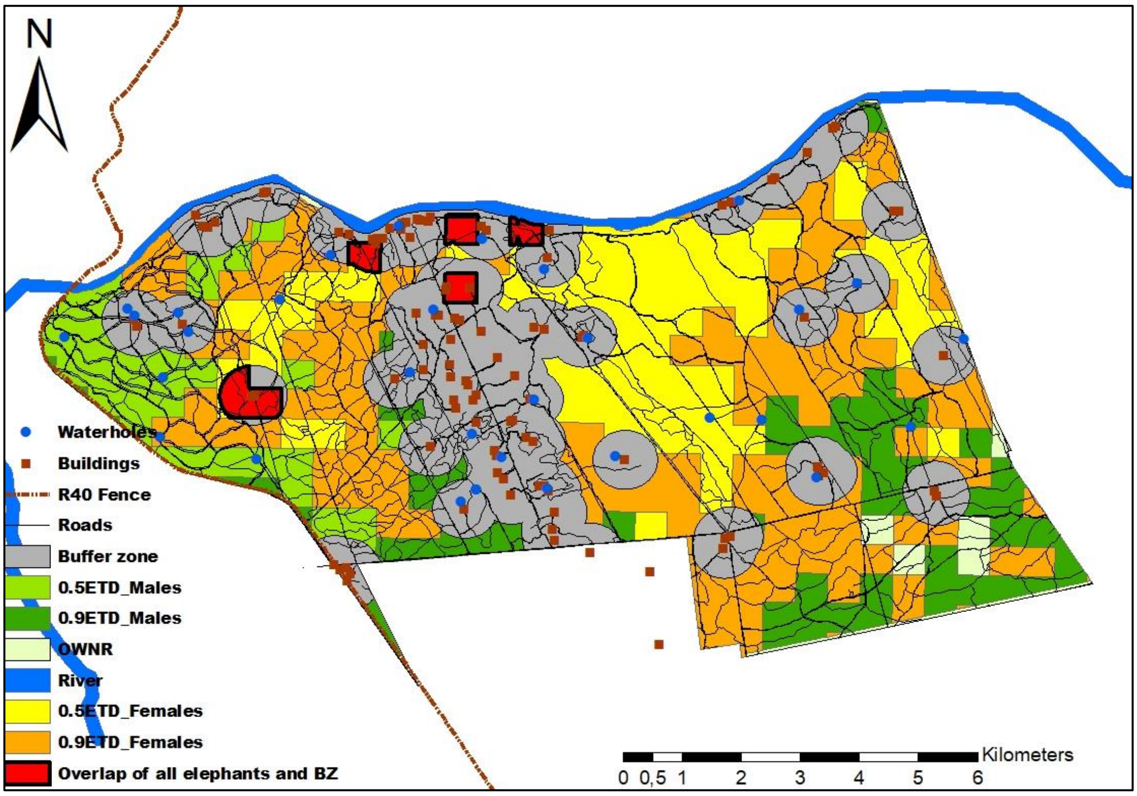

Figure 21. Overlapping area of all elephant home ranges and the area within the proximity of 500 m from the buildings.

5. Discussion

In order to manage and conserve an ecosystem, it is important to understand the impact that various forms of anthropogenic features and activities have on the wildlife of the landscape. This study provided information about response and displacement alterations of elephants towards anthropogenic features and its human-driven events on the landscape. Ground survey and Elliptical Time Density method of the home range of elephants were used to asses these findings. The results indicated the behaviour of these giant pachyderms towards these anthropogenic disturbances.

5.1. Relative abundance and spatial displacement of elephants

5.1.1. Elephant dung density

Among all studied anthropogenic features; roads, buildings, and waterholes, elephants did show most presence around waterholes. This was found due to the higher density of the dung around waterholes compared to lower density around roads and buildings. Additionally, this study showed that elephants visited waterholes that were far away from the objects with the high density, disturbance, and with less tourists more frequently. This result corresponds with the statement that elephants are concentrated around water resources during the dry season, and show that water is an indispensable and strong driver for elephants as they make periodical visits to thermoregulate, hydrate, and cool themselves down (Thaker et al. 2019; Dunkin et al. 2013; Nasseri et al. 2010; Carrigy (n.d). The results showing more frequent visits around low intensity waterholes are consistent with the study of Evans et al. (2020) which states that elephants rather increase their home range to satisfy their ecological needs in the areas with less human disturbance. In addition, Wittemyer et al. (2016) found that despite on elephants' needs, they will stay further away from water sources where there is a high human presence. This corresponds with my results and hypotheses which predicted the elephants' avoidance in high intensity areas. In contradiction Forrer's (2017) showed that the preference and displacement of elephants on the landscape is around water resources, no matter the season. However, elephants disperse widely across the landscape in rainy seasons when the availability of surface water increases (Forrer 2017). To see this effect on my study, the longer period during the season would be beneficial.

The studies of Wittemyer et al. (2016) and Songhurst et al. (2016) showed that elephant avoidance is correlated with the areas with a high density of human settlements and human activities. It was hypothesized that this study would have similar results relating to lower dung density in areas with higher intensity buildings. The results did not show a statistically significant difference between the intensities of buildings. However, elephants were slightly more present or spent more time in the proximity of buildings with high human activity and in a high density of these similar types of buildings.

A possible explanation for this result could be the location of one studied high intensity building representing dark green (Figure 3), which is relatively outside the other possible disturbances (e.g. other buildings with increased human and vehicular activity or far away from the busy roads). Moreover, this building had no electric fence, and this could be the reason why elephants visited this area more often or spent there more time. This assumption is consistent to the findings recognized by Songhurst et al. (2016); Jachowski et al. (2013); Boettiger et al. (2011), who pointed out electrical fences as a disturbance for elephants.

Another reason could be explained by the elephants' behaviour, as they are also active at night (Thaker et al. 2019) and they rather move when the disturbance and human activity are not considerably high (Wittemyer et al. 2016). However, to confirm this pattern, diurnal data would be needed to compare elephant activity during the day and during the night.

Furthermore, almost every touristic lodge (i.e. high intensity building) has a swimming pool or own artificial waterhole and usually more attractive vegetation due to irrigation. Thus, these features might be attractive for elephants to come, especially during the dry season since elephants sensing the greener vegetation. Despite all these facts, the difference in the displacement of elephants between the types of buildings associated with high human activity and low human activity was not statistically significant. Such a result might have been influenced by the one low intensity building representing light green (Figure 3), which is close to the highly dense human area.

Lastly, the indication of roads from the analyses showed that they were the most significant factor of the study when analysing the dung density of elephants for disturbance of elephants among all anthropogenic features. Among three studied anthropogenic features, roads confirmed the difference between the intensities and thus potential disturbance. The evaluation of the records revealed higher overall density of dung in proximity to low intensity roads. The higher occurrence and relative abundance of elephants was further confirmed by its statistically significant difference contrasting high intensity roads. These low intensity roads were predicted to be one of the least sources of anthropogenic feature disturbance.

The hypothesis said that elephants' relative abundance and time spent at the unit area was going to be higher around low anthropogenic features. The hypothesis was found consistent with these results. Szott et al. (2019) finds roads as an anthropogenic influence and argues that elephants are likely to move away from the areas with the increased vehicular activity. Moreover, Boettiger et al. (2011); Songhurst et al. (2016); Jachowski et al. (2013); classify roads as a barrier for the animals' movement. This proposes the idea, that elephants are likely to avoid vehicles as well as human presence. It needs to be considered, that all studied low intensity roads were close to some waterhole and one of them was closer to the river (see Figure 3), compared to others.

Overall, the roads, waterholes, and buildings impact the movement of elephants differently as they all serve for different purposes and therefore have a different impact on elephant displacement. Roads were shown as the significant driver for the elephant avoidance by the density of the dung comparing both intensities.

Age of the dung

Among all three types of age of dung (fresh, middle old, old), fresh dung was found as a significantly least present. This finding is considered as relevant because dung can dry out faster during the dry season and later might be difficult to recognize the correct age. This leads to the fact that the other two categories of age of dung were higher.

Middle age dung findings resulted from the elephant visits around anthropogenic features from previous days. In the contrary, the old dung with its highest presence means that most of the elephants visited all studied anthropogenic features in the last weeks or months. The result suggests that elephants were migrating to other areas with more attractive vegetation. Therefore, their spatio-temporal movement can vary. Possible lower presence of elephants could go along with Avgar et al. s' (2012) statement, who confirm that elephants move to the more favourable areas for the rich resource. Furthermore, assessing the age of the dung might have been also affected by the ambient temperature, especially in the case of middle age dung. Since the survey was done in the dry season, the temperatures range from 18-45°C (Clark 2013), which could cause have caused the quick evaporation of moisture from the dung. If the dung was also mashed or broken, this combination might have led to the incorrect classification. The temporal pattern for the study is therefore important.

Social group of elephants

The majority of findings (44 %) did belong to the social group of elephants that could not be recognized, since the pile of dung was mashed or there were no other indicators that could potentially help with estimation of the social group (e.g. different sizes of dung around). The elephant social structure consisted of breeding herds as the next highest representation (24 %), bachelor groups (18 %), and adult individuals (14 %).

Individual elephants' presence was mostly seen, according to their proportion of dung around low intensity of anthropogenic features. This could be explained by the prudence of individuals compared to the higher number of individuals in a group. Bachelor groups did not differ either among the anthropogenic features and their intensities, although not statistically tested. Bachelor groups were more often or spent a longer time at a high intensity of buildings, which could be explained by their curiosity. However, they were more present at low intensity waterholes, which on the other side brings the assumption of the lower chance from potential disturbance. What should be mentioned is, that a considerably higher proportion of breeding herd dungs was present at low intensity roads, which is also consistent with the hypothesis and previous findings with total dung density. This suggests, that breeding herds were more likely to avoid high intensity roads connected to high vehicular activity and disturbance.

Trying to estimate the occurrence of different social types of elephants around the anthropogenic features across the landscape served as additional information and indicative overview. Furthermore, the amount of data when divided into these groups, was insufficient for statistical testing. Nevertheless, a study focusing on the social group of elephants could bring new further information as a future research.

5.1.2. Tree damage density

Tree damage was used as another tool to see if there are any differences in the spatial displacement of elephants toward anthropogenic features. Damage of trees suggested the amount of time spent in particular areas and possible effect on the elephant movement. The relatively short period (approx. 2 months) of investigating levels of tree damages from 761 studied trees on a given transect routs, provided a general estimate of elephant avoidance. The results showed a higher density of tree damages than the density of trees per hectare, which is explained by the higher number of tree damages per 1 tree. This means that one tree could have had more tree damages.

The relative impact of tree damage showed that the density of all types of tree damages observed was significantly lower on the sites studied for buildings, followed by the mean density of damages around waterholes, and the highest mean density at road areas. These findings showed the lowest density of trees around buildings, and therefore the lower number of tree damages occurred. The human disturbance and avoidance for elephants could be confirmed by the comparing of the intensities, however, they did not show any statistically significant difference. The slightly higher density of tree damages was found at low intensity buildings. It is possible to explain such a situation by the similar findings of Songhurst et al. (2016), that elephants try to avoid possible conflicts with humans, human settlements interactions and disturbances from humans. The possible avoidance might be due to electric fences that almost every building had, no matter of human presence and activity (i.e. intensity). Boettiger et al.s' (2011) study showed that the response of elephants towards fences was evasive in the case of fenced protected areas, where elephants were clustering close to the protected areas but rather in an unfenced open landscape. In other words, they tried to avoid the electrical fencing areas. To prove these findings from my study, higher sample size and temporal data would be beneficial.

To see some avoidance from elephants, the mean density of tree damages would have to be higher at high intensity roads and waterholes. However, the density of tree damages did not significantly different between the low and high intensity of any of anthropogenic features, which indicates a similar level of impact held by elephants for a long period of time. Nevertheless, it is important to mention that the mean damage density was higher at low intensity sites for buildings and waterholes. These findings correspond with the hypothesis of the elephants' avoidance of high intensity anthropogenic features, but still would need to be proved.

The percentage proportion of damage level severity corresponds to the density of trees among anthropogenic features. The highest proportion of two first damage levels (primary and small and secondary branches broken) and their proportional similarity may be due to the simplicity of browsing the woody trees and shrubs, especially during the wet season when the branches have nutritious leaves. There is the possibility that other browsing herbivores such as kudu, bushbuck, giraffe (Masupa & Rempho 2011) had been feeding on the same trees. However, these species browse mainly on mature green leaves (Masupa & Rempho 2011). Despite no statistical significant difference of these damages between the intensities of anthropogenic features, it could be suggested that these low time dominated damages were the most common, which confirms the presence of elephants in proximity to anthropogenic features but only for a short period of time.

The proportion of more time-consuming levels of damages (main or second trunk debarked or broken) were also represented similarly among three studied anthropogenic features. It is important to note, that elephants spent more time browsing trees around low intensity buildings due to the significantly higher proportion of trunk breaks and debarking. This result supporting the idea of Songhurst et al. (2016); Jachowski et al. (2013); Boettiger et al. and current study hypotheses, elephants avoiding the fenced inhabited areas with high human density and activities.

The last two types of tree damages (i.e. pushed over the trunk and kicked out or uprooted tree) are generally the most time-consuming events. The overall proportions of these exhausting damage levels were also similar among buildings, waterholes, and roads, same as the similarity among the intensities. However, results showed a significant difference between the low and high intensity of waterholes at the level of damage. This result corresponds to the previous dungs density findings that showed higher elephant occurrence in these low-density waterholes. These two factors support the hypothesis that elephants avoided high intensity area, in this case waterholes and spend more time at relatively not disturbed areas (e.g. without disturbance from tourists and its connected vehicular activity). The uprooting of the tree takes lots of time and elephants can spend even hours by digging and pushing the trees. Low intensity waterholes were identified as waterholes that are rarely visited by the tourists, the vehicular activity is low, and are relatively far away from the trafficked roads and highly dense areas with buildings and human activity, elephants were not much disturbed. Although if there was a possibility of tourists visiting these waterholes, the game drives in OWNR are mainly in these morning and evening hours when tourists can encounter animals. Elephants might have adapted the time visits of the waterholes to the hours out of the game drives. As it was mentioned above, elephants could have shifted their activities to the night and cold hours and to avoid interference with people.

Regarding the age of the tree damages, it was chosen in this study to focus on fresh damages that could have been imposed during the current season. Most of the overall fresh tree damage records fall into the last level of damage category i.e. uprooting. Because of the dry season and higher depletion of vegetation resources, elephant strategy is to look for the moisture and nutritional browse (Masupa & Rempho 2011). Most of these records were recorded in proximity of roads. The explanation could be the moisture, that could be held down the roots, since most of the roads are in proximity of waterholes. Additionally, the amount of fresh damage data was very low, and unfortunately insufficient for statistical testing.

5.1.3. Elephant spatial distribution in the reserve

The method of satellite data enabled to define the specific home range of both sexes of elephants during a certain period, which gave a better insight into the spatio-temporal displacement across the reserve.

Comparing of female and male elephants, females were more likely to avoid the areas with human disturbance (i.e. high intensity building areas). Male elephants did not show considerable avoidance during the last two years. All elephants of all home ranges shared the same spots only partly.

Female elephants spent most of their time in the core area outside the disturbance area. This means they rather tried to avoid the areas with a high density of roads and further away from the human settlements. The results of this study indicated that also female elephants using 90 % of their home range were rather avoiding these disturbance areas. Consistent with the literature (Danquah 2016; Songhurst et al. 2016; Wittemyer et al. 2016), these studies claim that human settlements influence the spatial behaviour of elephants. Another interesting finding was that female elephants were concentrating more towards the centre of the study area and did not show much activity by the borders of the study area. A possible explanation for this may be the electric fencing and highway on the western side of the reserve, and part of the internal fence that is shown in Figure 3. These factors might influence the elephant's behaviour as it was suggested by Songhurst et al. (2016); Jachowski et al. (2013); Boettiger et al. (2011).

The result of male elephants showed that their activity of 50 % of their home range was mainly on the west side of the reserve and in their 90 % home range and time spent per the unit area did not show any specific avoidance of some areas. However, the home range displacement was by approx. 20 % times higher than in females. In contrary to female elephants, their displacement was also by the fenced areas. A possible explanation for this might also be that the data extracted were from more male elephants, than females. One unanticipated finding was that there was not a direct avoidance of the areas with a high density of human settlements or other anthropogenic disturbance. These results corroborate the findings, that male elephants have larger home ranges and are less prone to stressful events and disturbances than females (Hunninck et al. 2017) and at the same time spend more time of foraging (Shannon et al. 2008).

Comparing all elephants and their home ranges showed only a small area of the whole reserve (5 %), where they overlapped (Figure 18). Elephants were concentrating rather on the western side of the reserve in about 2 km proximity from waterholes, which might be the explanation for their gathering. The other explanation could be some more attractive forage for the elephants it this polygonal area than other places.

A comparison of the findings with those of the study of MacFadyen et al. (2019) confirms that males and females can have different home ranges, thus their spatial displacement is different.

The interaction within the disturbance zone of all buildings was similar in both sexes of their 50 % of home range. The overlap within the disturbance zone was higher in males which may again confirm the statement, that male elephants are less stressed towards disturbances (Hunninck et al. 2017; Shannon et al. 2008). All elephants overlapped in 1.8 % of the buffer zone. These overlaps (see Figure 21), are mostly in the proximity of the river and one of them in the building that has no electrical fence, is outside the high density of buildings and is in the proximity of other waterholes, which might be the explanation for the gathering of all elephants.

Although all collars were set 4hourly but for two that were set on hourly, the overall ETD would have been influenced to a minimal extend as the two home ranges in question are small, the ETD parameter is coarse (500m x500m), and home ranges were clipped to the OWNR property.

5.1.4. Limitations

The applied methods and the time available for the field study imply inherently some constraints and limitations which lead us to be careful in particular interpretations of the findings.

In the case of a ground survey, one of the most important limitations was a rather short period of the field work and logistic constraints which did not enable a higher number of sites and a larger sample size of transects over the reserve area. Larger sample size would make the data more representative and accurate for interpretation and conclusions about the elephant population spatial behaviour. Then, there may be biased results due to the observer's decision making about the records (e.g. recognizing of a number of dung or recognizing the tree damage from elephants or other species), but this bias was reduced by training of the observer by the experienced person working in the reserve.

The results showed the highest proportion of recorded dung and tree damage was old (Figure 12 and Table 5), which means that elephant dung tree damage could be from the previous season or months or were rather concentrated in areas with higher vegetation availability. Because the data were collected during the dry season, most of the elephants could have left this part of the reserve for other feed, which also confirms in their study Wittemyer et al. (2007) stating that some of the elephants were even leaving the protected areas during the dry season.

What needs to be also considered is that this study focused only on 1 tree species, which raises the fact, that elephants were also browsing on other woody species (e.g. Marula trees, *Acacia* species, etc.) that are typical for the study areas (Naidoo et al. 2012) and elephants therefore, feed on them too. By excluding the other tree species for browsing, the accuracy of the results might decrease.

The data collection on more study sites, which would give more accurate statistical results, was limited by the time and in terms of permissions from the owners of the land. The initial plan of the line transect survey method was to have categories for low/high intensity waterholes, low/high intensity roads, low/high intensity buildings with electric fence, and low/high buildings without an electric fence and have at least three anthropogenic features of each category. Category of buildings with electrical fence and without fence was planned to use, to see further any difference in these two categories toward electric fences. However, during the data collection, there was not possible to finish the number of sites for buildings without an electric fence due to logistical constraints, therefore those two categories for buildings were joined. For that reason, the building category had 4 sites for each intensity compared to the other anthropogenic features.

5.1.5. Suggestions for the future research

Despite these promising results, there are still questions that could be answered. Further work should cover a longer period for ground survey, including touristic peak seasons and climate seasons. Using the camera traps data at the locations of study sites would help to see temporal distribution as well as time spent at a unit area. Future studies could also include other tree species to record tree damages.

6. Conclusions

This study focused on the elephant movement and potential avoidance pattern towards anthropogenic features. The study provides baseline information on how elephants in Olifants West Nature Reserve in South Africa utilize areas with different intensity around buildings, roads, and waterholes and if there is avoidance to some specific area in the reserve. Transect survey based on the dung and tree damage density served as a useful tool in determining the relative abundance of elephants around anthropogenic features. Satellite data proved to be a useful tool to determine elephant home range and avoidance to some areas. Generally, the avoidance pattern did not significantly differ among the intensity of anthropogenic features, apart from roads, where the density of dung was significantly higher at low intensity roads. Furthermore, the more time-consuming activities of elephants when utilizing the trees were generally higher at the features with low intensity, which reflected the potential disturbance from the anthropogenic sources. The study also showed that in the case of home ranges and avoidance, male and female elephants were found to use their home ranges differently, with females being more risk-averse and avoiding areas with high building density. In accordance with the literature review and my results, the prediction that relative abundance of elephants was going to be higher in the areas with low intensity of anthropogenic features and their relative abundance was going to be lower in areas with high intensity of disturbance related to human activity, and elephants were predicted to avoid the areas with increased human disturbance was confirmed partly. However, despite the low statistical significances between intensities, whole study, with the all methods used showed that anthropogenic features with high intensity can be classified as a disturbance in OWNR.

Further understanding of the avoidance pattern of all elephants in this area requires a more in-depth approach that focuses on the diurnal and seasonal movement of elephants around anthropogenic features.

Results demonstrated that the anthropogenic features have some influence on the distribution of elephants. As was confirmed in this study, the spatial decision and response were highly driven by the dependence on water, which could also regulate their spatial displacement by closing or opening some chosen waterholes. In the case of the dung density, roads showed to be a disturbance for elephants, which suggests regulating the traffic or closing of some roads, since there is a high density of the roads across the reserve.

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Appendices

List of the Appendices:

Appendix 1.: The format data sheet for density of dung and tree damage count

Appendix 1:

Line transect datasheet

Method: for any pile of dung and tree damage seen on the 100m transect and within 2m from the each side of transect line, record the data below.

Sheet number:

Site:

Date (dd/mm/yyyy): Line transect number:

Location:

Start point: Finish point:

Sign (dung, tree)	Distance from the start (m)	Tree damage		Dung pile			Other notes
		Type of damage[1]	Age of the damage[2]	Estimated size of a dung pile[3]	Estimated age of a dung[4]	Elephant social group (if known)[5]	

[2] 1 = fresh, 2= middle old, 3= old

[3] 1= small, 2= medium, 3= large

[4] 1= less than 24h, 2= less than a week, 3= more than a week

[5] 1= individual adult, 2= bachelor group, 3= breeding herd, 4=unknown

table 1

Clasification group	Type of damage
0	No damage
1	Small and secondary branches broken
2	Primary branches broken
3	Sedondary trunk debarked or broken
4	Main trunk debarked or broken
5	Trunks pushed over
6	Uprooted or kicked out