Universidade de Évora - Escola de Ciências e Tecnologia

Mestrado em Biologia da Conservação

Dissertação

Preliminary assessment on the distribution and density of the carnivores and ungulates of the Iona National Park.

Solange Alexandra Batista Nunes

Orientador(es) | Luís Miguel Pires Ceríaco
João Eduardo Rabaça
Rosemary Groom

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A dissertação foi objeto de apreciação e discussão pública pelo seguinte júri nomeado pelo Diretor da Escola de Ciências e Tecnologia:

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Covid-19 advertencies:

The initial goal of this study was to evaluate large carnivore dynamics with special focus on cheetah, in Iona National Park and its surroundings, both in the wet and dry seasons. After the initial phase of fieldwork conducted at the beginning of the wet season, I was scheduled to return to Angola in May 2020 (beginning of the dry season) but the flight to Angola was canceled due to the Covid-19 pandemic and so I was unable to conclude the fieldwork as planned. For the same reason, all activities inside Iona National Park were cancelled, including for researchers, and it was not possible to change the batteries on the cameras in the midterm of the survey period.

With these adversities, the goal and target species of the study was altered to assess wildlife within the park more generally and limited to the data we were able to acquire during the 2019 fieldwork and the period of camera trap operation. Therefore, this dissertation presents preliminary data and we hope that in a near future there will be opportunities to return to Angola and survey new and more compact data.

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Abstract:

In Angola, the terrestrial mammals were harshly affected during the civil war and post-war periods suffering from pressures such as poaching, habitat loss and human-wildlife conflicts. Protected areas play nowadays an important role for their recovery and conservation but there is a lack of contemporary studies. We conducted a preliminary assessment on the distribution and relative abundance of the large and medium-sized mammals in Iona National Park, one of the largest protected areas in Angola, using camera traps, opportunistic observations, and local knowledge. A total of 19 mammal species were recorded being springbok, gemsbok, aardvark and aardwolf the more common. Our research concluded that despite the arid conditions and war effects there is still a reasonable diversity of species within the park and we raise attention to the potential threats facing these due to the increasing human and livestock pressure.

Key words: Angola; Conservation; Iona; Carnivores; Ungulates.

Resumo:

Em Angola, a comunidade de mamíferos terrestres foi fortemente afetada nos períodos de guerra civil e pós-guerra, sofrendo pressões de caça furtiva, perda de habitat e conflitos homem-animal. As áreas protegidas desempenham atualmente um papel fundamental para a sua recuperação e conservação, mas existe uma lacuna de estudos contemporâneos. Realizamos um estudo preliminar da distribuição e abundância relativa de mamíferos de grande e médio porte no Parque Nacional do Iona, uma das maiores áreas protegidas de Angola, utilizando armadilhagem fotográfica, observações oportunistas e o conhecimento local. Um total de 19 espécies foram registadas sendo que as mais comuns foram: cabra-de-leque, guelengue-do-deserto, porco-formigueiro e protelo. Com este estudo concluímos que apesar das condições áridas e dos efeitos da guerra, ainda existe uma diversidade razoável de espécies dentro do parque e alertamos para as potenciais ameaças que estas enfrentam devido à crescente pressão humana e de gado.

Palavras-chave: Angola; Conservação; Iona; Carnívoros; Ungulados.

1. Introduction

Mammal inventories provide different types of data that include the mammal diversity in a specific area, allowing comparison between sites, the distribution of individual species and the impact of human activities on mammal's communities (Tobler *et al.* 2008). Furthermore, data on distribution and abundance of species also allows to plan and evaluate more efficiently conservation strategies, increasing the knowledge on biodiversity in a region or country that, if it is limited, it can bring consequences for conservation (Tobler *et al.* 2008; Huntley *et al.* 2019).

This is the case of Angola, which although its diverse biomes and geography, it remains one of the least well-known African countries regarding its biodiversity, and this is mainly due to the war periods that have occurred during the history of Angola (Huntley 1974; Huntley *et al*. 2019). Angola is situated in the west coast of Africa being the continent's seventh largest country (approximate area of 1 246 700 km^2) and encompasses 15 ecoregions (WWF; Figure 1).

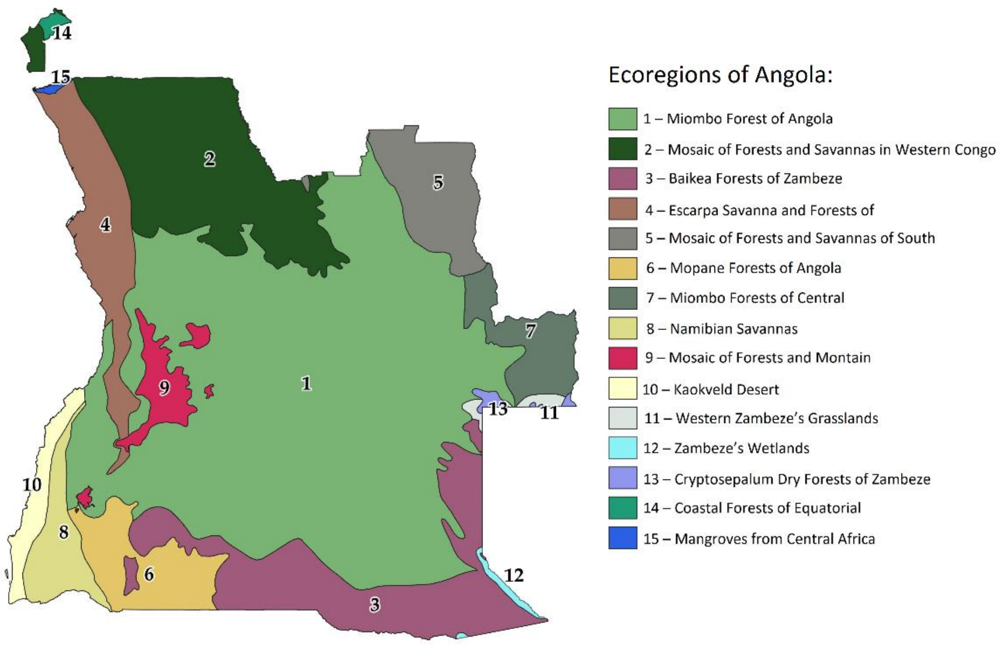

Figure 1. Angola ecoregions determined by World Wide Fund for Nature (Olson *et al.* 2001).

In 1975, Angola became independent but started a Civil War that lasted until 2002 and is considered the major cause of wildlife decline (Ball 2017; Huntley 2017). During this time, the distribution of rifles to militaries and citizens, the plantation of landmines and mainly the utilization of more powerful persecution equipment such as helicopters, led to a slaughter of mammal community in the country that has not been reversed after conflicts (Braga-Pereira *et al.* 2020a, 2020b; Huntley 2017). This decline in mammal species has led to changes in ecosystems and landscape that can still be seen today (Braga-Pereira *et al.* 2020a, 2020b). In the last 18 years of post-war recovery, Angola needed to focus their efforts on people, politics and economy rather than biodiversity conservation (Huntley *et al.* 2019). With it, the wildlife populations have been decimated (Huntley *et al.* 2019) with many large mammals left near extinction like the giant sable antelope (*Hippotragus niger variani*) and others extinguished like south-western black rhino (*Diceros bicornis*) (Vaz Pinto *et al.* 2016; Huntley 2017; Huntley *et al*. 2019). Similar realities were observed in other countries in the African continent, where armed conflicts occurred in 71% of protected areas, resulting in wildlife declines, especially large herbivores (Daskin & Pringle 2018). In some cases, the wildlife losses were recovered as it happened in the 1970s in Zambia and Zimbabwe (formerly Rhodesia), however this is not the case of Angola (Huntley 1974).

In Angola and in most African countries, the human population is quickly increasing (with a fertility rate in 2020 of 5,6) (Joppa *et al.* 2009; Governo de Angola 2016; Angola Population 2020) mostly in urban areas but also near protected areas that in some cases, may offer economic and occupational opportunities to people (Wittemyer *et al.* 2008; Joppa *et al.* 2009). This increment of settlements inside and in the vicinities of protected areas can lead to human-wildlife conflicts, habitat loss and exploitation of land and other resources which in some African countries, has been leading to a decrease in wildlife diversity (Wittemyer *et al*. 2008; Joppa *et al.* 2009).

The oldest protected area in the country is Iona National Park (hereafter INP) which is located in the Namibe province, southwest Angola (Woods 2020). INP was first established in 1937 as a Game Reserve, elevated to the status of Porto Alexandre National Park in 1957 and changed to Iona National Park in 1964 (Huntley 1974, Woods 2020). Currently, the park is managed through a partnership between the south African organization of African Parks and the Instituto Nacional da Biodiversidade e Áreas de Conservação (hereafter INBAC) from the Ministry of Culture, Tourism and Environment of the Republic of Angola (Woods 2020).

This park is located in the driest area of Angola (Huntley 1974; Huntley *et al.* 2019) and is bordered in the north by the Curoca river and in the south by Cunene river (15º 43' to 17º 16' S; 11º 55' to 13º 14' E) (Huntley 1971). This is the one of the largest conservation areas in Angola with 15,150 km^2 (Petracca *et al.* 2019; UNDP 2016). Beyond these rivers, the park is also crossed by six temporary rivers, which flow from South to North (Diniz 1973). The park lies on two of the country's ecoregions: the Namibian Savannas and the Kaokveld Desert (Olson *et al.* 2001).

Iona National Park has a great diversity of habitats that range from desert dunes to steppe formations of *Colophospermum mopane* (Diniz 1973). The vegetation present in the biogeographic region varies depending on soil substrate and climate conditions but in general, the flora in this region evolved simultaneously, sharing characteristics (like a deciduous habit), that are associated with the need for enduring long periods without water (Huntley 1974). According to Grandvaux-Barbosa (1970), three types of vegetation occur within Iona National Park: Sub-coastal steppes, with woody and herbaceous components (*Acacia, Commiphora, Colophospermum, Aristida, Schmidtida, Setaria*); Discontinuous coastal steppes (*Aristida, Cissus, Salvadora, Welwitschia*); Desert with moving dunes (*Odyssea, Sporobulus*).

Despite being poorly known, the park presents species of high importance for conservation such as gemsbok (*Oryx gazella*) which is an iconic species of the Kaokoveld desert (Farré *et al*. 2019) or the welwitschia (*Welwitschia mirabilis*) which is endemic to the central and northern Namib desert and a very important species for conservation due to its ancient origins with unusual and some unknown characteristics with specific adaptations and because it's very limited habitat (Bombi *et al.* 2020; Doniger *et al*. 2020; IUCN 2020). In INP it is also possible to observe vulnerable species such as the rare mountain zebra (*Equus zebra*), or the elusive cheetah (*Acinonyx jubatus*) (IUCN 2020); as well as the near threatened (IUCN 2020) brown hyena (*Hyeana brunnea*). Inside the park there are also some endemic species to Namibe province like Namib spiny tailed gecko (*Kolekanos plumicaudus*), Haacke's sand lizard (*Pedioplanis haackei*), Huntley's sand lizard (*Pedioplanis huntleyi*), Kaokoveld girdled lizard (*Cordylus namakuiyus*) and the Iona meerkat subspecies (*Suricata suricatta iona*) (Ceríaco *et al.* 2016; Crawford-Cabral 1971; Marques *et al*. 2018). Despite the occurrence of these species inside the INP, just a few published studies, were recently conducted inside the park to assess its biodiversity like the one conducted by Ceríaco *et al*. (2016) and socio-ecological and touristic studies conducted by Morais *et al.* (2018, 2019a, 2019b), making all the newly generated data essential for its future management.

Despite the crucial role that small mammals play on the bush-meat markets for local people (Bersacola *et al.* 2014), some of the most iconic and ecologically important mammal species in INP are large carnivores and ungulates because of their function on ecosystems but also for their relevance to the tourism sector (Beja *et al*. 2019; Ripple *et al*. 2014). However, they are also the most sensitive to war effects and hunting as they are important sources of food or causes of conflicts (Beja *et al.* 2019).

From all the species present in the park, carnivores are among the most iconic ones but also the most threatened and have been globally declining mainly due to human threats as habitat loss and degradation, persecution, hunting, depletion of prey, or just killing to remove them from human dominated landscapes (Ripple *et al.* 2014; Woodroffe & Ginsberg 1998). Globally, 64% of large carnivores' species are threatened with extinction and 80% have declining population trends (Wolf & Ripple 2018). In Africa, the decline of carnivores is also increasingly felt and emblematic species like the African lion, leopard and cheetah are now occupying 17%, 65% and 9% respectively of its historical range (Ogada *et al.* 2003; Ray *et al*. 2005; Ripple *et al*. 2014; Durant *et al*. 2016). Large carnivores, in general, tend to have slow life histories, low population densities and reproductive rates and roam widely in search of larger prey (Cardillo 2005). For that reason, they also have large energetic constraints and that is what makes them clash with humans and livestock (Cardillo 2005). With these characteristics, these animals are extremely vulnerable despite of playing an important role in maintaining the dynamics and balance in ecosystems working as indicators of its functioning (Ritchie *et al.* 2012, Ricklefs 1990). The presence of large carnivores is important to control herbivore and mesocarnivore populations and with it prevent infectious diseases of spreading into wildlife (Packer *et al.* 2003; Ripple 2014), to enhance the scavenger diversity and nutrient cycling and to increase the ecosystem connectivity by energetically coupling resources from different habitats (Wilmers *et al.* 2003; McCauley *et al.* 2012). Besides these effects, in many developing countries, large carnivores also became a source of income due for being the main attraction for tourists (Western & Henry 1979; Ripple 2014). In short, the presence of native carnivores in sustainable densities and abundances contributes to a proper functioning of the ecosystem and food-web that in turn offers greater resistance to the ecosystem against invasive species, because both native and exotic species are less likely to become invasive if the food-web of an ecosystem is still intact (Ripple *et al.* 2014, Ritchie *et al*. 2012, Wallach *et al.* 2010; McCauley *et al.* 2012).

The more abundant animals in INP, among large mammals, are ungulates that besides being consumers of plants and working as food for predators, they can also work as important regulators of ecosystems process at several scales of time and space (Hobbs 1996; Wilson & Agnew 1992). Besides that, large herbivores can act like ecosystem engineers by creating spatial heterogeneity, accelerating successional process and controlling the switching of ecosystems between alternative states (Wilson & Agnew 1992). They also play an important role in recycling the soil nutrients, accelerating it by excreting nutrients in an easily uptake form for microbes and plants which can change the quality and quantity of plant litter available for decomposition and elevate the annual net primary production in grassland ecosystems (Hobbs 1996; Ruess & McNaughton 1987; McNaughton 1976, 1979). The nitrogen present in dung and urine composition is particularly important for nitrogen recycling because it is a faster alternative to decomposition of litter, working as a more efficient pathway of nitrogen flow (Ruess & McNaughton 1987).

Historically, some of the most iconic ungulate and carnivore species that were recorded in Iona National Park and its surroundings were: black-backed jackal (*Canis mesomelas*), African wild dog (*Lycaon pictus*), cape fox (*Vulpes chama*), lion (*Panthera leo*), leopard (*Panthera pardus*), caracal (*Caracal caracal*), cheetah (*Acinonyx jubatus*), wildcat (*Felis silvestris*), Angolan genet (*Genetta angolensis*), brown hyena (*Hyaena brunnea*), spotted hyena (*Crocuta Crocuta*), Aardwolf (*Proteles cristatus*), plains zebra (*Equus quagga*), mountain zebra (*Equus zebra*), southern white rhinoceros

(*Ceratotherium simum*)*,* savanna elephant (*Loxodonta Africana*), south-western black rhinoceros (*Diceros bicornis*)*,* common hippopotamus (*Hippopotamus amphibius*)*,* common warthog (*Phacochoerus africanus*)*,* giraffe (*Giraffa camelopardali*)*,* greater kudu (*Tragelaphus strepsiceros*)*,* bushbuck (*Tragelaphus scriptus*), common eland (*Tragelaphus oryx*), common duiker (*Sylvicapra grimmia*)*,* steenbok (*Raphicerus campestris*)*,* dik-dik (*Madoqua kirkii*)*,* springbok (*Antidorcas marsupialis*)*,* klipspringer (*Oreotragus oreotragus*)*,* common impala (*Aepyceros melampus*)*,* gemsbok (*Oryx gazella*) (Beja *et al*. 2019; Crawford-Cabral & Veríssimo 2005; Crawford-Cabral & Simões 1988; Mendelsohn & Mendelsohn 2018; Freixial 2020). However, there is no contemporary published information on the distribution and abundance of the mammals' community in Iona National Park, other than the information from two aerial surveys conducted by Kolberg & Kilian (2003) and Van der Westhuizen *et al.* (2017).

The aerial surveys are one method that can be applied to assess the mammal communities but there are other methods like camera trapping (Palmer *et al.* 2018). Aerial surveys are mostly used to assess populations of diurnal species of large herbivores and can only be conducted in open landscapes with sparse vegetation (Hedges 2012), and for that reason, this methodology can also lead to an underestimations of population densities (Marsh and Sinclair 1989, Hedges 2012). Comparatively, camera traps is a much higher cost-benefit strategy which allows to collect more information regarding per example, behavior and sex ratios (Peres *et al.* 2017). The improvement on camera trap technology have been facilitating wildlife inventories, and with it, ecology and conservation have been also evolving (Taylor *et al.* 2018). Camera trap surveys can provide information regarding species behavior such as activity patterns, species interactions and predatory events, presence, distribution, densities and allows to monitor possible population changes (Swanson *et al*. 2015; Palmer *et al*. 2018). With technology improvement associated with the fact of being a non-invasive method, this methodology has been increasingly used in large and medium-sized mammal studies and in our study, it is also the main method applied (Swanson *et al.* 2015; Palmer *et al.* 2018).

The initial goal of this study was to assess the cheetah populations within the INP and its surroundings where there have been some reports in Omauha farm, of losses on springbok due to this predator (Álvaro Baptista pers. comm). The Omauha farm is a touristic lodge with 5000 hectares enclosed with permeable fences that allow the protection of wild animals (Álvaro Baptista pers. comm). According to Mr. Álvaro Baptista, cheetahs can kill about 40 springboks per year inside the farm, while leopards kill only eight to ten springboks or oryx cubs. To fulfill this initial goal, we perform the first systematic camera trap survey of a section of INP and its surroundings, although it was not possible to achieve the initial goal due to covid-19 pandemic, the study provide new data regarding the distribution and abundance of large mammals, based on the methodology of other surveys that has been conducted in Angola (Elizalde *et al.* 2019; Groom *et al.* 2018; Overton *et al.* 2017).

1.1. Research Objectives

Taking into account the lack of knowledge of these species, the war history in the region and the park's tourist and scientific interest, it is necessary to approximate the distribution and densities of these animals and, therefore, the objectives of this research are to:

- Make an initial survey of the distribution and relative abundance of large and medium sized carnivores and ungulates in Iona National Park;
- Analyze the most representative habitat for each mammal species found to occur.
- Make a preliminary description of key conservation problems for mammals that may occur in the park;

2. Materials and Methods

In order to evaluate the population of large and medium-sized terrestrial mammals in the survey area, two field surveys were conducted in November 2019 and in June 2020. These surveys were planned to cover the most suitable habitats for cheetah that was the initial target species in this study, which according to Muntifering *et al.* (2006) they prefer habitats with better sighting visibility and greater grass cover, like the Namibe savannas. During the field surveys different methodologies such as camera trapping, direct and indirect observations and other sources of information, were applied aiming to collect data on INP and its large and medium-sized mammals' community.

2.1. Survey area

The survey area was located mostly inside INP (16°40'S 12°20'E) and its vicinities, including the Omauha farm, comprised within the arid region of southwest Angola. This area with 5,625 km^2 was divided using a grid of 15x15km, covering approximately 29,4% of the park (Figure 2).

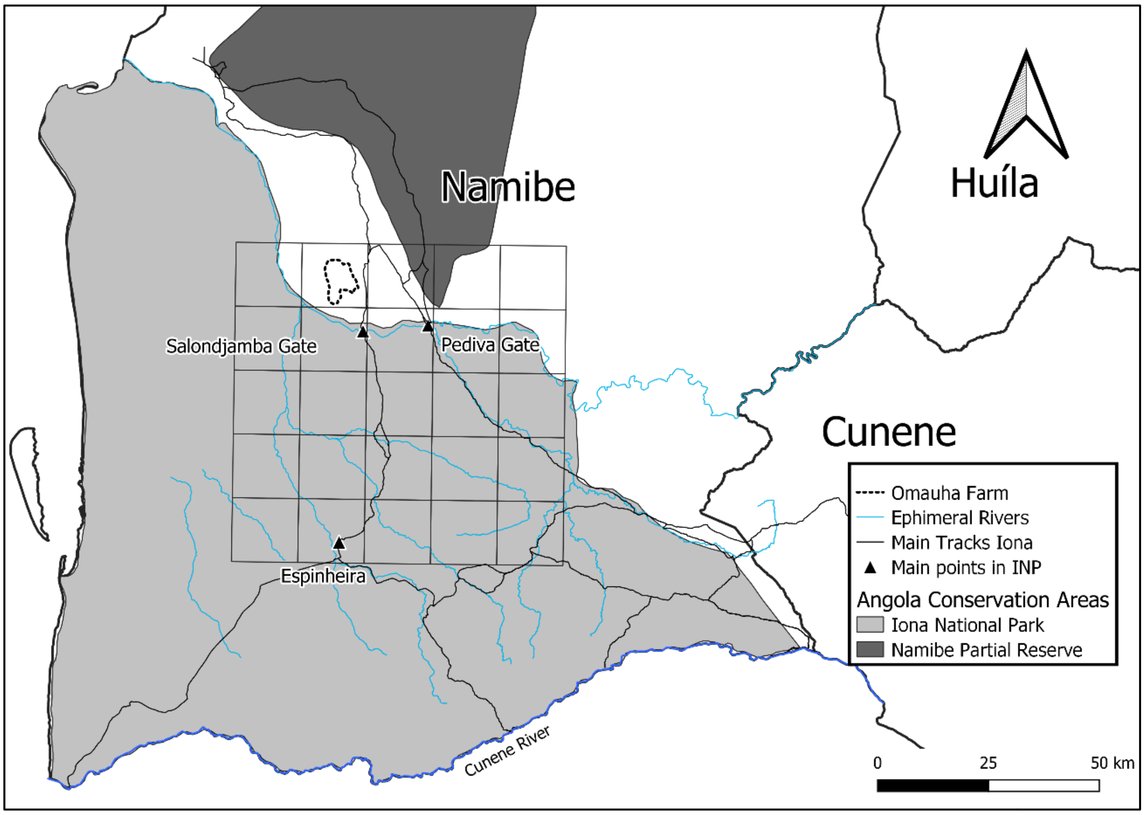

Figure 2. The location of the survey area within Iona National Park (Southwest Angola), with the grid dividing the 5,625 km^2 into 25 quadrants of 15x15km.

The west (and coastal) region of the survey area is characterized by desert dunes where plants like *Odyssea paucinervis, Acanthosicyos horridus* and *Welwitschia mirabilis* can be found. The landscape of the eastern region of the survey area is dominated by

Colophospermum mopane and the remnant area by Namibe Savanna habitat with shrubs of *Acacia, Commiphora* and *Combretum*, herbaceous plants of the genera *Eragrostis, Aristida* and also *Welwitshia mirabilis* (Grandvaux-Barbosa 1970).

The climate in the survey area is classified as arid, being typical of the Coastal Belt region (Huntley 1974) with an average annual precipitation less than 100mm (Diniz 1973; Figure 3). In this area there are two seasons: the dry season from May to October and the rainy season from November to April (SASSCAL 2020). The average annual temperature of a large part of this area is involved in the isotherms of 23ºC and 24ºC (Diniz 1973).

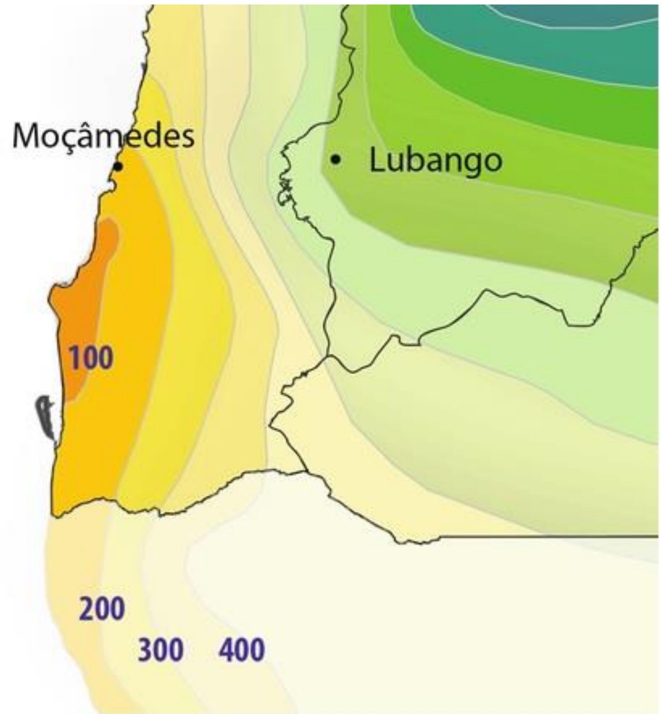

Figure 3. Mean annual rainfall southwestern Angola. Adapted from Huntley (2019).

The survey area represents a diversity of geologic formations with prevalence of desert dunes consisting almost exclusively of quartz sand and outcrops of old massif formations consisting essentially of metamorphized eruptive and sedimentary rocks of varied lithological composition like gneisses of different types, migmatites, mica schists, quartzite shales and quartzites (Diniz 1973). South of the Curoca river, the area is lithologicaly characterized by schist rocks, especially clay or sand shale, sometimes with intercalations of quartzites, limestones, conglomerates and amphibolic rocks (Diniz

1973). The western region of extremely dry climate or desert is dominated by arid soils with calcareous crust (Diniz 1973).

Nine different habitats have been classified inside the park: Cunene river; Curoca river; desert; sea; dry riverbed, valleys and hills; Namibe savannas; mountain savanna and steep slopes; pending savanna and urban region (UPND 2016). The survey area in the present study covers two of these habitats: 1) dry riverbed, valleys and hills; and 2) Namibe savannas (which is one of the most predominant habitats of INP). Those habitats were chosen based on the initial goal, being the more favorable ones to detect cheetahs by camera traps.

2.2. Camera trapping survey design

The camera trapping survey was conducted between November 2019 and June 2020, covering the survey area of 5,625 km^2 with 40 camera traps installed between November 13th and 22nd of 2019 - 31 inside INP, five inside Omauha Farm and four in the vicinities (Figure 6). In order to maximize the number of captures of large and medium-sized mammals while covering as large an area as possible, each sampling unit in the grid of 25 quadrants of 15x15km underwent a division into four smaller sampling units of 7,5x7,5 km (56,25km^2), making a total of 100 sampling units (Figure 6). The survey area was extended to the mountain range in the east because this area was completely unsurveyed and very little was known about its wildlife. A total of ten cameras were installed in the mountain range, from site 23 to site 32.

Trapping sites were chosen to maximize species detection and cameras were installed in strategic places like ecological corridors (e.g. regular used trails or dry riverbeds) and latrines (Meek *et al.* 2014). Camera traps were installed on trees at approximately 50 cm from the ground with no tall grass surrounding, but whenever it was necessary the grass, sticks and branches that were in front of cameras were trimmed (Swanson *et al*. 2015) (Figure 4). In the case where no appropriate trees were available, cameras were placed on poles (Swanson *et al*. 2015). In total, camera trapping covered 38 of the 100 grid units, usually with one device per sample unit at an average of 5,495 kilometers intervals, according to the habitat characteristics and the strategic places found (Figure 4). Six camera traps were stolen or lost, and one camera recorded incorrect dates (site 18). The lost cameras were from site 1, site 23, site 24, site 25, site 29 and site 30 (Figure 4). All trap locations were recorded by GPS (Garmin Oregon 450).

In the trapping survey we used eight Panthera V6 brand camera traps and 32 Cuddeback XChang Colour Model 1279 of which four were infrared, all having passive infra-red sensors and triggered by movement and body heat. The cameras were programed to take three photos when triggered during the day, with a with a time interval of one second, and one photo with infrared flash at night (Swanson *et al*. 2015; Palmer *et al.* 2018). The ones placed outside the park were collected from 9th to 10th of May 2020, while the cameras that were inside the park were collected on the 3rd of June 2020. The cameras were recording during a total of 2614 days. The batteries and SD cards (8GB and 16GB) of the cameras inside the farm and outside the park were changed (whenever necessary) on February 23rd 2020. The INP was closed during the covid-19 lockdown, so it was not possible to change the batteries in the cameras placed inside the park and for that reason these cameras did not work all the time.

Figure 4 – Camera trap installation, notebook registration, map observation and some of the camera trap stations from the survey area.

2.3. Direct and Indirect Observations

Following the methodology used elsewhere in Angola (Groom *et al.* 2018; Elizalde *et al.* 2019), while installing the camera traps opportunistic surveys were conducted on roads or trails, by foot or by car at a slow speed of about 20km/h, where all the animals found in or near the road were registered (Figure 5). For that we used binoculars, a notebook and software programs like Spatial Monitoring and Reporting Tool (SMART) and Cybertracker to record all information regarding the number of animals sighted, the species name, the distance and angle they were from the car and geographical coordinates (Groom *et al.* 2018; Elizalde *et al.* 2019; Overton *et al.* 2017). We also recorded all spoor (tracks and dung) opportunistically encountered. It was reported some herbivore kills due to cheetah and leopard in Omauha farm (Alvaro Baptista pers. comm.), and for that reason, all prey carcasses inside the farm, were recorded. It was also recorded the herbivore's species whenever it was possible to identify, and the possible predator, with the help of a farm worker that was knowledgeable of the local species.

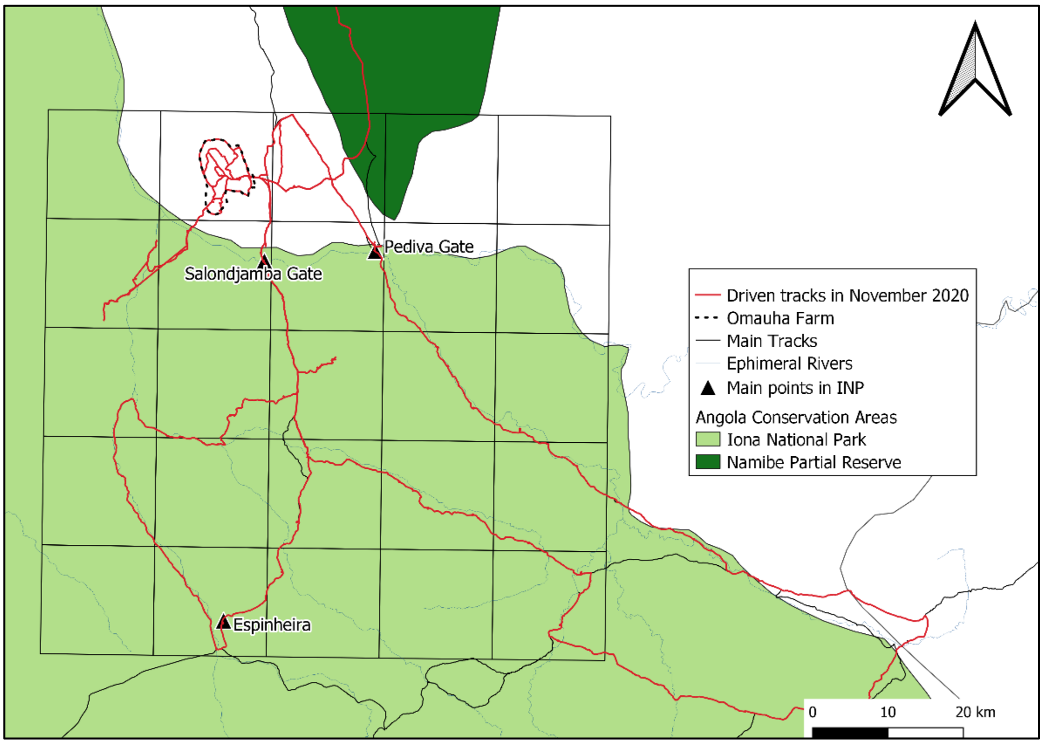

Figure 5. Driven tracks during the fieldwork in November 2020.

2.4. Other Sources of Information

By informal discussions with shepherds, farm owners and workers, it was recorded anecdotal information about the presence and the apparent density of certain species in the area. These informants had a good knowledge and understanding of the local fauna. However, like questionnaires and interviews, these types of methodology bring a great source of information but should always be interpreted with caution due to being not scientific supported and may not fully correspond to reality (Elizalde *et al*. 2019; Groom *et al*. 2019; Overton *et al.* 2017).

2.5. Data analyses

To analyze the data collected from camera trap surveys we used the digiKam 6.4.0. software to identify and classify the images and RStudio (RStudio Team 2020) with the camtrapR package (Niedballa *et al.* 2016) to analyze them (Elizalde *et al*. 2019). In this analysis we defined the independent capture events that discards the consecutive records of the same species in a 30 min time-lag between them, to avoid having repeated images of the same individual (Elizalde *et al*. 2019; Palmer *et al*. 2018; Swanson *et al.* 2015). To calculate the species accumulation curve (SAC) it was used TEAM library 1.7 R scripts (Boitani 2016) and the vegan R package (Oksanen *et al*. 2007).

For habitat analyses it was chosen to use the habitat classification from the UNDP (2016) Iona National Park Management Plan, allowing for potential comparison and trusting it could be useful for the park management. To compare species accounts, the data obtained was normalized, that is, it was calculated the number of independent events of each species per 100 camera trap days, obtaining the relative abundance index (RAI) (O'Brien *et al*. 2003).

It was calculated the number of days to first encounter for each species based on a table with all the records obtained, that was created with the function recordTable from the camtrapR package. It was also calculated the number of days between the first record of each specie and the respective camera trap setup date.

We also used QGIS 3.4 (QGIS Development Team 2019) to create maps with camera trap data and direct/indirect observations. To be possible to compare photo rates of each species between areas it was also calculated the RAI for each species separately for each unit (7,5km x 7,5km) to create the correspondent maps in QGIS 3.4 (Elizalde *et al.* 2019; Palmer *et al.* 2018; Vassiliki *et al*. 2019).

3. Results

3.1. Species detection and trapping success

The 2614 trap days yielded, after the removal of false positive images (i.e. images with no animals, that were triggered by other factors like wind or grass), a total of 3491 photographs that were processed and grouped into 550 independent events. A significant percentage (35,3%) of the camera traps recorded the presence of human population and domestic fauna in the survey area, with a total of 12 sites recording their presence. For the analysis, images of researchers, bats and birds were discarded. As a result, 347 wildlife independent events remained after filtering, that captured 17 species of wild mammals throughout the study of which 292 were records of herbivores and ungulates (279 ungulates and 13 of hare *sp.*), 41 of mesocarnivores, five of large carnivores and nine of primates. The list of these species is given in Table 1 and Table 2 together with the species that were recorded by direct and indirect sightings or gathered through the informal discussions with locals.

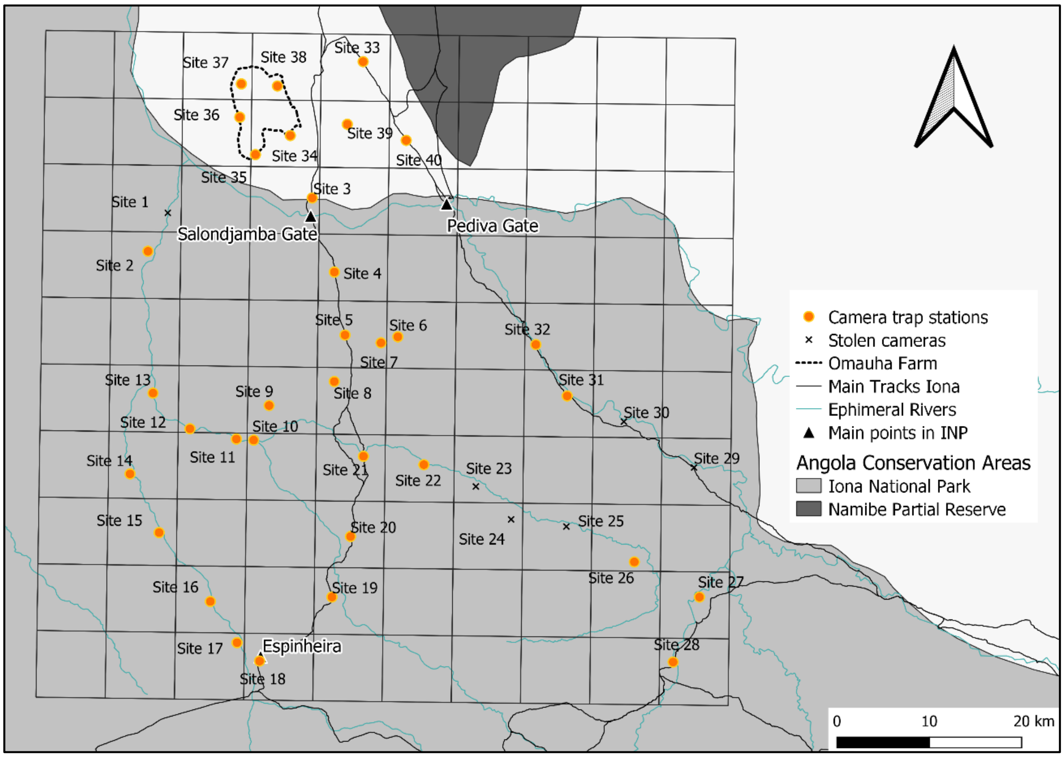

Figure 6. Camera trap's sites within the survey area within the 7,5x7,5km grid in the survey area.

The species accumulation curve (Figure 7) shows the beginning of a gradual levelling off with camera trap days, which demonstrates that although our camera trap design was sufficient to detect a high proportion of species of ground dwelling mammal in the survey area, an increase in camera trap days would allow to obtain a more reliable number of species. The total number of terrestrial mammal species estimated to occur in the survey area using the chao estimator is 24.0 (SE 7.3) and using jacknife1 estimator is 22.8 (SE 2.6).

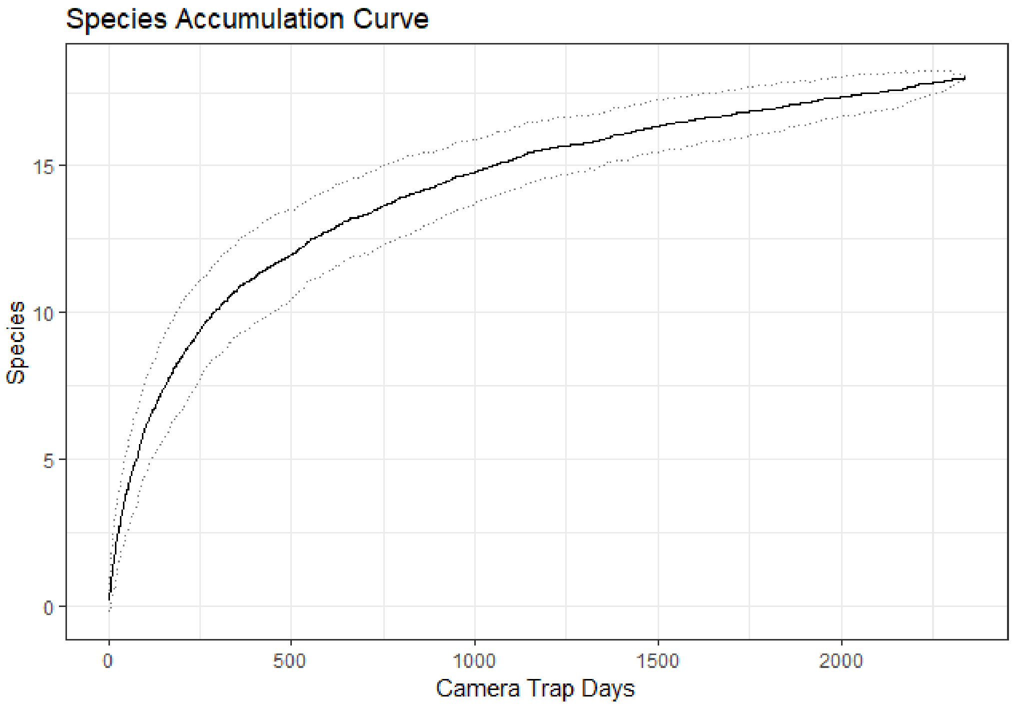

Figure 7. Camera trap rarefied species accumulation curve.

Table 1. Summary table with the number of independent events, capture percentages and species encounter rates for each the camera trap recorded species.

Species	**Independent events**	**Camera trap rates** (% trap stations)	**RAI** (event numbers per 100 camera trap-days)
Mesocarnivores			
Aardvark (*Orycteropus afer*)	14	32,4%	0,54
Aardwolf (*Proteles cristatus*)	26	35,3%	0,99
Black-backed jackal (*Canis mesomelas*)	5	8,8%	0,19
Cape Fox (*Vulpes chama*)	6	5,9%	0,23
Caracal (*Caracal caracal*)	2	5,9%	0,08
Wildcat (*Felis silvestris*)	1	2,9%	0,04
Zorilla (Striped Polecat) (*Ictonyx striatus*)	1	2,9%	0,04
Large carnivores			
Cheetah (*Acinonyx jubatus*)	3	8,8%	0,11

Leopard (*Panthera pardus*)	2	2,9%	0,08
Ungulates and lagomorpha			
Dik-dik (*Madoqua kirkii*)	10	8,8%	0,38
Hare *sp*.	13	23,5%	0,50
Kudu (*Tragelaphus strepsiceros*)	2	2,9%	0,08
Mountain zebra (*Equus zebra*)	11	11,8%	0,42
Gemsbok (*Oryx gazella*)	98	41,2%	3,75
Springbok (*Antidorcas marsupialis*)	115	67,6%	4,40
Steenbok (*Raphicerus campestres*)	29	32,4%	1,11
Primates			
Chacma baboon (*Papio ursinus*)	9	8,8%	0,34

Regarding ungulates, the two more well represented species were the gemsbok and springbok that were recorded in 41,2% and 67,6% trap stations, respectively (Figure 8; Table 1). The aardwolf was the carnivore more captured being recorded in 35,3% trap stations (Figure 8; Table 1). The first encounter rate of each species was also calculated (Figure 9) and showed that springbok and aardwolf were the species where less camera trap days were necessary to obtain their first capture. Gemsbok, hare sp. and aardwolf were the species that were captured most quickly, requiring 0 days for their first capture. The species-specific results are presented in section 3.2.

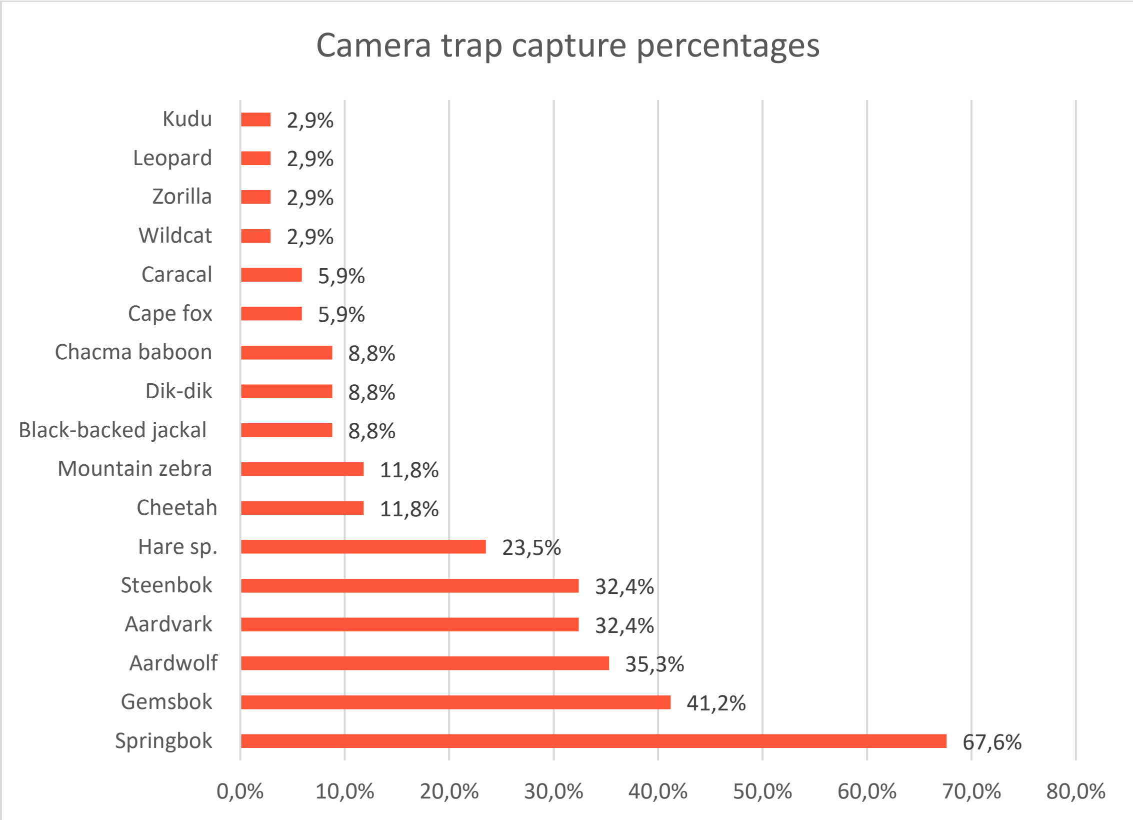

Figure 8. Percentages of the 34 camera trap stations that recorded each species.

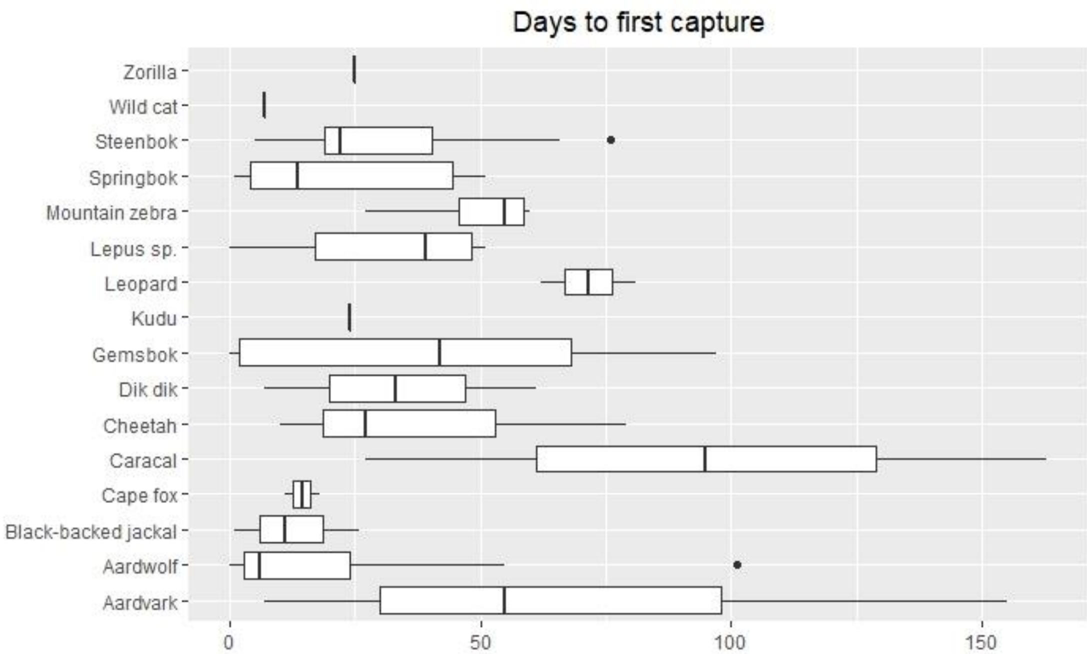

Figure 9. Boxplot with the days to first capture for each species.

3.2. Mammal community and spatial distribution patterns

Through the combination of data obtained from the complementary survey technics, it was possible to record a total of 24 species (13 species of carnivores, 9 species of ungulates and lagomorpha and 2 species of primates) (Table 1). We did not record dung piles of springbok and gemsbok because of their relatively high abundance in the survey area.

Table 2. Species found in survey area by camera trap, opportunistic sightings and personal communication.

Species	Camera Traps (number of independent events)	Opportunistic Sightings			Personal communication
		Direct Sighting (number of animals)	Spoor (number of footprints or dung)	Carcass (number of carcasses)	
Mesocarnivores					
Aardvark (*Orycteropus afer*)	14	-	1	-	X
Aardwolf (*Proteles cristatus*)	26	1	-	-	X
Black-backed jackal (*Canis mesomelas*)	5	1	-	-	X
Cape fox (*Vulpes chama*)	6	4	-	-	X
Caracal (*Caracal caracal*)	2	-	-	-	X
Honey badger (*Mellivora capensis*)	-	-	-	1	X
Slender mongoose (*Herpestes sanguineus*)	-	1	-	-	-
Wildcat (*Felis silvestris*)	1	-	-	-	-
Zorilla (*Ictonyx striatus*)	1	-	-	-	-
Large Carnivores					
Brown hyena (*Hyaena brunnea*)	-	-	2	-	X

Cheetah (*Acinonyx jubatus*)	3	-	-	-	X
Leopard (*Panthera pardus*)	2	-	1	-	X
Spotted hyena (*Crocuta crocuta*)	-	-	-	-	X
Ungulates and Lagomorpha					
Dik-dik (*Madoqua kirkii*)	10	9	-	-	X
Hare *sp.*	13	1	-	-	X
Klipspringer (*Oreotragus oreotragus*)	-	1	-	1	X
Kudu (*Tragelaphus strepsiceros*)	2	-	-	-	-
Mountain zebra (*Equus zebra*)	11	9	2	-	X
Gemsbok (*Oryx gazella*)	96	60	-	-	X
Rock hyrax (*Procavia capensis*)	-	1	-	1	X
Springbok (*Antidorcas marsupialis*)	116	464	-	37	X
Steenbok (*Raphicerus campestres*)	29	11	-	-	X
Primates					
Chacma baboon (*Papio ursinus*)	9	17	-	-	X
Malbrouck monkey (*Chlorocebus cynosurus*)	-	4	-	-	–

The camera trap data species richness analysis for each camera trap station shows an apparent variation with latitude and longitude (Figure 10). The sites with more species richness were site 12 and site 36 with six species which were located in the dry riverbed, valleys and hills and the Namibe savanna habitats, respectively (Figure 10; Table 48). The sites where no species were recorded were the sites 27, 33 and 35 that are in the habitat classified as Namibe savanna (Figure 10; Table 48). The sites with more independent events recorded were site 36 in the habitat classified as Namibe savanna with 39 independent events of six different species (Figure 10).

Based on the collected camera trap data, the captured species were more recorded in the habitat classified as dry riverbed, valleys and hills, where it was verified the highest number which are 6,42 records of springbok in 100 days of camera trapping (Figure 11). The highest number of records in 100 days of camera trapping for the habitat classified as Namibe savanna were of 3,82 records of gemsbok species, which are almost half of the value of the dry riverbeds, valleys and hills (Figure 11).

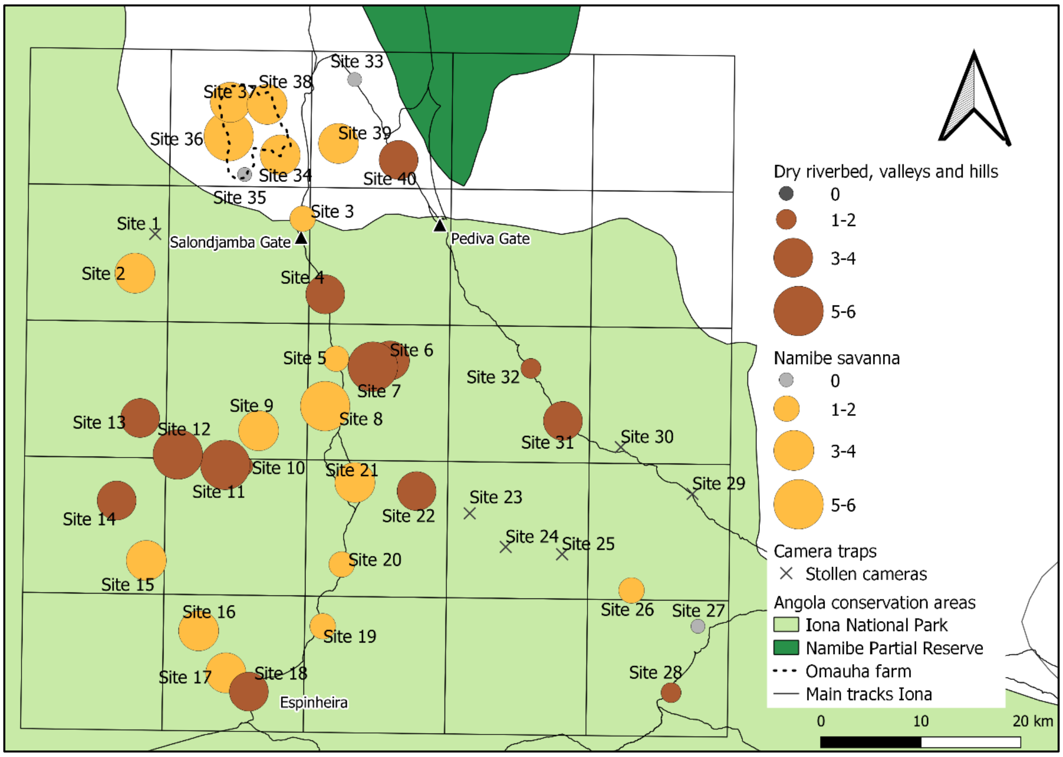

Figure 10. Species richness in the two habitats covered during the survey.

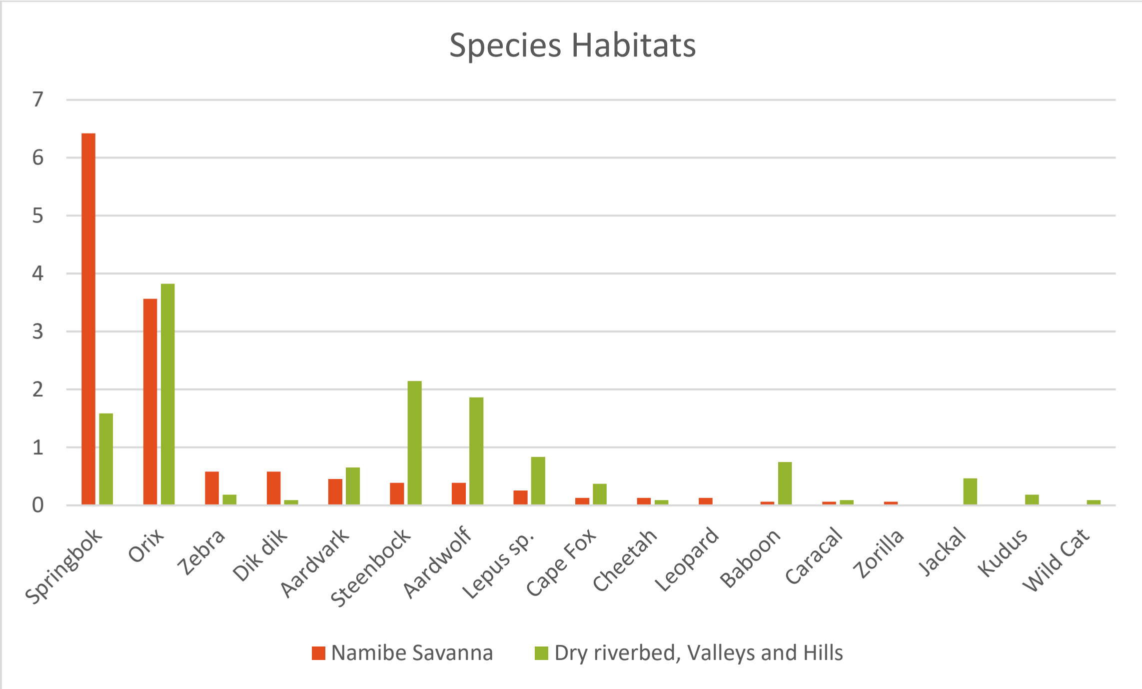

Figure 11. Species occurrence in both habitats (in 100 days of camera trap in each habitats).

3.2.1. <u>Mesocarnivores</u>

3.2.1.1. Aardvark *Orycteropus afer* (Pallas, 1766)

Aardvark (Figure 12) was quite common in the survey area, being mainly detected in the Omauha farm and in the central region of the survey area where it occurred in relatively high abundance (Figure 13). This species was captured in 14 independent events, each with a single individual, on 32% of the trap stations (11 camera trap sites; Figure 13; Table 1). Most of the capture events come from stations located at the habitat classified as dry riverbed, valleys and hills (Figure 13; Table 23). It was also possible to observe many burrows throughout the area that may have been dug by aardvark. Inside the Omauha Farm it was also recorded a footprint of this animal (Table 24).

Figure 12. Image of an aardvark caught at the habitat classified as Namibe savanna located on site 34.

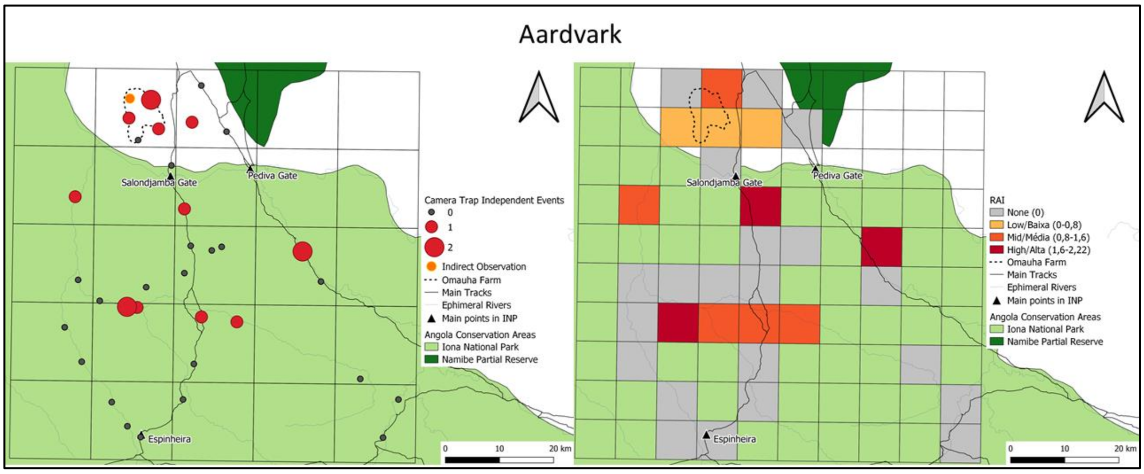

Figure 13. Map of camera trap independent events and indirect observation (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of aardvark within the survey area (right).

3.2.1.2. Aardwolf *Proteles cristatus* (Sparrman, 1783)

Aardwolf (Figure 14) seems to occur with quite frequency in the survey area, but it was mainly detected in its central part (Figure 15; Table 8). The species was captured in 26 independent events, each with a single individual, on 35% of the trap stations (12 camera trap sites; Table 1). Most of the capture events come from stations located at the habitat classified as dry riverbed, valleys and hills (Figure 15; Table 8). A direct observation of one individual was recorded by the researchers in the proximities of site 6 where the animal escaped from a burrow (Figure 15; Table 9).

Figure 14. Image of an aardwolf recorded on site 4 in the dry riverbed, valleys and hills habitat.

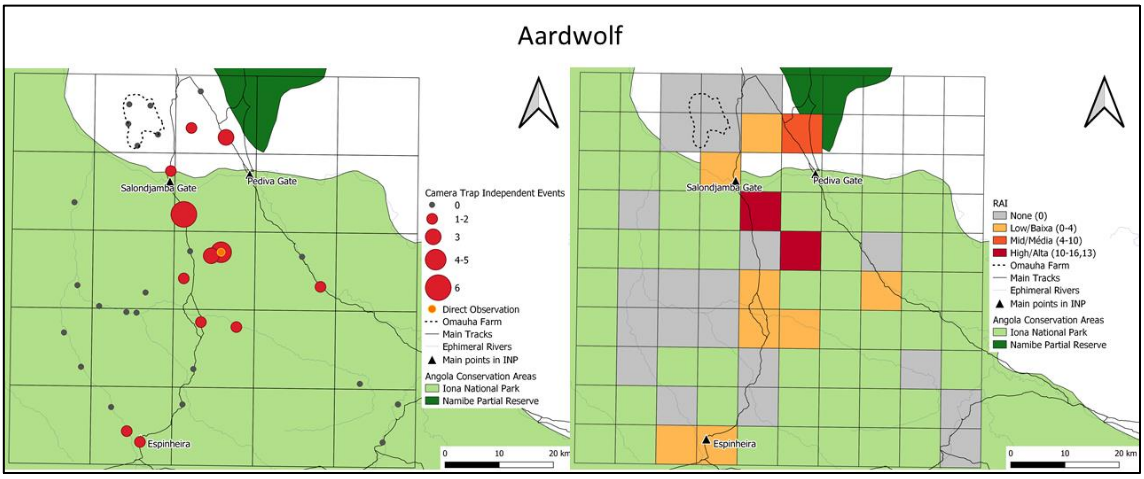

Figure 15. Map of camera trap independent events and indirect observation (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of aardwolf within the survey area (right).

3.2.1.3. Black-backed jackal *Canis mesomelas* Schreber, 1775

Black-backed jackal (Figure 16) was only captured in five independent events, each with a single individual on 9% of the trap stations (three sites; Figure 17; Table 1). These independent events were from stations located only at the habitat classified as dry riverbed, valleys and hills (Table 10). It was observed one individual in the vicinities of site 12 (Figure 17; Table 11).

Figure 16. Image of a black-backed jackal sniffing around on site 13.

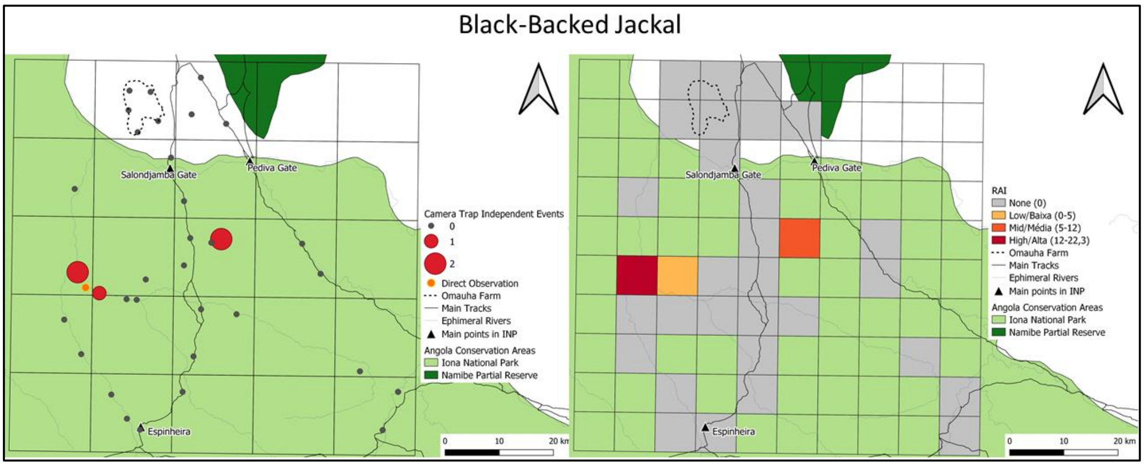

Figure 17. Map of camera trap independent events and direct sight (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of black-backed jackal within the survey area (right).

3.2.1.4. Cape Fox *Vulpes chama* (A. Smith, 1833)

Cape Fox (Figure 18) was captured in six independent events, each with single Individuals, on 6% trap stations (two sites; Figure 19; Table 1). All the independent events were from two stations located in the habitat classified as dry riverbed, valleys and hills (Figure 19; Table 12). It was also recorded two direct sightings, each one of a single individual, in the proximities of site 6 (Figure 19; Table 13).

Figure 18. Image of a cape fox walking by on site 17.

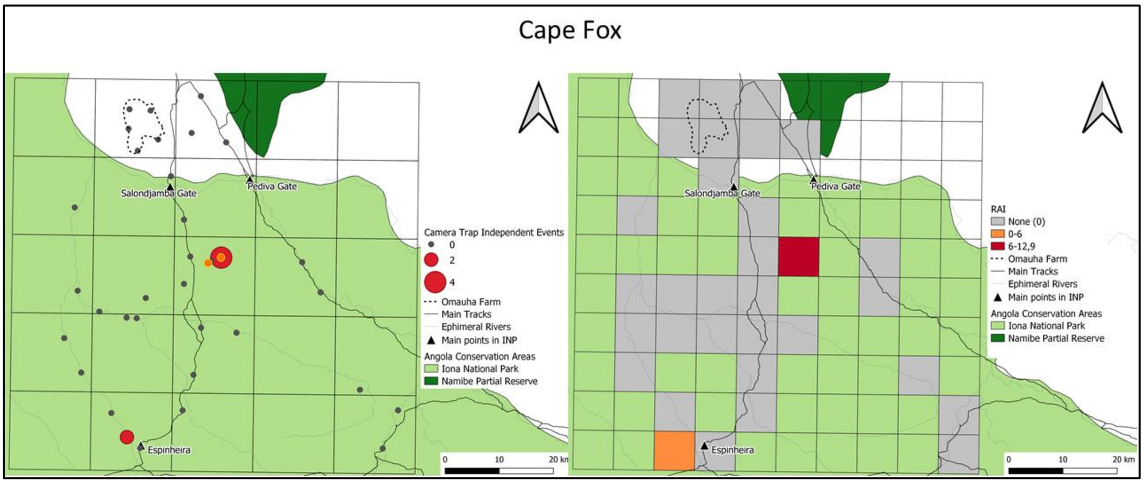

Figure 19. Map of camera trap independent events and direct sightings (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of cape fox within the survey area (right).

3.2.1.5. Caracal *Caracal caracal* (Schreber, 1776)

Caracal (Figure 20) was captured in two independent events, each with a single individual, on 6% of the trap stations (two sites; Figure 21; Table 1). These two independent events were from two stations, one located in the habitat classified as dry riverbed, valleys and hills and the other in Namibe savanna (Table 14).

Figure 20. Image of a caracal in the habitat classified as dry riverbed, valleys and hills located on site 31.

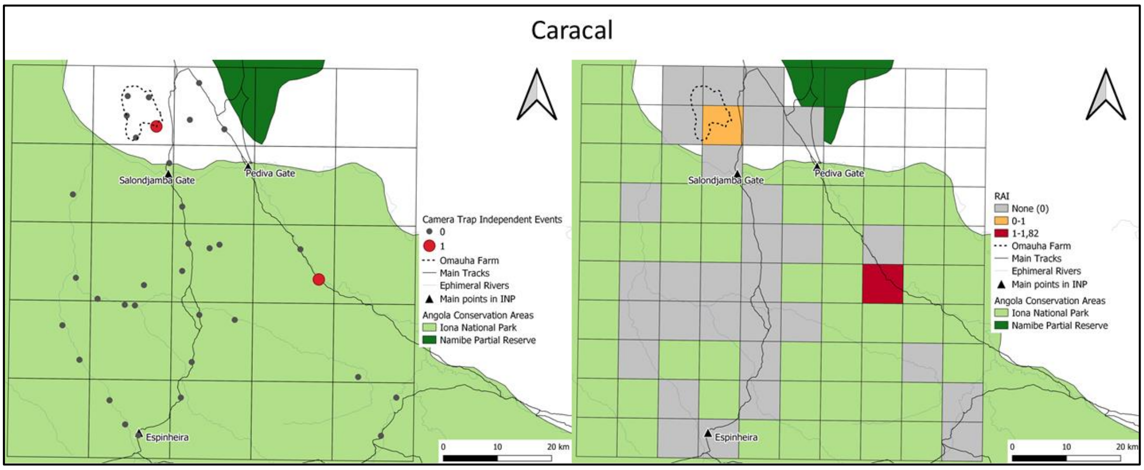

Figure 21. Map of camera trap independent events (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of caracal within the survey area (right).

3.2.1.6. Honey Badger *Mellivora capensis* (Schreber, 1776)

During our surveys it was only found one carcass of a honey badger (Figure 22) inside the Omauha Farm, in the proximities of site 34 which is located at the habitat classified as Namibe savanna (Figure 23; Table 15).

Figure 22. Photo taken by David Elizalde of a honey badger carcass found by the researchers inside the Omauha Farm (21st November 2019).

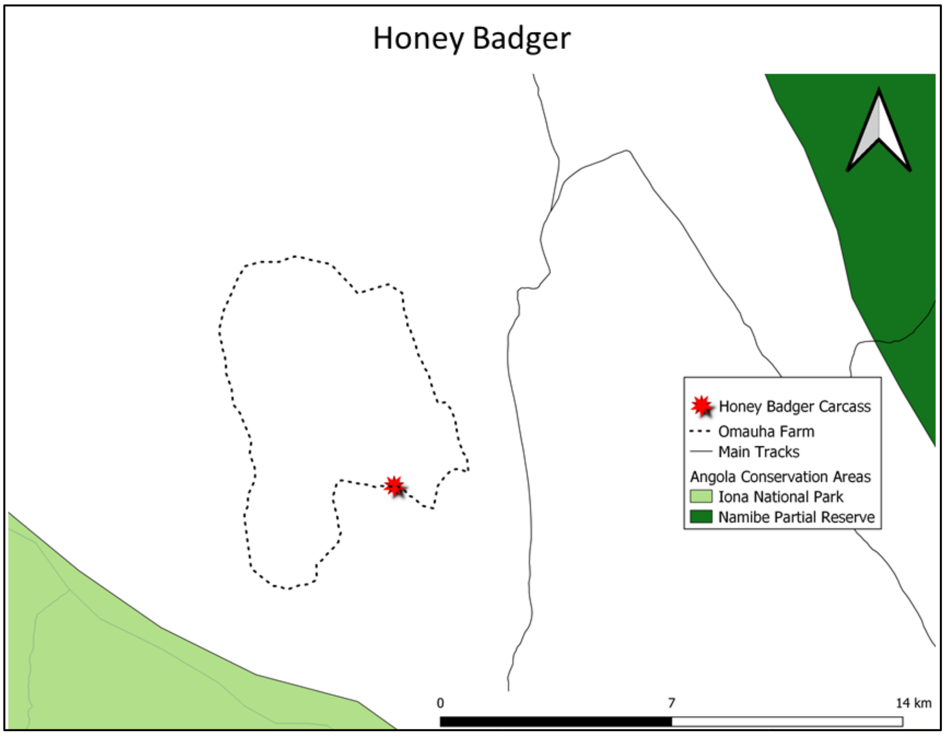

Figure 23. Map with the location of a honey badger carcass that was found inside the Omauha farm.

3.2.1.7. Slender Mongoose *Herpestes sanguineus* (Rüppell, 1835)

It was only recorded a direct observation of a slender mongoose in the habitat classified as Namibe savanna in the outskirts of site 8 (Figure 24; Table 16).

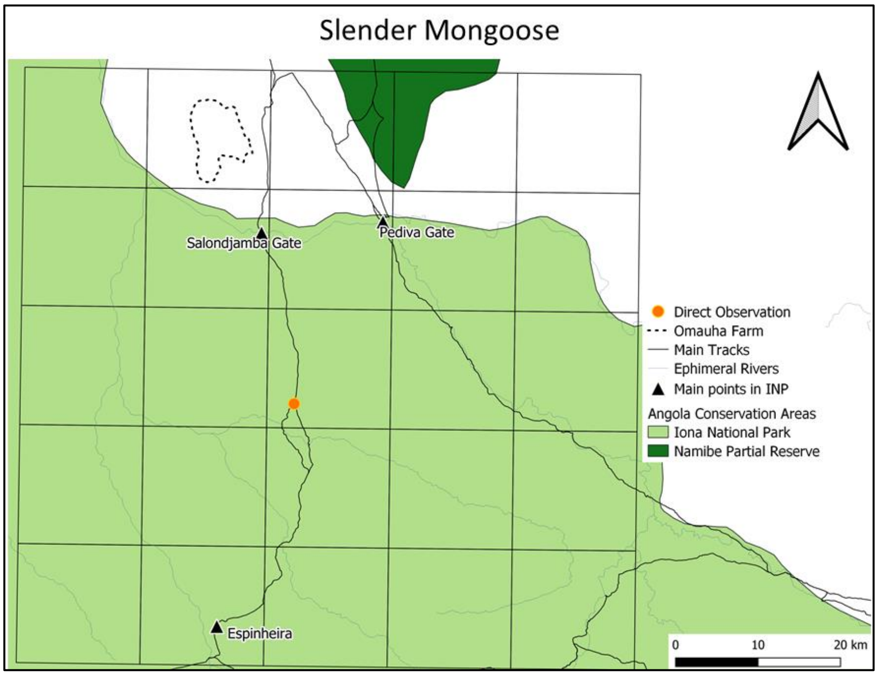

Figure 24. Map of direct sight of slender mongoose within the survey area.

3.2.1.8. Wild Cat *Felis silvestris* Schreber, 1777

Wild cat (Figure 25) was only recorded in one independent event with one individual. This capture was from the camera trap of site 8 which is located in the habitat classified as Namibe savanna (Figure 26; Table 17).

Figure 25. Image of a wild cat captured by camera trap on site 8.

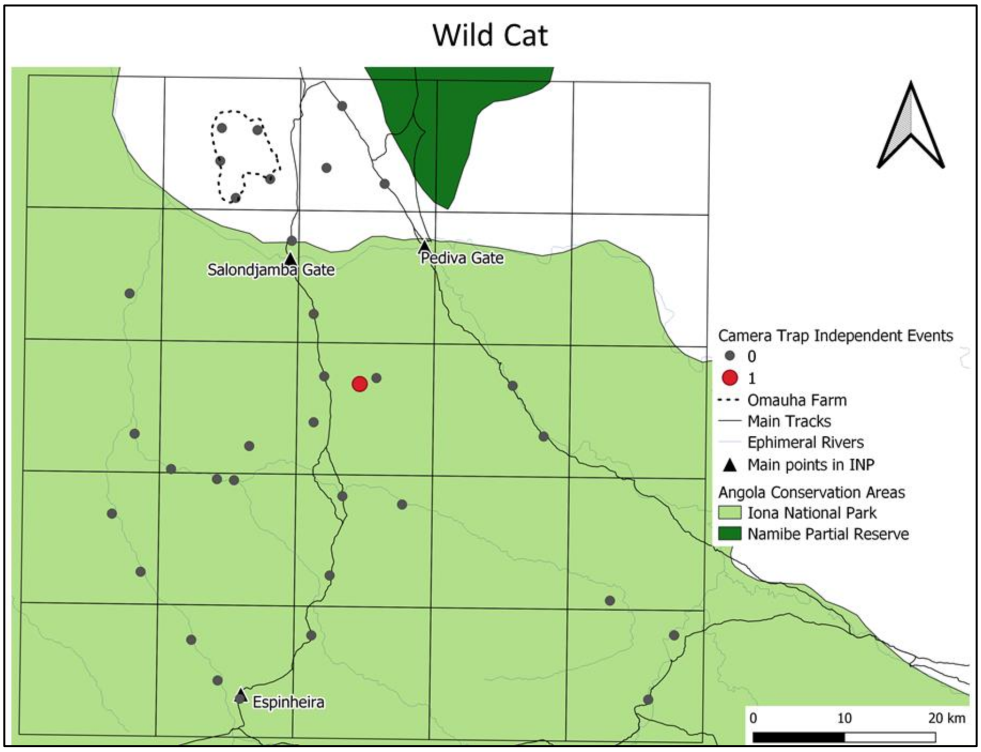

Figure 26. Map of the camera trap independent event of wild cat within the survey area.

3.2.1.9. Zorilla *Ictonyx striatus* (Perry, 1810)

Zorilla (Figure 27) was only recorded once in a single independent event with one individual., captured on site 8 at the habitat classified as Namibe savanna (Figure 28; Table 18).

Figure 27. Image of a zorilla captured on site 8 in the Namibe savanna habitat.

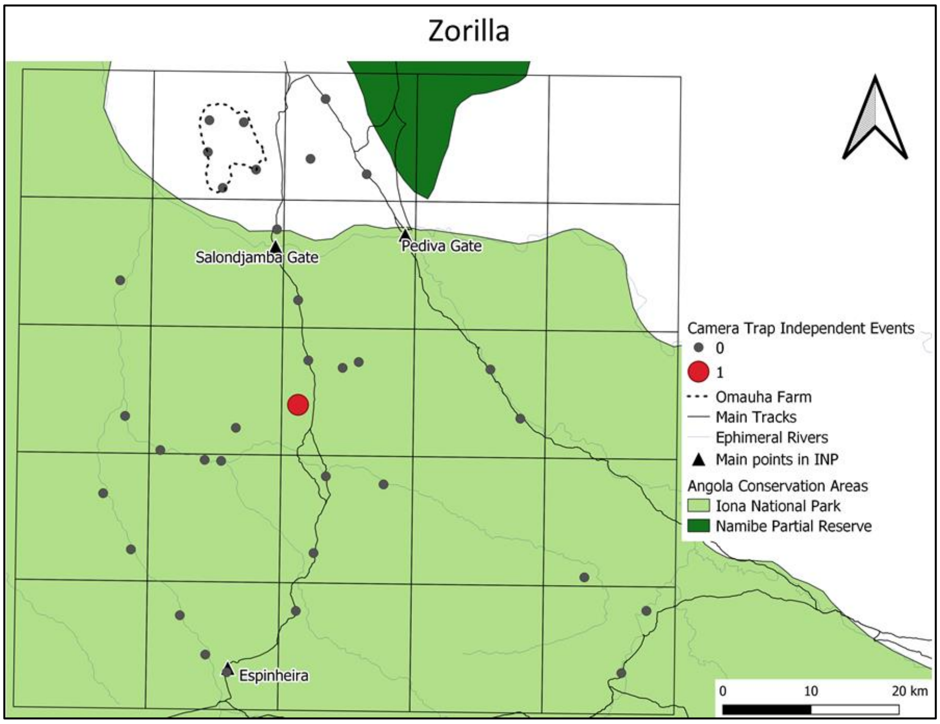

Figure 28. Map of camera trap independent events of zorilla within the survey area (right).

3.2.2. <u>Large Carnivores</u>

3.2.2.1. Brown hyena *Hyaena brunnea* Thunberg, 1820

During our surveys it was recorded two droppings of brown hyena (Figure 29) on arid regions located in the vicinities of site 13 and south of site 17 (Figure 30; Table 19). Local informants also stated that this species is quite common in INP and its surroundings but are more abundant in the coastal zone of the park.

Figure 29. A photo of a running brown hyena in Iona National Park taken by Sara Elizalde and David Elizalde (19th August 2018).

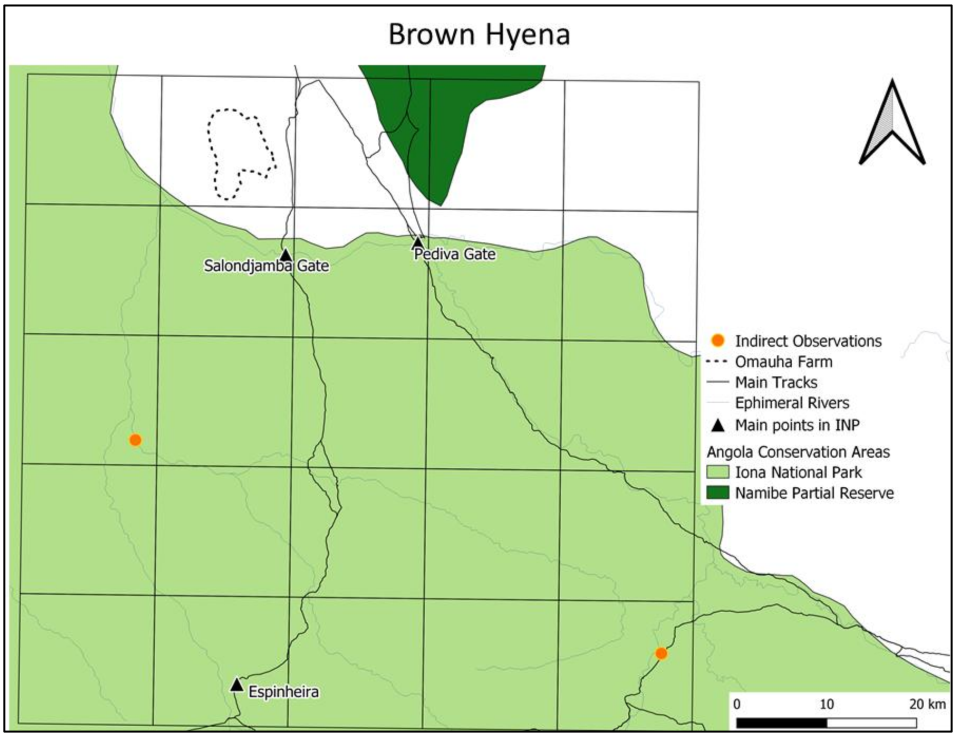

Figure 30. Map with the location of a brown hyena spoor.

3.2.2.2. Cheetah *Acinonyx jubatus* (Schreber, 1775)

Cheetahs (Figure 31) seems to occur mostly on western part of our survey area (Figure 32). This species was captured in three independent events, on 9% trap stations (three camera trap sites; Figure 32; Table 1), but likely the same individual based on the obtained images. All those capture events but one, come from stations located at the habitat classified as Namibe savanna (Figure 32; Table 20). According to local informants this species is a frequent predator in Iona National Park and its surroundings and there were reports mentioning stock losses: a) on the nearest game farms due to predation of this species on springbok and gemsbok cubs (Baptista pers. comm.); and b) in the vicinities of Salomdjamba gate where local shepherds reported to our team the loss of six goats in June when we retrieved the cameras. This livestock losses are frequently reported by transhumant shepherds (Scout Luis pers. comm.). It was also found a scat that could be from cheetah, but it was not fresh and was not possible to be sure.

Figure 31. Image of a cheetah walking in front of the camera trap on site 2.

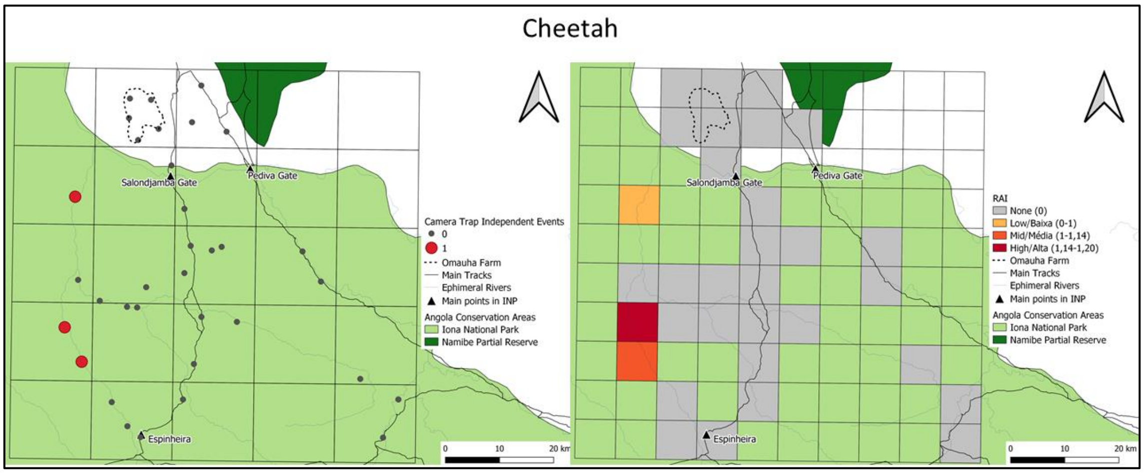

Figure 32. Map of camera trap independent events (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of cheetah within the survey area (right).

3.2.2.3. Leopard *Panthera pardus* (Linnaeus, 1758)

Leopard (Figure 33) was recorded in two independent events, which are likely the same individual (Figure 34). These records occurred both in site 36 which is located at the habitat classified as Namibe savanna (Figure 34; Table 21). It was also observed as indirect sightings, prey drag marks and footprints from an adult Leopard and its cubs inside a cave on site 35, where two carcasses of springbok and rock hyrax were also found. Inside the Omauha farm it was also spotted tracks of this species (Figure 34; Table 22). The owners and workers of this farm mentioned this species as a common predator in Iona National Park and outskirts that also preys inside the farm.

Figure 33. Image of a leopard walking by in the habitat classified as Namibe savanna located on site 36.

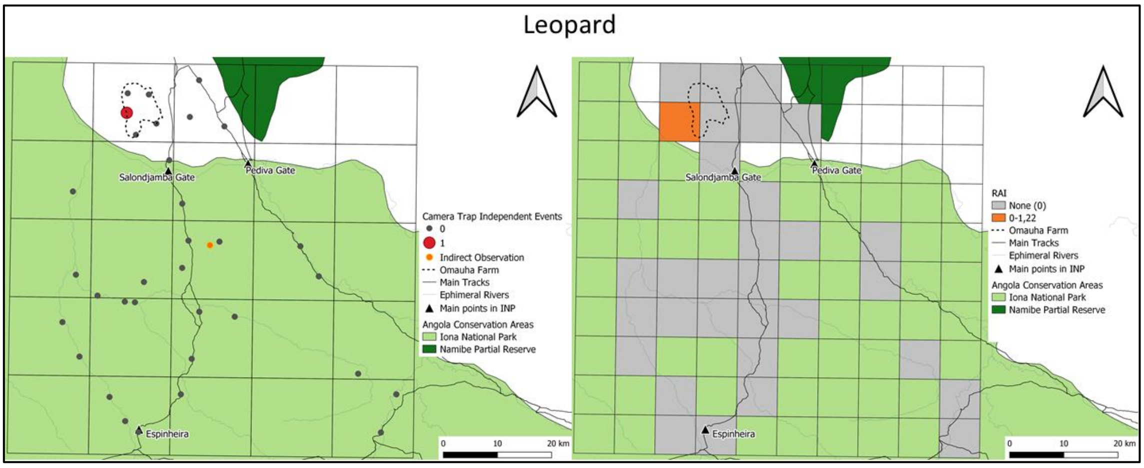

Figure 34. Map of the camera trap independent event and the indirect observation (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of leopard within the survey area (right).

3.2.2.4. Spotted Hyena *Crocuta crocuta* (Erxleben, 1777)

Spotted hyena was not recorded inside our survey area, however their presence was mentioned by local people near Otchifengo, which is close to the eastern boarder of the survey area (Figure 35). With this information and the historical records in Moçamedes (Silva 1970) and Cunene (Almeida 1912), it is possible that this species occurs in Iona National Park and its surroundings, although at very low densities.

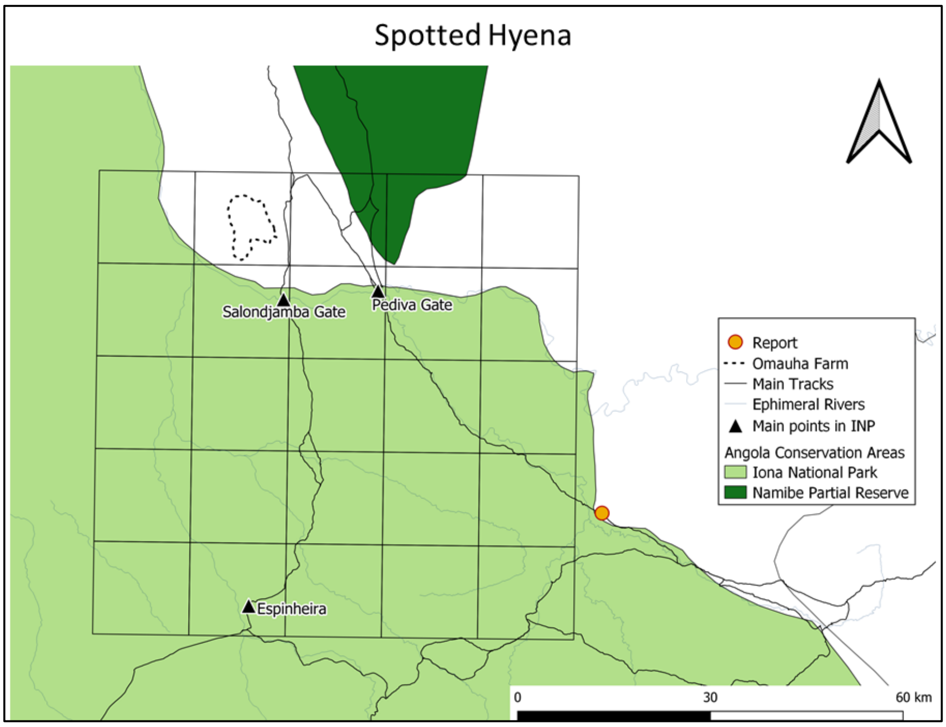

Figure 35. Map with one report of spotted hyena near Otchifengo.

3.2.3. Ungulates and Lagomorpha

3.2.3.1. Dik-Dik *Madoqua kirkii* (Günther, 1880)

Dik-dik (Figure 36, 37) was more recorded southeast of our study area, where the geology is represented by old massif formations mostly composed by shist (Figure 38). This species was captured in 10 independent events, on 9% trap stations (3 camera trap sites; Figure 38; Table 1) and in 3 of those events the species appeared in a monogamous pair which is their typical social unit (Kingdon 2013), however only 35,5% of the camera trap and direct sighting records (six records in 16) of this species were with pairs. Two of the camera traps stations where this species was recorded were located in the habitat classified as Namibe savanna (Figure 38; Table 25). It was also recorded several direct observations of this species in rocky areas, mainly in the south central and southeast region of the survey area (Figure 38; Table 26).

Figure 36. Image of a male dik-dik posing in site 26.

Figure 37. Image of a female dik-dik on site 26.

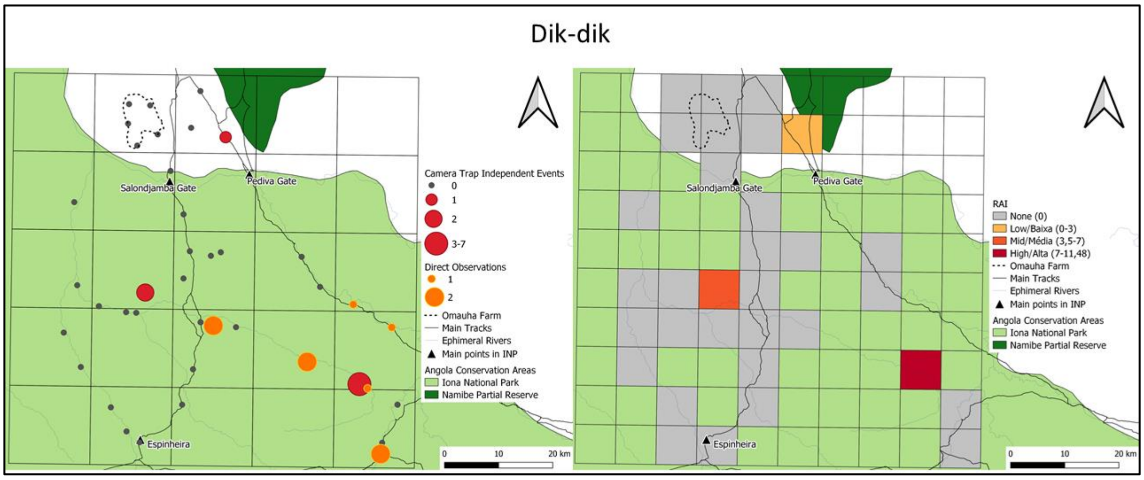

Figure 38. Map of camera trap independent events and direct sightings (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of dik-dik within the survey area (right).

3.2.3.2. Hare *sp*.

Hare *sp.* (Figure 39) was mainly detected in the central west region of the survey area (Figure 40). It was obtained 13 independent events of this species, each with a single individual, on 24% of the trap stations (8 camera trap sites; Figure 40; Table 1). Most of the capture events come from stations located at the habitat classified as dry riverbed, valleys and hills (Figure 40; Table 27). There are two hare species known to occur and one that probably exists in INP which are the cape hare (*Lepus capensis*), the Jameson's red rock hare (*Pronolagus randensis*) and the African savanna hare (*Lepus victoriae*), respectively (Freixial 2020). The records obtained can be of individuals of cape hare species. Due to their small size, cryptic behavior and the fact that we did not drive to observe species at night, we only record one direct observation of one individual in the proximities of site 2 (Figure 40; Table 28).

Figure 39. Image of a not identified hare, likely a Lepus *sp*., jumping on the habitat classified as Namibe savanna located at site 3.

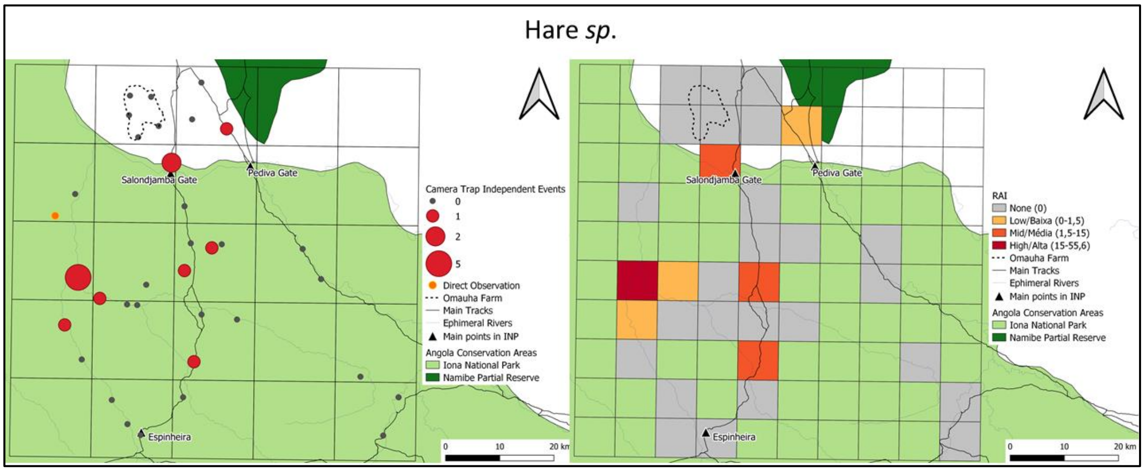

Figure 40. Map of camera trap independent events and the direct sight (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of hare *sp*. within the survey area (right).

3.2.3.3. Klipspringer *Oreotragus oreotragus* (Zimmermann, 1783)

Klipspringer (Figure 41) was not recorded inside the survey area by camera traps, however we found a carcass near the fence in Omauha Farm (Figure 42; Table 29). It was also found near the northern border of Namibe Partial Reserve, one individual on a rocky valley (Figure 41). Although we did not record any klipspringer inside the survey area, it is possible that they occur there particularly in rocky regions.

Figure 41. Photo taken by David Elizalde of a klipspringer found north of the city of Namib, in a rocky valley (22nd February 2020).

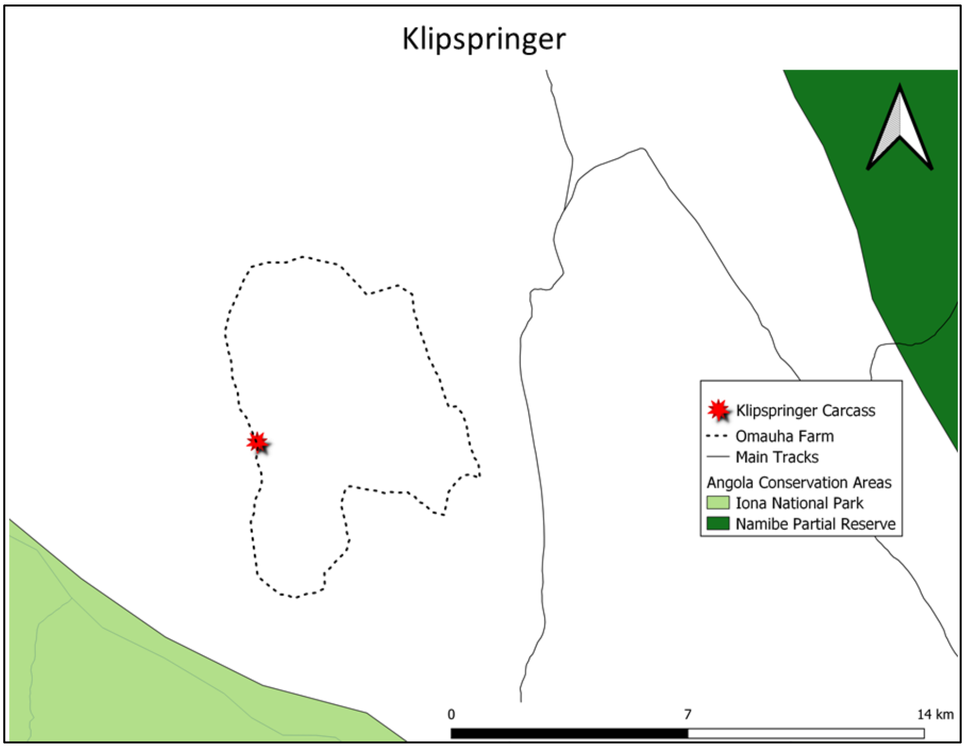

Figure 42. Map with the location of a klipspringer carcass that was found inside the Omauha farm.

3.2.3.4. Kudu *Tragelaphus strepsiceros* (Pallas, 1766)

Kudu (Figure 43) was only detected in two independent events with 3 individuals of this species in site 7 (Figure 44; Table 30). These three animals were eating and walking in front of camera trap located at the habitat classified as dry riverbed, valleys and hills (Table 30). This species may occur in other regions within the park, however, we did not obtain anymore record of these animals. This species prefers areas with some vegetation cover for protection and food (Kingdon 2013) as it is possible to see on the picture below, it seems to be confined to the more mountainous areas in the eastern part of the park, but it has been occasionally reported it the western side of the park.

Figure 43. Image of three kudus passing in front of the camera trap on site 7.

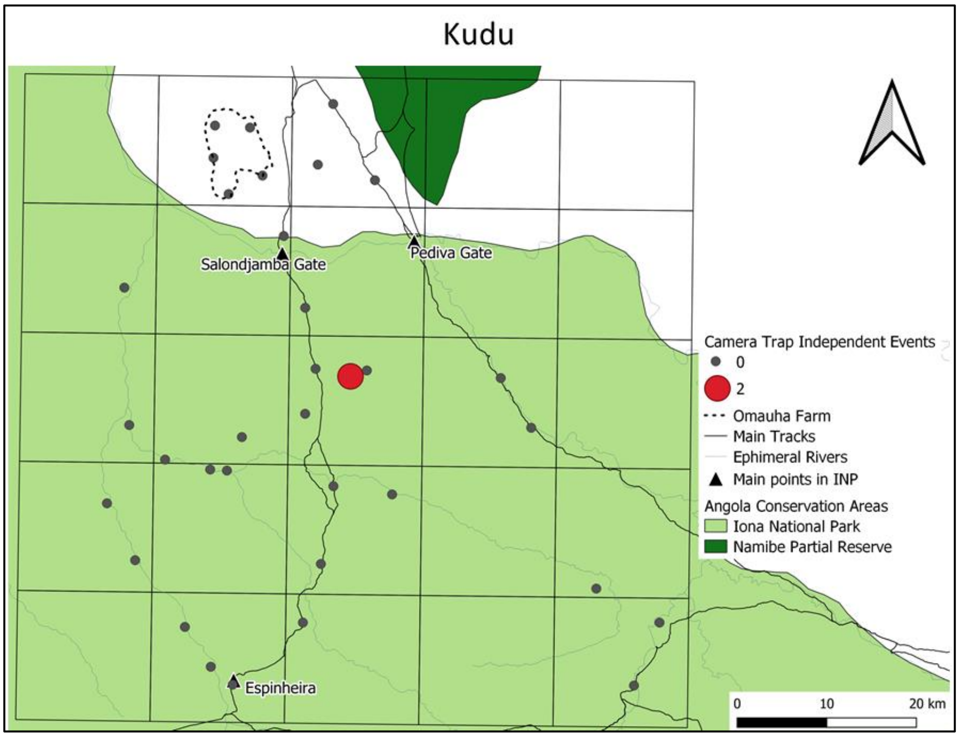

Figure 44. Map of camera trap independent events of kudu within the survey area.

3.2.3.5. Mountain Zebra *Equus zebra* Linnaeus, 1758

Mountain zebra (Figure 45) was mainly detected in the western part of the survey area, especially in the northwestern region where the species occurred with relatively high abundance (Figure 46). The species was recorded in 11 independent events, each with a single individual, on 12% trap stations (4 camera trap sites; Figure 46; Table 1). Most of the capture events come from stations located at the habitat classified as Namibe savanna (Figure 46; Table 31). Four direct observation were recorded by the researchers where one of those were of three individuals in the Omauha farm outskirts and the three remaining were of two individuals in the proximities of site 10, 12 and 18 (Figure 46; Table 4, 32). Farm owners also mentioned this group of three individuals as being quite frequent in the vicinities of the farm and affirmed that this species used to be more common than nowadays.

Figure 45. Image of a mountain zebra walking in front of the camera trap locates at site 11.

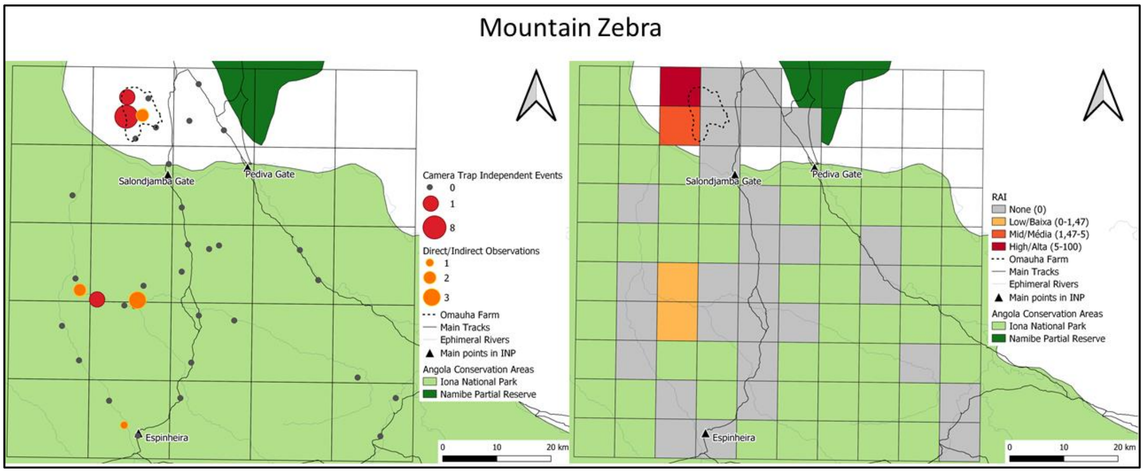

Figure 46. Map of camera trap independent events and direct sightings (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) for mountain zebras within the survey area (right).

Table 3. Statistic values of the number of individuals found together in mountain zebras herds each record of both camera trap and direct sightings.

Zebra Herds				
Max	Min	Average	1st Quartile	3rd Quartile
3	1	1,352941	1	2

3.2.3.6. Gemsbok *Oryx gazella* (Linnaeus, 1758)

Gemsbok (Figure 47, 48) was mainly recorded in the western region of the survey area where the species occurred with relatively high abundance, especially in the vicinities of the Omauha farm (Figure 49, 50). The species was captures in 98 independent events (two of those events had gemsbok and springbok together), with single individuals and herds (Table 5), on 41% of trap stations (14 camera trap sites; Figure 49; Table 1). Most of the capture events come from stations located at the habitat classified as Namibe savanna (Table 33). Direct observations were also recorded in the proximities of the sampling sites where the species were captured in the camera trap records (Figure 50; Table 34).

Figure 47. Photo taken by Solange Nunes of five gemsbok protecting themselves from the sun under a tree (13th November 2019).

Figure 48. Image of three gemsbok running on the green Namibe savanna on site 38.

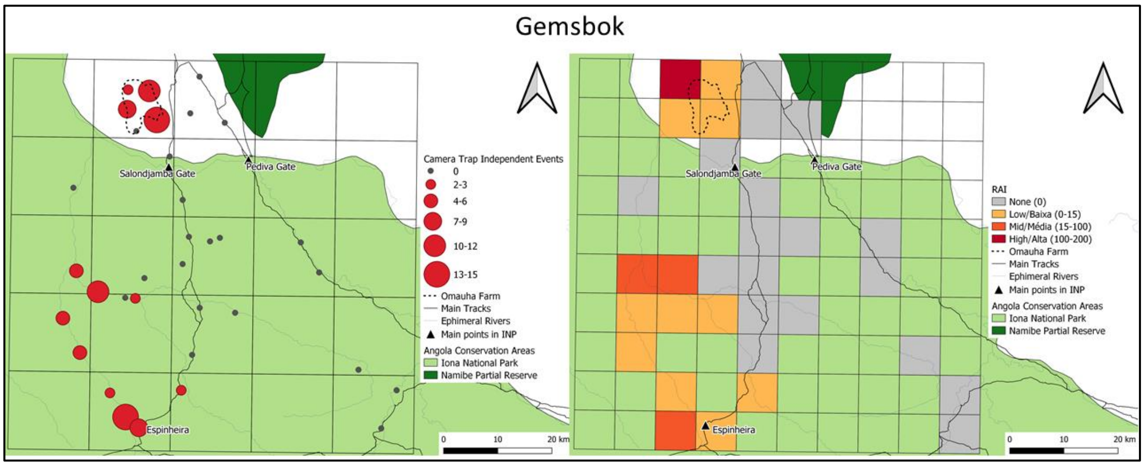

Figure 49. Map of camera trap independent events (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of gemsbok within the survey area (right).

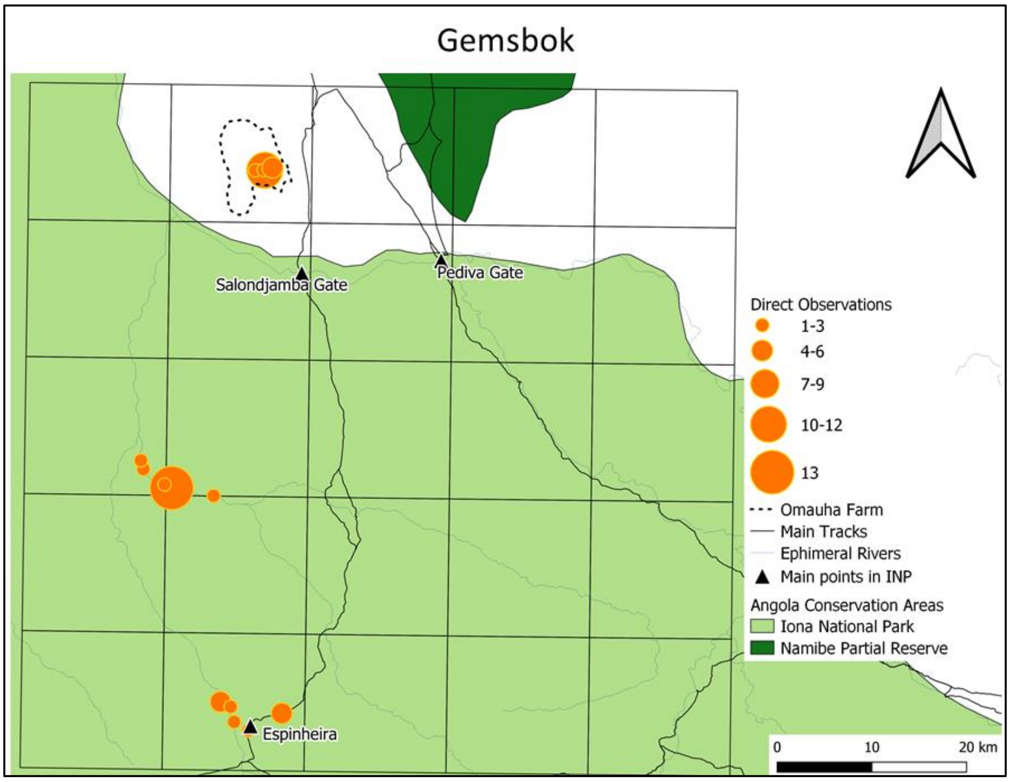

Figure 50. Map of direct sightings of gemsbok recorded within the survey area.

Table 4. Statistic values of the number of individuals found together in gemsbok herds in each record of both camera trap and direct sightings.

Gemsbok Herds				
Max	Min	Average	1st Quartile	3rd Quartile
22	1	3,384913	1	3

3.2.3.7. Rock Hyrax *Procavia capensis* (Pallas, 1766)

Rock hyrax (Figure 51) were not recorded on the camera traps, however it was possible to see a group of this species on a cluster of rocks inside the Omauha farm (Figure 52; Table 35). In the farm it was also recorded a rock hyrax carcass inside a cave (Figure 52; Table 35).

Figure 51. Photo taken by Sara Elizalde of seven rock hyrax sunbathing on the rocks (22nd November 2019).

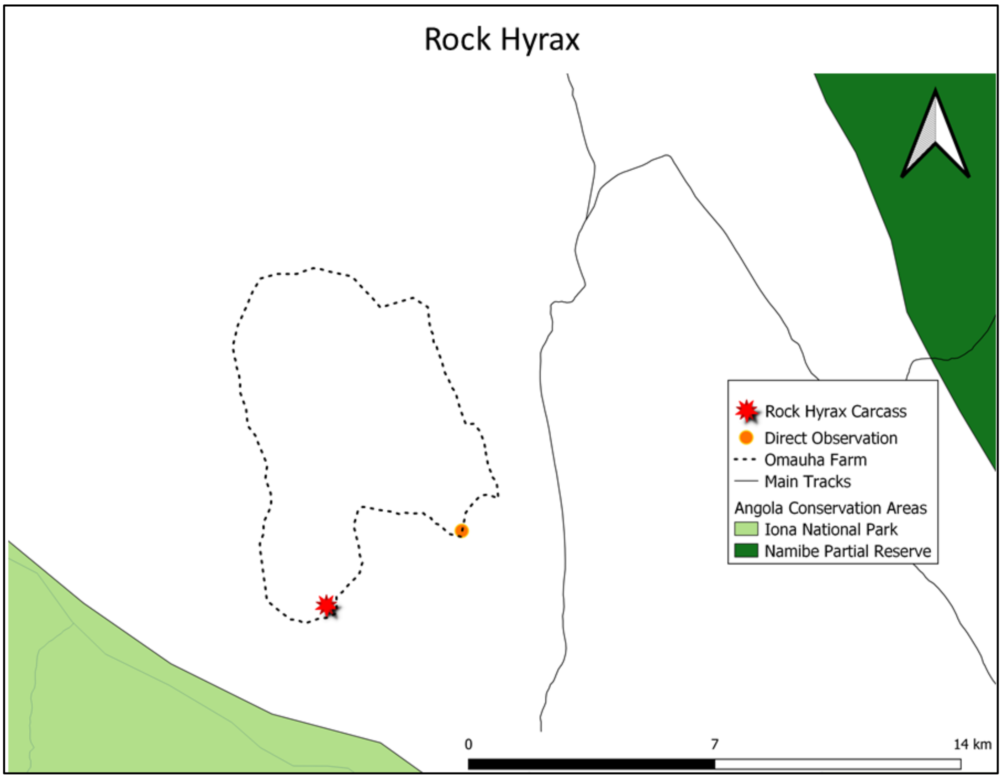

Figure 52. Map of the direct sight and carcass location of rock hyrax within the survey area.

3.2.3.8. Springbok *Antidorcas marsupialis* (Zimmermann, 1780)

Springbok (Figure 53, 54) was recorded throughout the survey area, especially in the western half where it occurred in relatively high abundance (Figure 55). This species was captured in 115 independent events (of those, two had gemsbok and springbok together) on 68% of the trap stations, being the more representative species (23 camera trap sites; Figure 55; Table 1). Based on both camera trap record and direct/indirect observations, there were more records of this species near and inside the Omauha Farm (28,8%) and near Espinheira (15,5%) (Figure 55, 56). Most of the capture events come from stations located at the habitat classified as Namibe savanna. It was also possible record direct observation of individuals but mostly of herds (Table 6) at almost all our displacements, especially in the western zone (Figure 56; Table 36). Inside the Omauha Farm it was also recorded 37 springbok carcasses being mostly of them near the fence (Figure 56; Table 37). Some of these carcasses were fresh but most of them were just bones. Farm owners stated that springboks inside the farm are frequently killed by cheetahs and leopard (but mostly the first).

Figure 53. Photo taken by David Elizalde of a single springbok in the habitat classified as Namibe savanna (11th November 2019).

Figure 54. Image of a springbok herd on site 36 located at the habitat classified as Namibe savanna.

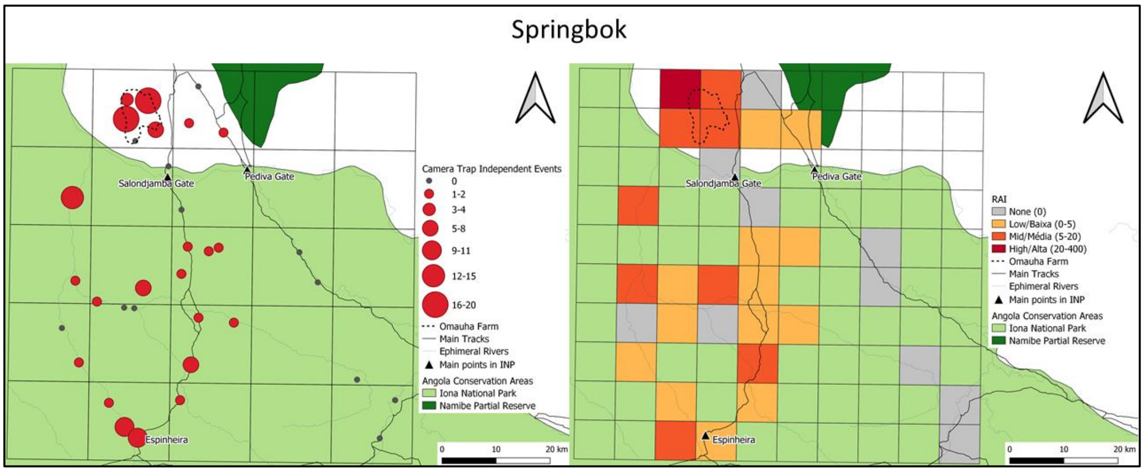

Figure 55. Map of camera trap independent events (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of springbok within the survey area (right).

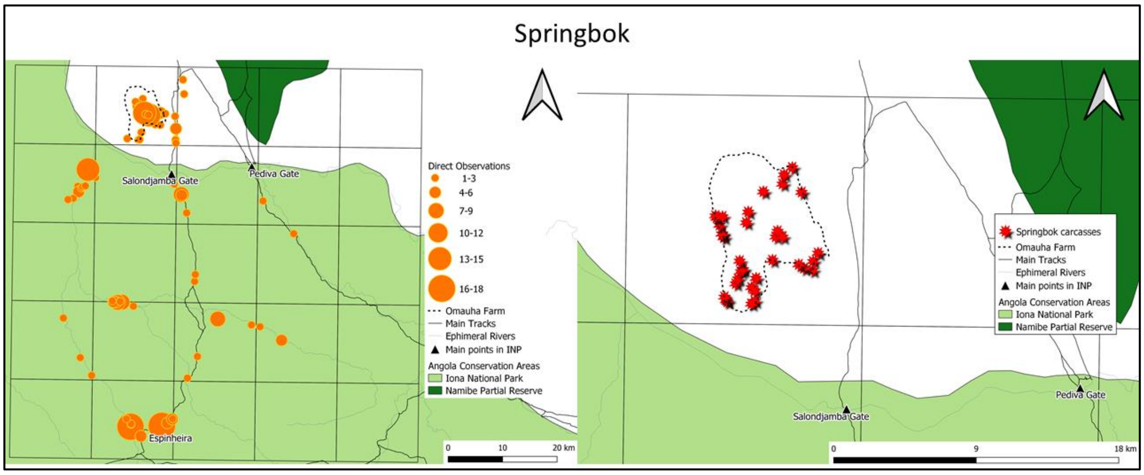

Figure 56. Map with the direct observations(left) and the locations of the thirty-seven carcasses of springbok found inside the Omauha farm (right).

Table 5. Statistic values of the number of individuals found together in springbok herds in each record of both camera trap and direct sightings.

Springbok Herds				
Max	Min	Average	1st Quartile	3rd Quartile
170	1	4,78125	1	6

3.2.3.9. Steenbok *Raphicerus campestris* (Thunberg, 1811)

Steenbok (Figure 57, 58) was mostly recorded in the south center of the survey area, especially near the ephemeral rivers, in dry riverbeds and seems to be distributed in a horizontal line that divides the survey area (Figure 59). The species was captured in 29 independent events of single individuals or in monogamous pair (Table 7), on 32% of the trap stations (11 camera trap sites; Figure 59; Table 1). Most of the capture events were from stations located at the habitat classified as dry riverbed, valleys and hills (Figure 59, Table 38). Direct observations of some individuals and pairs were also recorded mostly in the west center of our survey area but also east of the farm and near Espinheira (Figure 59; Table 39).

Figure 57. Image of a female steenbok grazing on site 32.

Figure 58. Image of a female steenbok walking on site 22 located at the habitat classified as dry riverbed, valleys and hills.

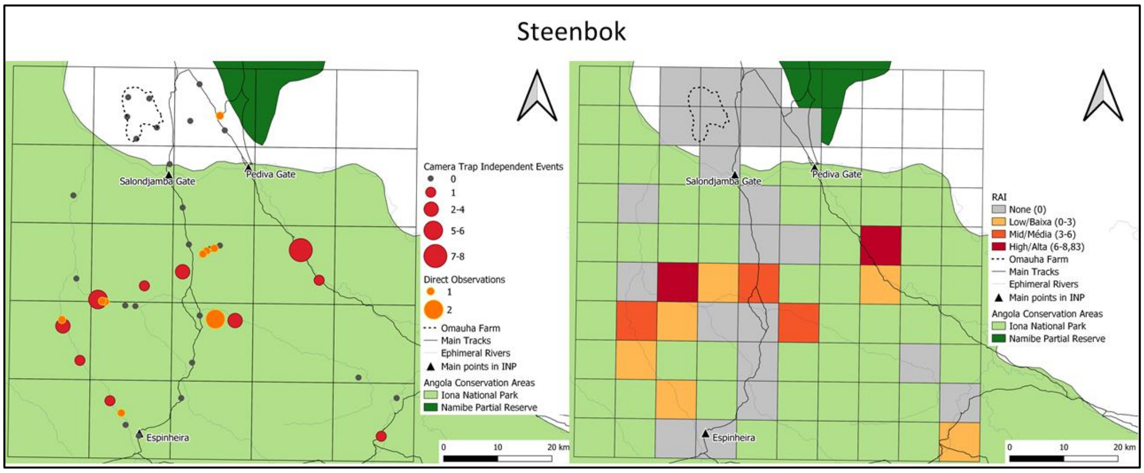

Figure 59. Map of independent events and direct sightings (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of steenbok within the survey area (right).

Table 6. Statistic values of the number of individuals found together in steenbok herds in each record of both camera trap and direct sightings.

Steenbok individuals found together				
Max	Min	Mean	1st Quartile	3rd Quartile
2	1	1,102564	1	1

3.2.4. Primates

3.2.4.1. Chacma baboon *Papio ursinus* Shortridge, 1942

The Chacma baboon (Figure 60) was mainly recorded in the northern central region of the survey area, in 9 independent events of single individuals or troops of three to four animals (Figure 61; Table 40) on 9% trap stations (three camera trap sites; Table 1). Only one of the recorded events was from a camera trap station located in the habitat classified as Namibe savanna being all the remnant events from stations located in the dry riverbed, valleys and hills habitat (Figure 61; Table 40). It was also possible to record direct observations of several individuals inside the Omauha farm and near the Salondjamba gate (Figure 61; Table 41).

Figure 60. Images of tree adult chacma baboons and one cub holding their mother on site 28.

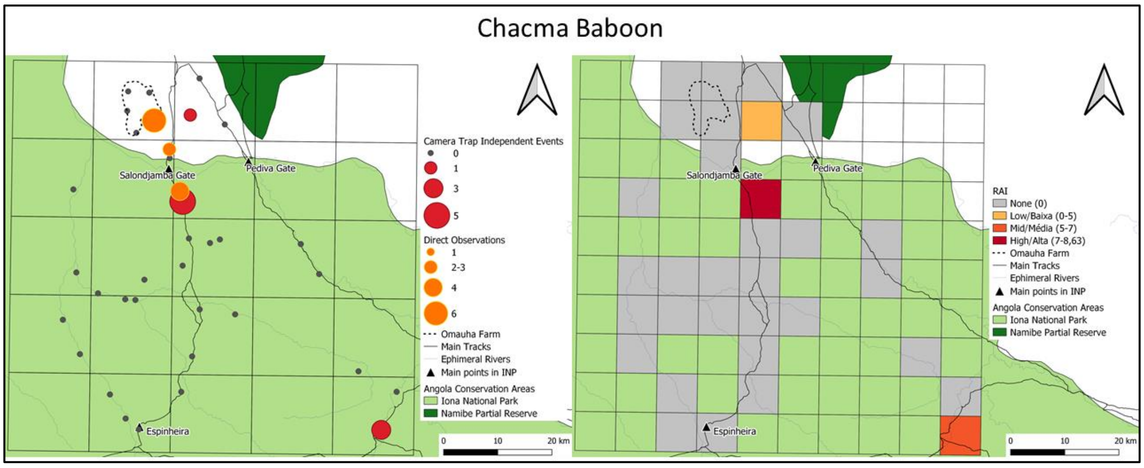

Figure 61. Map of independent events and direct sightings (left) and relative abundance index (number of camera trap captures per 100 camera trap nights) of chacma baboon within the survey area (right).

3.2.4.2. Malbrouck monkey *Chlorocebus cynosurus* (Scopoli, 1786)

The Malbrouck monkey (Figure 62) was not recorded in any camera trap stations, however it was possible to observe some individuals outside the survey area, in the southeastern border region of the INP (Table 42).

Figure 62. Photo taken by Solange Nunes of a malbrouck monkey found outside the survey area (17th November 2019).

3.3. Domestic Animals and Human Settlements

In INP there is two main ethnic groups, the Himba and Mucubal people. Both are nomad and builds human settlements and corrals in their stops, which are not permanently used (Morais *et al.* 2019a). During the survey, a wide presence of active and non-active human settlements (Table 51) and cattle (Figure 63) were recorded. These cattle stocks were mainly represented by cows (Table 46, 47), donkeys (Table 48, 49) and goats ((Figure 64; Table 43, 44) but also other domestic animals like, horses (Table 50) and sheep (Table 45). A total of 20 independent occurrences of cow, nine of donkey, seven of goat, four of horse and 20 of dogs were recorded, all that images resulting in 60 independent events on 35% trap stations (Figure 65, 66).

Figure 63. Images of domestic animals and human settlements inside the survey area.

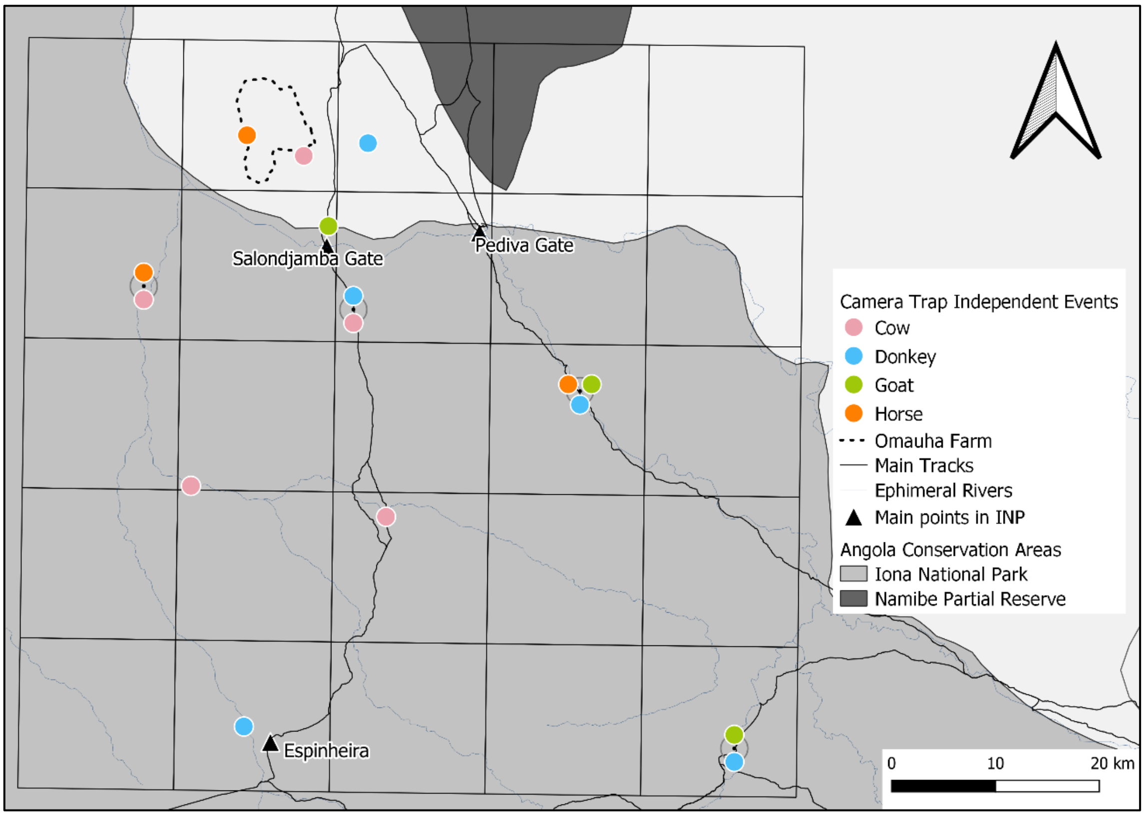

Figure 64. Maps of camera trap independent events of all the domestic animals recorded within the survey area.

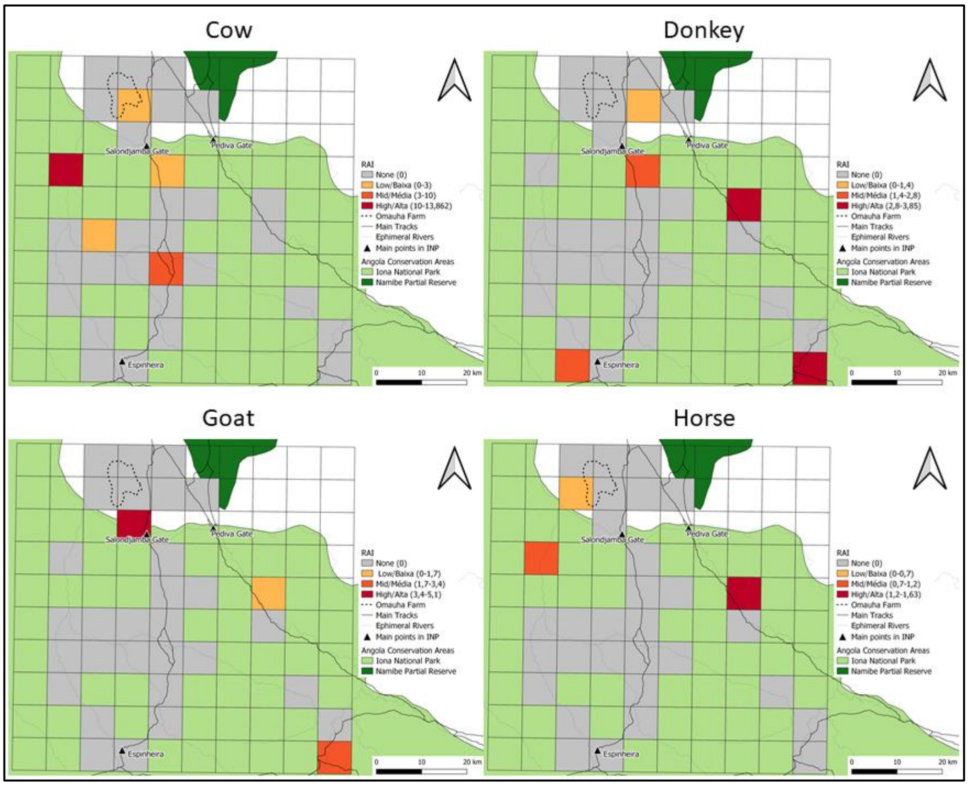

Figure 65. Maps of relative abundance index (number of camera trap captures per 100 camera trap nights) of all the domestic animals recorded within the survey area.

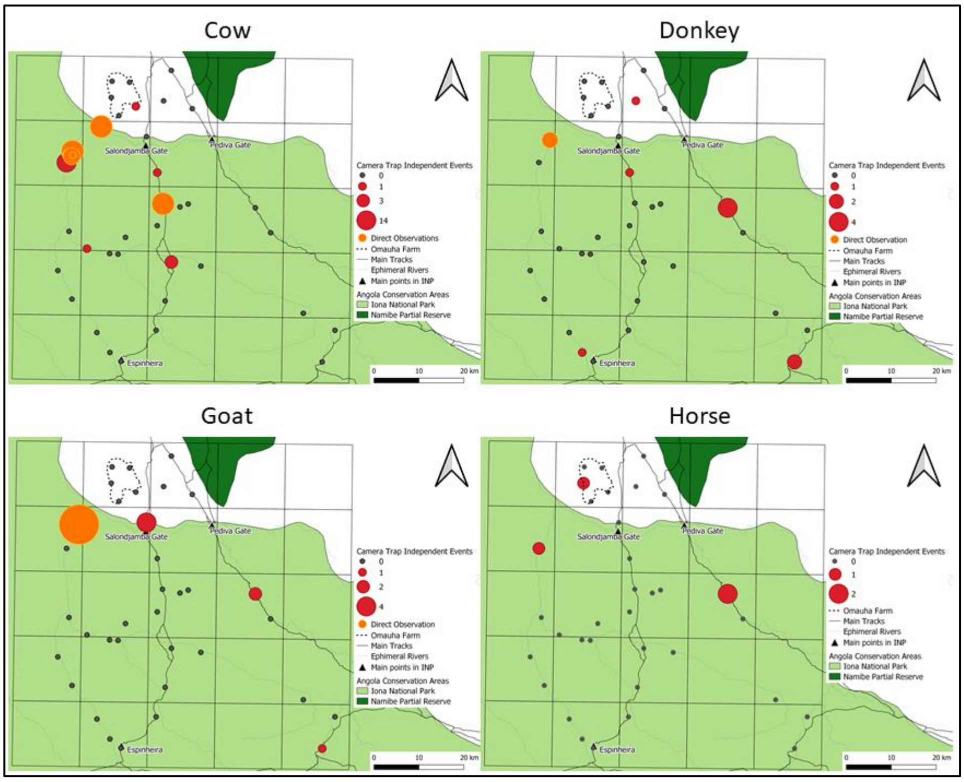

Figure 66. Maps of independent events and direct sightings of all the domestic animals recorded within the survey area.

3.4. Spatial interactions between wild and domestic species

Species recorded were clustered into six guilds (domestic species, large carnivores, primates, mesocarnivores, ungulates and lagomorpha) and their recorded presence shows different spatial interactions and distribution patterns (Figure 67). Large carnivores were only detected in the western region of the survey area while mesocarnivores are evenly distributed in the survey area. The domestic fauna seems to be dispersed through the survey area, however there were more records in the northern region. Primates were mainly detected in the northern region of the survey area, in the Omauha farm vicinities and the Salondjamba gate, however this group was also recorded at the most southeastern end of the survey area. Lagomorphs were mostly detected in the western-central region of the survey area while ungulates were the most recorded guild, being detected in 29 of the 31 camera trap stations that had records.

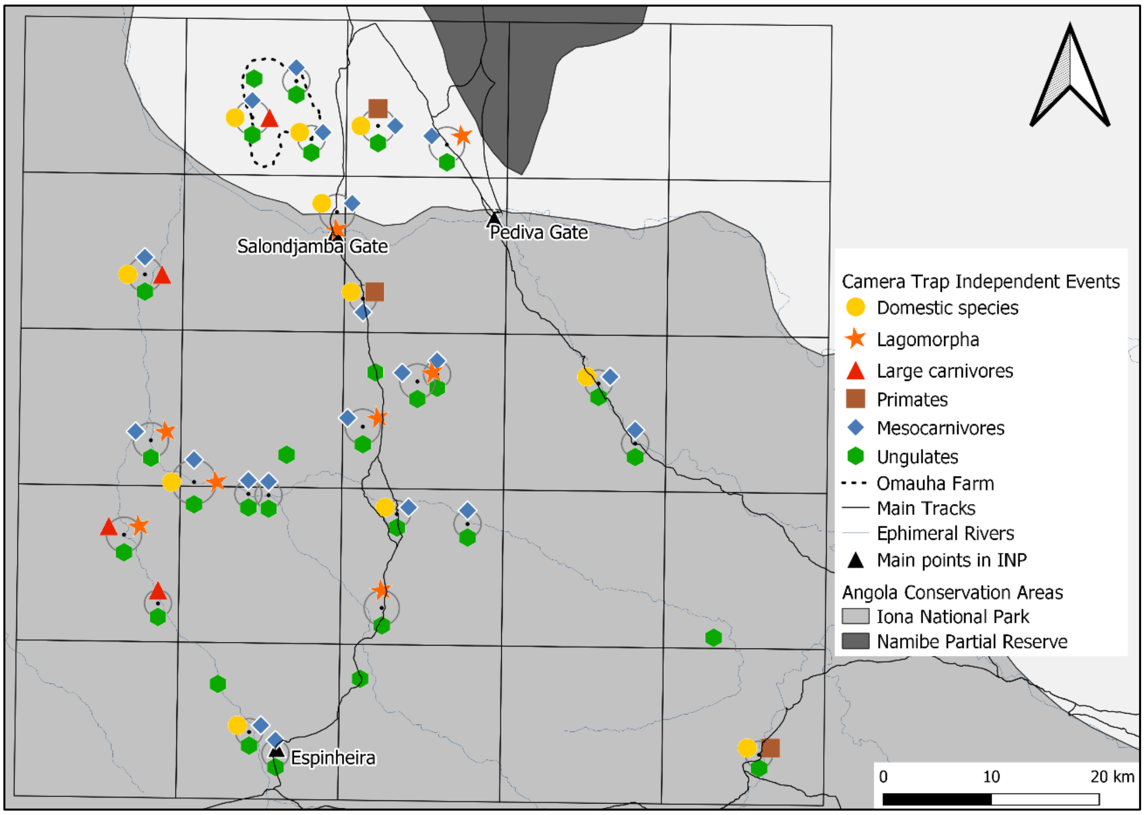

Figure 67. Camera trap independent events of each group of animals within the survey area.

4. Discussion:

This study was subject of several limitations that need to be taken into account when interpreting results, namely the very short field session, the bigger sampling effort during the wet season, the cameras inside the park did not work all the time, the relatively low number of camera traps across a vast area, the camera trap design targeting only medium to large animals, the biggest effort during daytime, the fact that only two habitats were covered and the limited data yielded that did not allow more detailed and sophisticated analyses. Besides these limitations, this study was firstly designed to survey large carnivores like cheetahs and leopards and for that reason some habitats might have been compromised together with their species which led to an inappropriate survey of small animals, like genets, mongooses and rodents. Due to their small size, cryptic behavior and the fact that we did not drive to observe species at night, most of these animals were not detected. With these limitations the data obtained was not robust enough to perform some data analysis that were intended at the beginning of the study, such as the distance sampling. For that reason, although some initial conclusions can be extracted from the results, these should be considered preliminary and must be carefully interpreted. Nevertheless, the results of this study can provide useful data to inform the design of subsequent studies.

Data was recorded for eight species of mesocarnivores, four species of large carnivores, ten species of ungulates and lagomorpha, two species of primates and five species of domestic animals. Some of the reported species are globally classified as vulnerable according to IUCN Red List, like cheetah, leopard and mountain zebra (IUCN 2020). Several species that were historically recorded inside the park, but their presence was not detected in this study. Some of these can be considered as locally extinct, like African wild dog, lion, plains zebra, southern white rhinoceros, savanna elephant, south-western black rhinoceros and, giraffe, while other might have come undetected due to some fails in the camera trap implementation settings and locations or due to their distribution in the park being different from the survey area (common warthog, and common impala) (Beja *et al.* 2019; Crawford- Cabral & Veríssimo 2005; Crawford-Cabral & Simões 1988; Freixial 2020).

The distributions and relative abundances of the detected species may be related, among other factors, with the available resources inside the area, the interspecific competition, the different types of habitats, the different species characteristics and the human activities (Gandiwa 2014). It is also possible that this harsh climate of desert can lead species to be less conspicuous and so, it can also make it difficult to detect them (Davimes *et al*. 2017). This can potentially be the case for species like leopard and cheetah in this survey. Some species like springbok are more common than other like mountain zebras and this may be related to the last one being more hunted in the past for being a major source of food, for skin trade or for being captured for private farms but it also could be because zebras have slower reproduction rate than antelopes (Van der Westhuizen *et al.* 2017). Just like mountain zebra, dik-dik were also not too recorded in the survey area and these may be explained for the fact that this species makes latrines that are easily used by hunters to install snare traps.

Hunting and persecution may have also happened with lions, elephants and rhinos that as being big, iconic mammals and the two last one a source of ivory, were more explored and hunted during the colonial and war times (Braga-Pereira *et al*. 2020a; 2020b; Dudley *et al.* 2002). Among other factors, this may also have contributed to low densities of other large carnivores like leopards that may be killed in defense of humans and livestock, or for commercial trade, and at the same time, their preys were also being hunted for bushmeat, making it difficult for them to survive (Braga-Pereira *et al.* 2020a; 2020b; Dudley *et al.* 2002). The restrictions of this study have limited the analysis possibilities specially for low density and low detection rate species such as cheetah that need larger quantities of data to obtain reliable conclusions on their distribution and densities (Brassine & Packer 2015).

Among the mammals reported during our research, ungulates were the most represented group, with springbok and gemsbok being the species better represented within the survey area. We obtained few records of carnivores, which was somehow to be expected, due to the restriction mentioned above. In general, carnivores have often low detection rates even with intense camera trap sampling efforts (Gerber *et al*. 2011; Maffei *et al.* 2004), but their detection depends in many other factors like the habitat type, the local where camera traps are implemented, the heigh of camera traps from the ground and the camera setting choice and model (Sollmann *et al*. 2013). With the harsh conditions in INP, it is not expected to have high abundances of large carnivores and so, it is likely that the records obtained of cheetahs and leopards were the same individuals or the same familiar group. The increase of reports of cheetahs and leopard kills in Omauha farm could be related to an ecosystem imbalance due to the decline of other competitors such as lions or spotted hyenas or the higher abundances of preys in the Omauha surroundings (Marker *et al.* 2003; Durant 1998). However, this area may already be part of the home ranges of these predators before the creation of the farm. Most of the large carnivores' records come also from the farm which may be because the prey availability is much higher or simply because the distance between camera trap is much tight inside the farm.

Springbok were the species more recorded in the survey area and based on our direct sightings and camera trap data, this species' distribution is very patchy, and it seems to be correlated with rain and pasture availability (Bigalke 1972; Bergström & Skarpe 1999; Stapelberg *et al.* 2008). Inside the Omauha farm, the relative abundance of springbok is quite high as it were the area with more camera trap independent events (51 independent events) having the highest RAI of 4,40 records per 100 camera trap nights. With such relative abundance of springbok in the survey area, the predators may be attracted to this region and their prey consumption rate may also increase (Scogings & Sankaran 2020), which might explain the 32 springbok carcasses found inside the farm and the presence of cheetah and leopard inside the farm. The springbok carcasses found were mostly arranged along the fence (Figure 54), which may suggest that predators are using those fences to corner preys, working as a barrier which makes it impossible for them to escape (Davies-Mostert *et al.* 2013). Experienced farm workers mentioned that those carcasses were mostly killed by cheetahs based on the way they found carcasses when they were still fresh. Although obstacles can benefit preys increasing chances of prey escaping and survive during a predator pursuit, this only occurs when it is possible to move over or around those obstacles which is not the case of fences (Wheatley *et al*. 2020). In some reserves, fences are facilitating the prey capture hunting thus conferring a double advantage by reducing both the time expended hunting and the overall number of hunts (Davies-Mostert *et al*. 2013). These facilities combined with the quite high abundances of springbok inside the farm may be reducing the compensatory nature of cheetah predation by enabling them to catch a higher quantity of preys with less effort that otherwise they may not be able to kill (Davies-Mostert *et al.* 2013).

Regarding species richness inside the park, it is also possible to observe an apparent inverse correlation between the number of species and the longitude (Figure 7) that can be explained by two factors as the more people use of the east than the west and the fact that the habitat is more mountainous, rocky and hard in the east, which can make it harder to detect animals and less propitious for some species. In addition, mountainous and rocky areas are habitats where it is more difficult to detect animals, as it is more difficult to access them, compared to plains, for example, and usually the sampling effort is much less in these areas, not being properly sampled.

To preserve the diversity in Iona National Park it is important to decrease the negative impacts of livestock and human settlements which may compete for resources, cause landscape changes and persecution (Gordon 2018). The domestic fauna and human settlements seem to occur through all the survey area, although the livestock records obtained were mainly in the northwestern region (Figure 58). Cows and goats were more common to spot but donkeys were also quite frequently observed as they are the main means of locomotion of some people that inhabit in Iona. Feral dogs were also recorded within the survey area and might play a huge role on other small mammals occurring both inside and outside the park as they are known to kill wild species frequently (Drouilly *et al*. 2020; Potgieter *et al*. 2015). With the human presence inside the park as reality, it is crucial to plan accordingly when thinking in conservation strategies for this park (Dudley 2008).

The ecotourism could be a great tool to work towards conservation while increasing revenues from national parks, local communities, and surrounding farms. For example, some protected areas like Volcanoes National Park in Rwanda and the Kruger National Park have been growing with ecotourism (Brett 2018; Munanura *et al.* 2020) and some Namibian farmlands have been remarkably successful with it by providing accommodation to visitors who go there to see and know more about wildlife, while generating revenue for farm owners (Marker & Dickman 2004). But this conservation tool only provides success if it is effectively managed. Examples of an inadequate use of ecotourism in Kenya, prove that sometimes this tool can worsen the situation inside the parks (Drughi 2018). Although, if effectively managed, the ecotourism can bring benefits for both wildlife and local communities (Snyman 2012). The Torra Conservancy and Damaraland Camp partnership, in Namibia, shows that a partnership between local communities and a private investor can be positive for both (Snyman 2012). However, although it is good tool for conservation management, ecotourism should not be the only source of income of conservation areas due to its volatility that can be verified with the Covid-19 pandemic (Lindsey *et al*. 2020). This example showed how quickly tourism can cease to function and, therefore, protected areas must have other tools to achieve a good conservation management without tourist revenues (Lindsey *et al.* 2020). It has also been reported that management practices that involve communities are more effective in long-term conservation (Borrini *et al.* 2004). The involvement of the local communities in INP could certainly prove beneficial to the conservation of its mammalian fauna, as it would likely create opportunities that would support the local economy, as for example sustainable ecotourism. This is the recent approach of partnership between the international organization African Parks and the Instituto Nacional da Biodiversidade e Áreas de Conservação, which main objectives focus economic and conservational development of the park, through adequate conservation, ecotourism and other sustainable and the work with local communities (Woods 2020).

The INP surrounding farms can also benefit with the conservation of this protected area as it can attract tourists that can generate revenue for those farms. With this, it would be good if surrounding farms can also promote the conservation of protected areas as well as implement conservation strategies (Hansen & DeFries 2007). In some cases, the surroundings private reserves can work as buffer areas as it happens in the Kruger National Park (Venter *et al*. 2008). The fences between the park, the Limpopo National Park and all private reserves on the vicinities are being removed resulting in a semi-open system which will increase the available habitats and area for wildlife and decrease the negative human impacts that may occur outside the area (Hansen & DeFries 2007; Venter *et al*. 2008).

As the local population in the Iona National Park is nomadic (Morais *et al.* 2019a) (apart from a few government facilitated settlements such as Iona's commune), special care must be taken to not disrupt their traditional way of live, because fixing pastoralist population can have negative effects on the ecosystem (Groom & Western 2013; Western *et al.* 2009). Both direct displacement of livestock and the persisting grazing in the same grasslands decrease the vegetation growth rates and biomass which consequently reduce wildlife abundance (Groom & Western 2013; Western *et al.* 2009). These effects on vegetation were also stated during this survey where we record some specimens of *Welwitchia mirabilis* completely devoid of leaves that were probably eaten by cattle, based on the amount of cow dung around it (Figure 68). To avoid this to happen, the implementation of exclusion wired fences around *W. mirabilis* specimens can be a good solution to let these plants grow healthy and to keep livestock away (Marsh *et al*. 1990, Spooner *et al.* 2002).

Figure 68. Image of a specimen of *Welwitchia mirabilis* completely devoid of leaves.

According to IUCN (Dudley 2008), National Parks should deliver benefits to local communities and consider their needs. A healthy management of this area should provide work and educational opportunities that can be created through tourism (Dudley 2008). Nevertheless, the local communities' needs should not overlap with the conservation of the park, which is the main objective (Dudley 2008). A good conservation strategy can pass by providing some communal land for agricultural and livestock purposes in the surroundings of the park and the park fences should be improved to not allow people going inside without being noticed (Gandiwa *et al.* 2013).

Nowadays the preoccupation with environment and biodiversity is growing up but there is still a lot to do and to change. It is also necessary to invest in education of farm managers, rangers, communities and local authorities for them to know better and to preserve the local biodiversity of the park as well as make sure that local people are aware that large mammals are declining and that they play important roles on the environment (Snyman 2012). Large mammals have been decreasing their numbers in African protected areas since 1970 (Craigie *et al.* 2010) and this can have effects on local communities. They can benefit with their presence, whether they are carnivores or herbivores, from different ways. For example, with the loss of large predators, herbivore's populations can expand leading to a decrease on grass biomass, an alteration on nutrient cycling dynamic and on small rodent's populations (Ripple *et al*. 2014; Holdo *et al.* 2009). With less large predators, other mesocarnivores can proliferate and can also change the entire ecosystem (Ripple *et al*. 2014; Brashares *et al*. 2010).

Until now, no further camera trap studies have been conducted in INP and so, this research allows to obtain a current perspective of the park and to evaluate the dynamics between the groups of animals, as well as to rethink the possible strategies and appropriate mechanisms of conservation that can be applied. The results obtained also give rise to future studies, with longer duration of field work aiming to obtain more species records and different perspectives that can be possible to compared with this survey. As recommendations for future studies, the field work time should be longer, the sampling grid to set camera traps should be smaller, more habitats should be cover, specific groups of animals should be assessed separately, with specific sampling techniques, like live trapping sessions for small carnivores and complementary methods should also be implemented, as distance sampling, spoor searching and night spotlight transects.

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Appendix I – Record tables.

Table 7. Aardwolf – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.41946199	-16.28431597	Site 3	Namibe savanna	2
12.44194301	-16.35957104	Site 4	Dry riverbed, valleys and hills	6
12.50643899	-16.42531903	Site 6	Dry riverbed, valleys and hills	5
12.489314	-16.43147897	Site 7	Dry riverbed, valleys and hills	3
12.44184301	-16.47074701	Site 8	Namibe savanna	1
12.34304401	-16.73597599	Site 17	Namibe savanna	1
12.36593197	-16.75469999	Site 18	Dry riverbed, valleys and hills	1
12.47144203	-16.54668404	Site 21	Namibe savanna	1
12.53284399	-16.55525403	Site 22	Dry riverbed, valleys and hills	1
12.67848602	-16.48541199	Site 31	Dry riverbed, valleys and hills	1
12.45511299	-16.209481	Site 39	Namibe savanna	1
12.51492097	-16.22583702	Site 40	Dry riverbed, valleys and hills	3

Table 8. Aardwolf – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.50641668	-16.42530754	Direct sighting	1

Table 9. Black backed jackal – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.50643899	-16.42531903	Site 6	Dry riverbed, valleys and hills	2
12.29522098	-16.51878202	Site 12	Dry riverbed, valleys and hills	1
12.25770702	-16.48251504	Site 13	Dry riverbed, valleys and hills	2

Table 10. Black backed jackal – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12,27154657	-16,50908675	Direct sighting	1

Table 11. Cape fox – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.50643899	-16.42531903	Site 6	Dry riverbed, valleys and hills	4
12.34304401	-16.73597599	Site 17	Namibe savanna	2

Table 12. Cape Fox – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12,48348379	-16,43476069	Direct sighting	2
12,50602667	-16,425035	Direct sighting	2

Table 13. Caracal – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.67848602	-16.48541199	Site 31	Dry riverbed, valleys and hills	1
12.39716303	-16.22093202	Site 34	Namibe savanna	1

Table 14. Honey badger – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.3864249698	-16.21566600	Carcass	1

Table 15. Slender mongoose – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.48996833	-16.431575	Spoor	1

Table 16. Wild cat – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.44184301	-16.4707470	Site 8	Namibe savanna	1

Table 17. Zorilla – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.44184301	-16.47074701	Site 8	Namibe savanna	1

Table 18. Brown Hyena – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12,26111082	-16,4958441	Spoor	1
12,81004232	-16,7183547	Spoor	1

Table 19. Cheetah – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.25258299	-16.3384590	Site 2	Namibe savanna	1
12.23438001	-16.5645919	Site 14	Dry riverbed, valleys and hills	1
12.26388004	-16.6242550	Site 15	Namibe savanna	1

Table 20. Leopard – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.34586603	-16.2023080	Site 36	Namibe savanna	1

Table 21. Leopard – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12,48996833	-16,431575	Spoor	1

Table 22. Aardvark – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.25258299	-16.33845904	Site 2	Namibe savanna	1
12.44194301	-16.35957104	Site 4	Dry riverbed, valleys and hills	1
12.35995903	-16.53024604	Site 10	Dry riverbed, valleys and hills	1
12.34241897	-16.52918497	Site 11	Dry riverbed, valleys and hills	2
12.47144203	-16.54668404	Site 21	Namibe savanna	1
12.53284399	-16.55525403	Site 22	Dry riverbed, valleys and hills	1
12.646614	-16.43326197	Site 32	Dry riverbed, valleys and hills	2
12.39716303	-16.22093202	Site 34	Namibe savanna	1
12.34586603	-16.20230801	Site 36	Namibe savanna	1
12.38412397	-16.17061503	Site 38	Namibe savanna	2
12.45511299	-16.209481	Site 39	Namibe savanna	1

Table 23. Aardvark – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.34749103	-16.16848502	Spoor	1

Table 24. Dik-dik – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.37562698	-16.4951540	Site 9	Namibe savanna	2
12.74665997	-16.6540139	Site 26	Namibe savanna	7
12.51492097	-16.2258370	Site 40	Dry riverbed, valleys and hills	1

Table 25. Dik-dik – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12,49359	-16,55262	Direct sighting	2
12,65614167	-16,6154183	Direct sighting	2
12,760875	-16,661425	Direct sighting	1
12,73613	-16,5158516	Direct sighting	1
12,78343884	-16,7750976	Direct sighting	2
12,80276122	-16,5555334	Direct sighting	1

Table 26. Hare *sp.* – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.41946199	-16.2843159	Site 3	Namibe savanna	2
12.489314	-16.4314789	Site 7	Dry riverbed, valleys and hills	1
12.44184301	-16.4707470	Site 8	Namibe Savanna	1
12.29522098	-16.5187820	Site 12	Dry riverbed, valleys and hills	1
12.25770702	-16.4825150	Site 13	Dry riverbed, valleys and hills	5
12.23438001	-16.5645919	Site 14	Dry riverbed, valleys and hills	1
12.45831203	-16.6281579	Site 20	Namibe savanna	1
12.51492097	-16.2258370	Site 40	Dry riverbed, valleys and hills	1

Table 27. Hare *sp.* – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.21790427	-16.3760216	Direct sighting	1

Table 28. Klipspringer – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.34577299	-16.2018770	Carcass	1
12.340000	-15.68000	Direct sighting	1

Table 29. Kudu – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.489314	-16.4314789	Site 7	Dry riverbed, valleys and hills	2

Table 30. Mountain zebra – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.34241897	-16.5291849	Site 11	Dry riverbed, valleys and hills	1
12.29522098	-16.5187820	Site 12	Dry riverbed, valleys and hills	1
12.34586603	-16.2023080	Site 36	Namibe savanna	8
12.34749103	-16.1684850	Site 37	Namibe savanna	1

Table 31. Mountain zebra – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.36526448	-16.520103	Direct sighting	3
12.26590409	-16.503249	Direct sighting	2
12.26524822	-16.502383	Direct sighting	2
12.37370382	-16.200010	Direct sighting	2
12.37579287	-16.195124	Spoor	1
12.34208666	-16.736445	Spoor	1

Table 32. Gemsbok – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.35995903	-16.5302460	Site 10	Dry riverbed, valleys and hills	1
12.34241897	-16.5291849	Site 11	Dry riverbed, valleys and hills	11
12.29522098	-16.5187820	Site 12	Dry riverbed, valleys and hills	11
12.25770702	-16.4825150	Site 13	Dry riverbed, valleys and hills	5
12.23438001	-16.5645919	Site 14	Dry riverbed, valleys and hills	5
12.26388004	-16.6242550	Site 15	Namibe savanna	5
12.31595797	-16.6942050	Site 16	Namibe savanna	2
12.34304401	-16.7359759	Site 17	Namibe savanna	15
12.36593197	-16.7546999	Site 18	Dry riverbed, valleys and hills	8
12.43947999	-16.6896290	Site 19	Namibe savanna	1
12.39716303	-16.2209320	Site 34	Namibe savanna	13
12.34586603	-16.2023080	Site 36	Namibe savanna	7
12.34749103	-16.1684850	Site 37	Namibe savanna	2
12.38412397	-16.1706150	Site 38	Namibe savanna	10

Table 33. Gemsbok – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.33053444	-16.5226610	Direct sighting	3
12.29935769	-16.5208157	Direct sighting	2
12.29224693	-16.5168889	Direct sighting	3
12.28901141	-16.5149741	Direct sighting	13
12.28188383	-16.5115062	Direct sighting	1
12.26106072	-16.4963677	Direct sighting	1
12.25856387	-16.4877578	Direct sighting	1
12.38123287	-16.2009215	Direct sighting	12
12.37179263	-16.2010161	Direct sighting	1
12.38015822	-16.2006212	Direct sighting	1

12.38888851	-16.1982892	Direct sighting	6
12.33733167	-16.7264033	Direct sighting	2
12.33733167	-16.7264033	Direct sighting	5
12.35086167	-16.74623	Direct sighting	1
12.347385	-16.7313	Direct sighting	2
12.36500167	-16.754645	Direct sighting	2
12.39810833	-16.73776	Direct sighting	4

Table 34. Rock hyrax – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.39772043	-16.2204546	Direct sighting	9
-16.24030301	12.36173398	Carcass	1

Table 35. Springbok – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.25258299	-16.3384590	Site 2	Namibe savanna	13
12.452756	-16.4235439	Site 5	Namibe savanna	1
12.50643899	-16.4253190	Site 6	Dry riverbed, valleys and hills	1
12.489314	-16.4314789	Site 7	Dry riverbed, valleys and hills	1
12.44184301	-16.4707470	Site 8	Namibe savanna	1
12.37562698	-16.4951540	Site 9	Namibe savanna	8
12.34241897	-16.5291849	Site 11	Dry riverbed, valleys and hills	1
12.29522098	-16.5187820	Site 12	Dry riverbed, valleys and hills	1
12.25770702	-16.4825150	Site 13	Dry riverbed, valleys and hills	1
12.26388004	-16.6242550	Site 15	Namibe savanna	2
12.31595797	-16.6942050	Site 16	Namibe savanna	2
12.34304401	-16.7359759	Site 17	Namibe savanna	10
12.36593197	-16.7546999	Site 18	Dry riverbed, valleys and hills	9
12.43947999	-16.6896290	Site 19	Namibe savanna	1
12.45831203	-16.6281579	Site 20	Namibe savanna	7
12.47144203	-16.5466840	Site 21	Namibe savanna	2
12.53284399	-16.5552540	Site 22	Dry riverbed, valleys and hills	2
12.39716303	-16.2209320	Site 34	Namibe savanna	8
12.34586603	-16.2023080	Site 36	Namibe savanna	20
12.34749103	-16.1684850	Site 37	Namibe savanna	4
12.38412397	-16.1706150	Site 38	Namibe savanna	19
12.45511299	-16.209481	Site 39	Namibe savanna	1
12.51492097	-16.2258370	Site 40	Dry riverbed, valleys and hills	1

Table 36. Springbok – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.42480237	-16.24244	Direct sighting	1
12.42250321	-16.31968	Direct sighting	1
12.43445852	-16.33772	Direct sighting	9
12.42458022	-16.24386	Direct sighting	2
12.43758027	-16.34230	Direct sighting	1
12.35208228	-16.53040	Direct sighting	3
12.332636	-16.52344	Direct sighting	8
12.32492378	-16.52386	Direct sighting	8
12.32243703	-16.52354	Direct sighting	4
12.31771368	-16.52288	Direct sighting	5
12.31575397	-16.521348	Direct sighting	3
12.26060111	-16.619107	Direct sighting	2
12.28019267	-16.649755	Direct sighting	1
12.28024432	-16.649818	Direct sighting	1
12.4576119	-16.487602	Direct sighting	1
12.45758884	-16.487627	Direct sighting	2
12.4587728	-16.475759	Direct sighting	3
12.43517232	-16.339034	Direct sighting	6
12.42534924	-16.224156	Direct sighting	4
12.49737382	-16.5525121	Direct sighting	8
12.5553989	-16.5627384	Direct sighting	3
12.57015209	-16.5658905	Direct sighting	2
12.60729996	-16.5892642	Direct sighting	5
12.62827868	-16.4054205	Direct sighting	3
12.34161316	-16.2413400	Direct sighting	2
12.28691008	-16.3084547	Direct sighting	3
12.27282148	-16.3030615	Direct sighting	1
12.27320428	-16.3019438	Direct sighting	7
12.27387528	-16.2947459	Direct sighting	15
12.25636329	-16.3237008	Direct sighting	2
12.25786103	-16.3329727	Direct sighting	5
12.24846083	-16.3444052	Direct sighting	1
12.23950891	-16.3464630	Direct sighting	1
12.26255766	-16.3266653	Direct sighting	3
12.26489595	-16.3244033	Direct sighting	2
12.26930745	-16.3230050	Direct sighting	1
12.42391033	-16.2028514	Direct sighting	3
12.38968778	-16.2170193	Direct sighting	1
12.36073101	-16.2434684	Direct sighting	2
12.37129094	-16.1972919	Direct sighting	3
12.39790796	-16.1930864	Direct sighting	1
12.39901033	-16.1969498	Direct sighting	5
12.36827259	-16.1726337	Direct sighting	1

12.36046414	-16.1848262	Direct sighting	4
12.38969058	-16.2169978	Direct sighting	3
12.37344711	-16.1993599	Direct sighting	1
12.37909661	-16.2006758	Direct sighting	13
12.50595167	-15.9824166	Direct sighting	1
12.43946167	-16.164505	Direct sighting	1
12.43946167	-16.164505	Direct sighting	1
12.42542667	-16.2491766	Direct sighting	1
12.443825	-16.3695166	Direct sighting	2
12.3293	-16.5223816	Direct sighting	1
12.23149667	-16.55091	Direct sighting	1
12.33733167	-16.7264033	Direct sighting	3
12.34208667	-16.736445	Direct sighting	1
12.34208667	-16.736445	Direct sighting	2
12.346155	-16.7430616	Direct sighting	1
12.346155	-16.7430616	Direct sighting	1
12.34705833	-16.73843	Direct sighting	15
12.34705833	-16.73843	Direct sighting	18
12.34811667	-16.7344966	Direct sighting	1
12.34815833	-16.73351	Direct sighting	1
12.34021833	-16.7248066	Direct sighting	1
12.36500167	-16.754645	Direct sighting	6
12.39649167	-16.7383133	Direct sighting	6
12.39649167	-16.7383133	Direct sighting	15
12.40099667	-16.7368366	Direct sighting	170
12.41047167	-16.731905	Direct sighting	4
12.418885	-16.7253066	Direct sighting	2
12.418885	-16.7253066	Direct sighting	4
12.41899833	-16.7251516	Direct sighting	1
12.41899833	-16.7251516	Direct sighting	5
12.41975167	-16.7247	Direct sighting	2
12.44513833	-16.6544566	Direct sighting	1
12.46243167	-16.6172633	Direct sighting	1
12.57537667	-16.3487983	Direct sighting	1
12.39848333	-16.21794	Direct sighting	3
12.36583833	-16.23049	Direct sighting	1
12.36278333	-16.2430083	Direct sighting	1
12.35580667	-16.17771	Direct sighting	2
12.361415	-16.1860833	Direct sighting	1
12.37138333	-16.1973333	Direct sighting	14
12.373265	-16.1991933	Direct sighting	1
12.37804167	-16.2006683	Direct sighting	1
12.4070383333	-16.19844	Direct sighting	1
12.4374233333	-16.1397433	Direct sighting	1
12.4374233333	-16.1397433	Direct sighting	2

12.4011419992	-16.2101630	Carcass	1
12.398198023	-16.2151279	Carcass	1
12.39778697	-16.2204290	Carcass	1
12.3928040	-16.2191910	Carcass	1
12.38971101	-16.2170159	Carcass	1
12.37416	-16.214367	Carcass	1
12.36449	-16.2250959	Carcass	1
12.361841	-16.2305459	Carcass	1
12.363666	-16.2327009	Carcass	1
12.363780	-16.2386190	Carcass	1
12.36173398	-16.2403030	Carcass	1
12.3475150	-16.2390329	Carcass	1
12.34688	-16.238236	Carcass	1
12.345857	-16.236184	Carcass	1
12.352471	-16.228336	Carcass	1
12.3538480	-16.2253610	Carcass	1
12.355577	-16.22114	Carcass	1
12.35639696	-16.22010	Carcass	1
12.3567999	-16.219858	Carcass	1
12.3548159	-16.2148610	Carcass	1
12.34546797	-16.2010399	Carcass	1
12.34446298	-16.198900	Carcass	1
12.3444130	-16.198743	Carcass	1
12.3429269	-16.193634	Carcass	1
12.3411190	-16.189332	Carcass	1
12.340548969	-16.188060	Carcass	1
12.3446469	-16.18858	Carcass	1
12.35986598	-16.185851	Carcass	1
12.3587200	-16.19213	Carcass	1
12.376132	-16.20056	Carcass	1
12.3771629	-16.197187	Carcass	1
12.380137033	-16.169278	Carcass	1
12.381018	-16.163804	Carcass	1
12.385894982	-16.159544	Carcass	1
12.391407005	-16.1741650	Carcass	1
12.380146002	-16.2006039	Carcass	1
12.36881199	-16.173895	Carcass	1

Table 37. Steenbok – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.44184301	-16.4707470	Site 8	Namibe savanna	3
12.37562698	-16.4951540	Site 9	Namibe savanna	1
12.34241897	-16.5291849	Site 11	Dry riverbed, valleys and hills	1
12.29522098	-16.5187820	Site 12	Dry riverbed, valleys and hills	6
12.23438001	-16.5645919	Site 14	Dry riverbed, valleys and hills	3
12.26388004	-16.6242550	Site 15	Namibe savanna	1
12.31595797	-16.6942050	Site 16	Namibe savanna	1
12.53284399	-16.5552540	Site 22	Dry riverbed, valleys and hills	3
12.78606297	-16.7556840	Site 28	Dry riverbed, valleys and hills	1
12.67848602	-16.4854119	Site 31	Dry riverbed, valleys and hills	1
12.646614	-16.4332619	Site 32	Dry riverbed, valleys and hills	8

Table 38. Steenbok – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.48347907	-16.4347629	Direct sighting	1
12.49694986	-16.4301341	Direct sighting	1
12.30800124	-16.5227317	Direct sighting	1
12.30252084	-16.5216049	Direct sighting	1
12.2327587	-16.5537436	Direct sighting	1
12.49472742	-16.5516792	Direct sighting	1
12.47705333	-16.4400466	Direct sighting	1
12.33553667	-16.7152933	Direct sighting	1
12.49857667	-16.5527683	Direct sighting	2
12.506465	-16.2004783	Direct sighting	1

Table 39. Chacma baboon - camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.44194301	-16.3595710	Site 4	Dry riverbed, valleys and hills	5
12.78606297	-16.7556840	Site 28	Dry riverbed, valleys and hills	3
12.45511299	-16.209481	Site 39	Namibe savanna	1

Table 40. Chacma baboon – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12,41972768	-16,26697172	Direct sighting	1
12,41916648	-16,26811314	Direct sighting	1
12,41885881	-16,26898791	Direct sighting	2
12,41885235	-16,2689835	Direct sighting	3
12,4370711	-16,34166432	Direct sighting	4
12,39250167	-16,218925	Direct sighting	6

Table 41. Malbrouck monkey – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
13.2892	-16.9908	Direct sighting	4

Table 42. Goat – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.41946199	-16.2843159	Site 3	Namibe savanna	4
12.36593197	-16.7546999	Site 18	Dry riverbed, valleys and hills	1
12.646614	-16.4332619	Site 32	Dry riverbed, valleys and hills	2

Table 43. Goat – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.9345307	-16.8463435	Direct sighting	100
12.27869195	-16.2885738	Direct sighting	50

Table 44. Sheep – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
13.17355537	-16.8363899	Direct sighting	200

Table 45. Cow – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.25258299	-16.3384590	Site 2	Namibe savanna	14
12.44194301	-16.3595710	Site 4	Dry riverbed, valleys and hills	1
12.29522098	-16.5187820	Site 12	Dry riverbed, valleys and hills	1
12.47144203	-16.5466840	Site 21	Namibe savanna	3
12.39716303	-16.2209320	Site 34	Namibe savanna	1

Table 46. Cow – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.45405468	-16.4249512	Direct sighting	20
12.32494721	-16.2633264	Direct sighting	20
12.26512754	-16.3153480	Direct sighting	20
12.25675455	-16.3221572	Direct sighting	10
12.26330051	-16.3255081	Direct sighting	15
12.26603513	-16.3230308	Direct sighting	4

Table 47. Donkey – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent events
12.44194301	-16.3595710	Site 4	Dry riverbed, valleys and hills	1
12.34304401	-16.7359759	Site 17	Namibe savanna	1
12.78606297	-16.7556840	Site 28	Dry riverbed, valleys and hills	2
12.646614	-16.4332619	Site 32	Dry riverbed, valleys and hills	4
12.45511299	-16.209481	Site 39	Namibe savanna	1

Table 48. Donkey – opportunistic observations.

Longitude	Latitude	Observation category	Number of animals
12.27560568	-16.2915535	Direct sighting	3

Table 49. Horse – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent records
12.25258299	-16.3384590	Site 2	Namibe savanna	1
12.646614	-16.4332619	Site 32	Dry riverbed, valleys and hills	2
12.34586603	-16.2023080	Site 36	Namibe savanna	1

Table 50. Humans and dogs – camera trap records.

Longitude	Latitude	Station	Habitat	Number of independent records
12.41946199	-16.2843159	Site 3	Namibe savanna	15
12.36593197	-16.7546999	Site 18	Dry riverbed, valleys and hills	2
12.646614	-16.4332619	Site 32	Dry riverbed, valleys and hills	3

Table 51. Geographical coordinates and elevation of each camera trap site.

Sites	Longitude	Latitude	Elevation (m)	Habitats
Site 1	12.27270903	-16.29945603	237	Dry riverbed, valleys and hills
Site 2	12.25258299	-16.33845904	246	Namibe savanna
Site 3	12.41946199	-16.28431597	236	Namibe savanna
Site 4	12.44194301	-16.35957104	284	Dry riverbed, valleys and hills
Site 5	12.452756	-16.42354399	374	Namibe savanna
Site 6	12.50643899	-16.42531903	402	Dry riverbed, valleys and hills
Site 7	12.489314	-16.43147897	431	Dry riverbed, valleys and hills
Site 8	12.44184301	-16.47074701	409	Namibe savanna
Site 9	12.37562698	-16.49515403	363	Namibe savanna
Site 10	12.35995903	-16.53024604	332	Dry riverbed, valleys and hills
Site 11	12.34241897	-16.52918497	329	Dry riverbed, valleys and hills
Site 12	12.29522098	-16.51878202	307	Dry riverbed, valleys and hills
Site 13	12.25770702	-16.48251504	290	Dry riverbed, valleys and hills
Site 14	12.23438001	-16.56459197	320	Dry riverbed, valleys and hills
Site 15	12.26388004	-16.62425503	348	Namibe savanna
Site 16	12.31595797	-16.69420503	388	Namibe savanna
Site 17	12.34304401	-16.73597599	418	Namibe savanna
Site 18	12.36593197	-16.75469999	438	Dry riverbed, valleys and hills
Site 19	12.43947999	-16.68962901	492	Namibe savanna
Site 20	12.45831203	-16.62815798	433	Namibe savanna
Site 21	12.47144203	-16.54668404	383	Namibe savanna
Site 22	12.53284399	-16.55525403	411	Dry riverbed, valleys and hills
Site 23	12.58566801	-16.57737002	452	Namibe savanna

Site 24	12.62149201	-16.61079898	482	Dry riverbed, valleys and hills
Site 25	12.67763802	-16.61805301	518	Dry riverbed, valleys and hills
Site 26	12.74665997	-16.65401397	592	Namibe savanna
Site 27	12.81280903	-16.68966397	614	Namibe savanna
Site 28	12.78606297	-16.75568403	665	Dry riverbed, valleys and hills
Site 29	12.80739499	-16.55807002	472	Dry riverbed, valleys and hills
Site 30	12.73604999	-16.51150804	417	Dry riverbed, valleys and hills
Site 31	12.67848602	-16.48541199	390	Dry riverbed, valleys and hills
Site 32	12.646614	-16.43326197	346	Dry riverbed, valleys and hills
Site 33	12.47118898	-16.145902	419	Namibe savanna
Site 34	12.39716303	-16.22093202	355	Namibe savanna
Site 35	12.36173398	-16.24030301	294	Namibe savanna
Site 36	12.34586603	-16.20230801	276	Namibe savanna
Site 37	12.34749103	-16.16848502	281	Namibe savanna
Site 38	12.38412397	-16.17061503	323	Namibe savanna
Site 39	12.45511299	-16.209481	416	Namibe savanna
Site 40	12.51492097	-16.22583702	325	Dry riverbed, valleys and hills

Appendix II – Images of the most representative habitats found in the survey area.

Figure 69. Images of Namibe savannas in the survey area.

Figure 70. Images of sandy dry riverbed (left) and rocky dry riverbed (right) founded inside the INP.

Figure 71. Images of desert dunes near the Omauha farm.

Figure 72. Images of mountain habitat in INP.

Figure 73. Images of rocky savannas in the survey area.

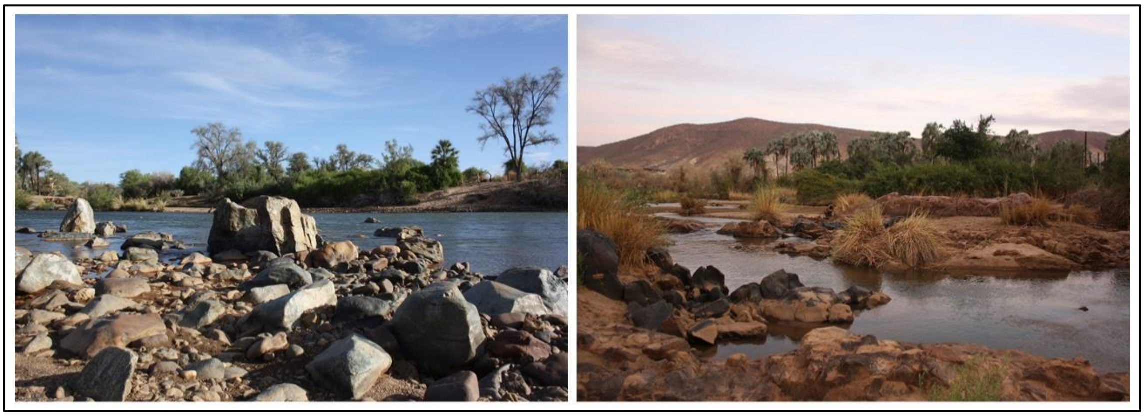

Figure 74. Images of the Cunene river which was not covered by the survey area.

Figure 75. Images of rocky outcrops in Namibe savannas.