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EXPEDITION REPORT

Expedition dates 2012:
29 July – 16 November

Report published: September 2013

A game of cats & elephants: safeguarding big cats, elephants and other species of the African savannah, Namibia

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A game of cats & elephants: safeguarding big cats, elephants and other species of the African savannah, Namibia

Expedition dates 2012:
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Authors:
Kristina Killian
Biosphere Expeditions

Jörg Melzheimer
Biosphere Expeditions

Matthias Hammer (editor)
Biosphere Expeditions

Abstract

This research project started in 2010 and was based on a game farm, Ongos, situated 15 km northwest of Windhoek, in the Khomas region of central Namibia. After two years of research, when Ongos was sold, the project moved to Okambara, another game farm located 85 km south of Windhoek's international airport, also in the Khomas region. Okambara is also game-fenced and comprises an area of 150 km^2. This report covers the survey work conducted during the period of July - November 2012. The key study species were the African leopard (*Panthera pardus*) and the African elephant (*Loxodonta africana)*. Leopards are protected animals and listed as "Near Threatened" by the IUCN (International Union for Conservation of Nature). However, the conservation of leopards outside of protected areas in Namibia is not assured. Their "problem predator" image and high trophy value, together with habitat loss, habitat fragmentation and local outbreaks of wildlife diseases, are the main threats. These threats and the lack of scientific data on this species living on commercial farmland demonstrate the need for research.

The basic questions that this study addressed were: What is the behaviour and ecology of leopards living on commercial farmland, particularly game farms? Are there any differences in the ecology of leopards found in protected areas and national parks? Active and passive methods were used to answer these questions. Passive methods included camera traps, spoor counts, and faeces collection; active methods included GPS/GSM telemetry.

Data collected on Okambara were added to the Ongos dataset. Data showed differences in the ecology of leopards living on farmland and in protected areas. Home range sizes differed between the study sites and were bigger than those of leopards living in protected areas. This is an interesting and surprising result, and the null hypothesis that high prey animal density with restricted movement, as is the case on fenced game farms, results in smaller home ranges for leopards is rejected.

The camera trap surveys on Okambara yielded a density of 1.3 individuals per 100 km^2. This is a lower density than on the previous Ongos study site with 2.7 individuals per 100 km^2 and the 2.5–3.8 individuals per 100 km^2 reported in the literature for protected areas. The camera trap surveys also revealed interspecific behaviour showing that different predator species avoid each other and therefore direct competition and conflict. Despite and indeed perhaps because of this, different strands of evidence show that the habitat on Okambara is suitable for the reproduction of different predator species.

Investigations on game species started on Okambara, as a core conservation area, and a variety of study methods were tested. With the limited dataset of one year, no conclusions could be reached and the aim is to develop and standardise methods applicable for game counts on a larger scale.

A study on elephant feeding ecology was also initiated and confirmed the importance of even a small herd of nine individuals as significant ecosystem engineers. This study has important implications for the increasing trend of stocking Namibian game farms with elephants and as such should be continued and expanded.

Zusammenfassung

Im Jahr 2010 startete dieses Forschungsprojekt auf der Wildtierfarm Ongos, 15 km nordwestlich von Windhoek, in der Khomas Hochland Region in Zentral-Namibia. Nach zwei Jahren Forschung auf Ongos wurde die Farm verkauft und der Forschungsschwerpunkt auf die Wildtierfarm, Okambara Game Reserve’ verlegt. Okambara umfasst 150 km^2 und befindet sich 85 km südlich von Windhoeks internationalen Flughafen, ebenfalls in der Region Khomas in Zentral-Namibia. Dieser Bericht befasst sich mit Untersuchungen, die dort im Zeitraum Juli - November 2012 durchgeführt wurden und vergleicht diese mit den Ergebnissen von Ongos. Fokus der Studie waren, wie bereits auf Ongos, der afrikanische Leopard (*Panthera pardus*), sowie ein weiteres Studientier, der afrikanische Elefant (*Loxodonta africana*). Der Leopard ist eine geschützte Art und als "potenziell gefährdet" von der IUCN (International Union for Conservation of Nature) eingestuft. Ein Großteil der namibischen Leopardenpopulation lebt auf kommerziell genutztem Farmland und somit außerhalb geschützter Gebiete. Dadurch ist die Erhaltung dieser Art in Namibia nicht gesichert. Ihr "Problem-Raubtier"-Status, ein hoher Trophäenwert, fortschreitender Verlust von Lebensraum, sowie Wildtierkrankheiten sind ihre stärksten Bedrohungen. Diese Bedrohungen und der Mangel an wissenschaftlichen Daten machen es sinnvoll und notwendig, diese Spezies im Lebensraum Farmland besser zu erforschen.

Die Fragestellungen des Projekts waren: Wie ist das Verhalten und die Ökologie von auf kommerziellem Farmland vorkommenden Leoparden? Weisen sie irgendwelche Unterschiede zu Leoparden in Schutzgebieten und Nationalparks auf? Zur Beantwortung wurden passive (Kamerafallenuntersuchungen, Analyse von Fährten und Kotproben) und aktive Methoden eingesetzt (GPS/GSM-Telemetrie).

Daten der beiden Studiengebiete Ongos und Okambara wurden zusammengefasst und zeigen, dass Leoparden, die auf kommerziell genutztem Farmland leben, sich in ihrer Ökologie deutlich von Leoparden unterscheiden, die in Schutzgebieten vorkommen . Die Leoparden-Streifgebiete auf Ongos und Okambara unterschieden sich voneinander und waren insgesamt größer als die in Schutzgebieten. Das ist ein interessantes und überraschendes Ergebnis. Die Testhypothese, dass die auf kommerziellem Farmland vorherrschende hohe Beutetierdichte und deren durch Zäune eingeschränkte Bewegungsfreiheit zu kleineren Leoparden-Streifgebieten führe, wurde nicht bestätigt.

Der Kamerafallenstudie zufolge weist Okambara eine geringe Leopardendichte von 1,3 Tieren pro 100 km^2 auf (Ongos 2,7 Tiere pro 100km^2). Aufnahmen der Kamerafallen, sowie Hinweise von Spuren und Kot zeigen, dass unterschiedliche Raubtierarten im Untersuchungsgebiet vorkommen (Leopard, Gepard, Wüstenluchs, Braune Hyäne, Honigdachs). Dies Raubtierarten vermeiden sich allerdings in Raum und Zeit und damit Konflikte. Damit ist Okambara ist ein geeignetes Habitat für deren Fortpflanzung und Bestand.

Verschiedene Wildtierzählungsmethoden wurden auf Okambara getestet. Das Ziel ist, ein Verfahren zu entwickeln und zu standardisieren, das einheitlich für Wildtierzählungen in größerem Maßstab, d.h. anwendbar von allen Farmbesitzern, geeignet ist.

Eine ernährungsökologische Studie von Elefanten wurde initiiert und bestätigte den wichtigen Einfluß selbst der kleinen Okambara-Herde von neun Tieren auf das Gesamtökosystem. In Namibia existiert eine zunehmde Tendenz, Wildtierfarmen mit Elefanten zu bestücken. Die angestossene Studie liefert hierfür wichtige Rückschlüsse und wird fortgesetzt.

Contents

Please note: Each expedition report is written as a stand-alone document that can be read without having to refer back to previous reports. As such, much of this section, which remains valid and relevant, is a repetition from previous reports, copied here to provide the reader with an uninterrupted flow of argument and rationale.

1. Expedition review

Matthias Hammer
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Our projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Our expeditions are open to all and there are no special skills (scientific or otherwise) required to join. Our expedition team members are people from all walks of life, of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

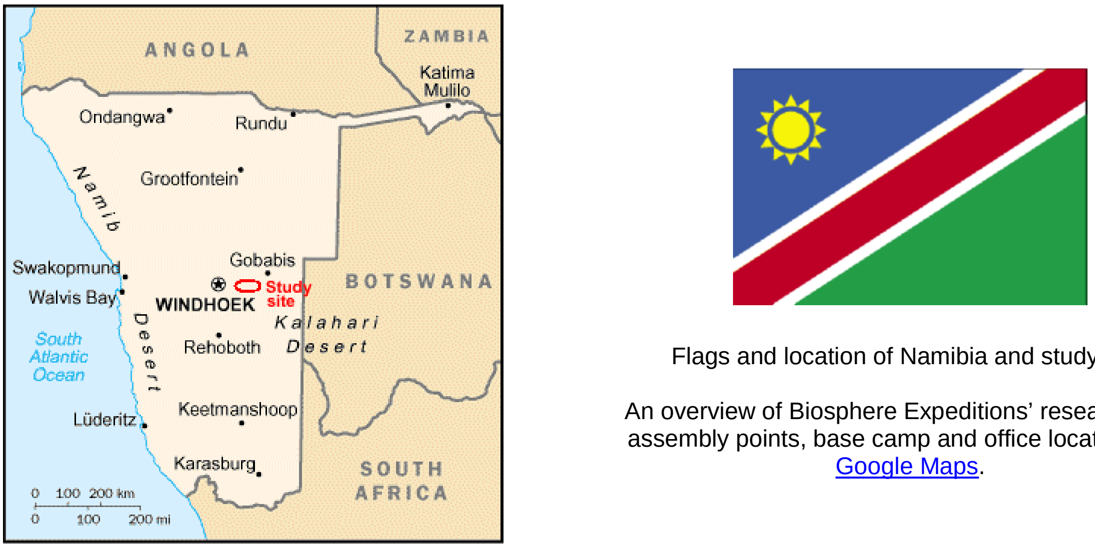
This expedition report deals with an expedition to Namibia that ran from 29 July to 16 November 2012. The expedition was part of a long-term research project and assisted the local scientist in ascertaining the status of the African leopard (*Panthera pardus* - Linnaeus 1758) living in parts of mountainous game farmland in the Khomas region of Namibia. The expedition's emphases were on capture activities, GPS-tracking, searching for leopard signs such as counting tracks and collecting scats, identifying individuals with the help of camera trap surveys, and on recording prey animals by hide-based observations at water points and on game study drives. Additionally, a herd of elephants was observed daily to obtain information about their feeding and social behaviour within the confines of the fenced farm area study site.

Namibia is one of a few African countries that support six species of large carnivores. Lions, spotted hyaenas and wild dogs are mainly restricted to protected areas, but cheetahs, leopards and brown hyaenas still occur on areas with intensive livestock and/or game farming. The leopard is currently not listed as an IUCN endangered species in Namibia. However, we believe that high trophy take-off together with "problem predator" take-off, combined with habitat loss and fragmentation, may put the local leopard population under threat. There is thus an urgent need to gain a better scientific insight into both leopard demographics and ecology outside protected areas in Namibia.

A good knowledge of leopard ecology on Namibian game farmland will help to conserve and protect the predator. No effective population density estimates exist, while removal through human conflict is poorly monitored and hunting quotas are set without reliable scientific basis. The Ministry of Environment and Tourism started a leopard study covering the whole of Namibia in 2011 with results outstanding.

1.2. Research area

At 825,418 km^2 Namibia is the world's thirty-fourth largest country (Figure 1.2a). However, after Mongolia, Namibia is the second least densely populated country in the world (2.5 inhabitants per km^2). About 40% of the total area in Namibia is used for commercial livestock farming, while communal areas comprise another 40% and national parks and restricted areas (Berry 1990) make up the remaining 20%. It is estimated that commercial farmland hosts about 80% of the commercially useable larger game species (Brown 1992) and also represents most important habitat types.

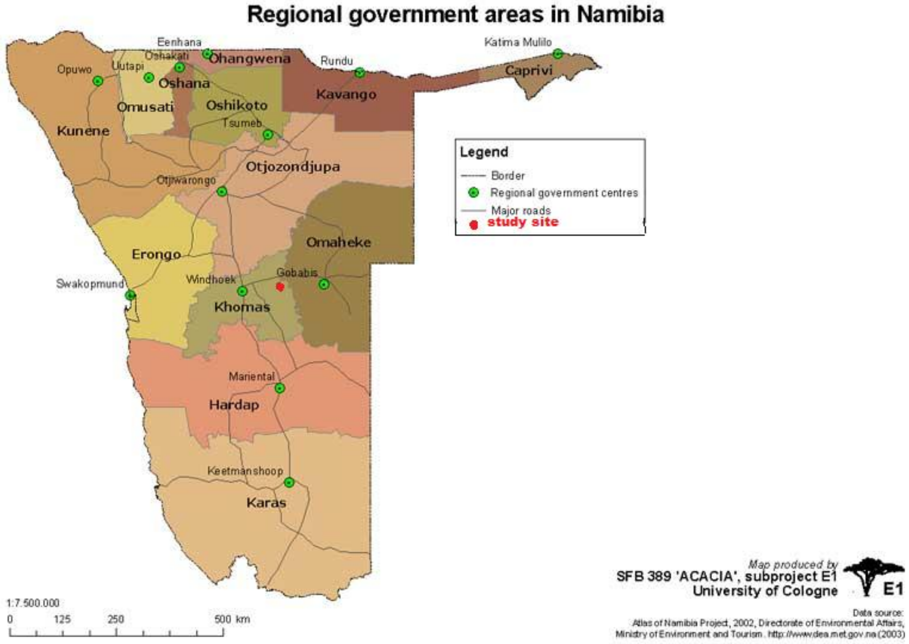


Flags and location of Namibia and study site.

An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at Google Maps.

Figure 1.2a. Map and flag of Namibia and location of study site.

The study area was centred on Okamabara Game Reserve in the Khomas region very close to the Omaheke region in the east (Figure 1.2b). The Khomas region spans 36,804 km² (Figure 1.2b; Mendelsohn 2009) and, due to the inclusion of Windhoek, Namibia's capital, has the highest human population of any region in Namibia.


Regional government areas in Namibia

Map produced by SFB 389 'ACACIA', subproject E1 University of Cologne E1

Data source: Atlas of Namibia Project, 2002, Directorate of Environmental Affairs, Ministry of Environment and Tourism. http://www.dea.met.gov.na (2003)

Figure 1.2b. Regional government areas and study site (red dot) in Namibia.

1.3. Dates

The expedition ran from July to November 2012, split into seven two-week groups:

29 July – 10 August | 12 – 24 August | 2 – 14 September | 16 – 28 September | 30 September – 12 October | 21 October – 2 November | 4 – 16 November 2012

All groups were composed of a team of international research assistants, guides, support personnel and an expedition leader (see below for team details).

1.4. Local conditions & support

Expedition base

The expedition team was based at the Okambara Bush Camp on the Okambara Game Reserve, about 85 km southeast of Windhoek's international Hosea Kutako airport, in the Khomas region. The camp (S 22.69227, E 18.21029) was situated in the southern part of the Reserve.

Team members stayed in chalets equipped with beds, mosquito nets, basic furniture and en-suite bathrooms. Breakfast and all meals were prepared by the expedition cooks, who could cater for vegetarians and some other special diets. Chalets had 220V mains electricity from European style sockets. There was also a communal building called lapa with a dining room, rest areas with sofas, and a fireplace with a view of a waterhole.

Weather

The climate is semi-arid savannah type with three distinct seasons. The hot, dry season runs from September to December when temperatures can reach 40º C or more during the day and plummet at night, sometimes to levels below zero. Second is a hot, wet season from January to April and third is a cold, dry season from May to August with warm days, which are contrasted by very cold nights, when temperatures often drop to below freezing. The expedition started at the end of winter in July/August 2012. Annual rainfall was highly variable. Average daily temperatures during the expedition ranged from 20 to 34º C. Daytime temperatures reached 42°C, and night-time 20°C.

Field communications

There was good mobile coverage around the camp but no coverage in the mountains. Regular expedition diary updates were uploaded to the Biosphere Expeditions blog, Facebook and Google+ for friends and family to access.

Transport & vehicles

Team members made their own way to the Windhoek assembly point. From there onwards and back to the assembly point all transport and vehicles were provided for the expedition team, for expedition support and for emergency evacuations.

Courtesy of Land Rover, and with the support of their local dealer in Windhoek, Novel Motor Company, the expedition had the use of one Defender 110 Station Wagon, two Defender 130 Double Cabs and one Defender 130 Single Cab. Team members wishing to drive the Land Rovers had to be older than 21, have a full clean driving licence and a new style EU or equivalent credit-card sized driving licence document. Off-road driving and safety training was part of the expedition.

Medical support and insurance

The expedition leader was a trained first aider and the expedition carried a comprehensive medical kit. Namibia’s healthcare system is of an excellent standard and the nearest doctor and hospital were in Windhoek. All team members were required to carry adequate travel insurance covering emergency medical evacuation and repatriation and emergency procedures were in place, but did not have to be invoked. There were some stomach upsets, but no serious medical incidents during the expedition.

1.5. Local scientists

Kristina Killian was born in Germany and studied biology at the University of Hamburg, Germany. Her research focus lies primarily on the ecology and behaviour of mammals and their conservation. Her interest in biodiversity has increased to include domestic animals and crops and the people that share the ecosystems with them. Amongst other things, she has investigated zebra herd behaviour, red deer and whale acoustics and the endangered Darwin’s fox (*Lycalopex fulvipes*) on Chiloé, Chile. She has travelled and worked in Spain, Australia, Argentina and Namibia. Her other big passion is horses and she has worked in a professional equestrian centre and travelled as a horse groom around Europe.

Jörg Melzheimer is a keen biologist and conservationist and runs different projects in Namibia. He was raised in the German countryside and developed his interest in nature early. He studied spatial ecology and conservation management at the University of Potsdam (Germany), Universidade Federal de Santa Catarina (Brazil), University of the Witwatersrand (South Africa) and the Free University of Berlin. Currently his main research focus is a cheetah research project of the Leibniz Institute for Zoo and Wildlife Research in Berlin, where he heads the spatial ecology working group, coordinates the project’s field work and acts as its PR and liaison manager, responsible for stakeholder involvement and media work. On the field science side he is involved in research on spatial ecology of cheetahs, leopards, wild dogs, brown hyaenas, kudus, oryx, jackals and bat-eared foxes. Jörg also chairs the management boards of two conservancies and is the talks & event coordinator of the Namibian Environmental and Wildlife Society (NEWS).

1.6. Expedition leaders

The 2012 expedition was led by three expedition leaders. The first group was led by Malika Fettak. Malika Fettak is half Algerian, but was born and educated in Germany. She majored in Marketing & Communication at the University of Frankfurt, which led her to jobs in PR & Communications. She has travelled widely, especially in Africa and Northern Europe. Her love of nature and the outdoors, and taking part in a few Biosphere expeditions, persuaded her that a change of career was in order and here she is since 2008, leading expeditions and making herself useful around the office. Malika is a keen sportswoman - triathlon, skiing, volleyball, etc. - and enjoys the outdoors.

The second group was led by Kathy Gill who was born and educated in England. Since gaining her BA in Business at Bristol, she has worked in sustainable development and regeneration for a variety of public sector organisations, most recently the Regional Development Agency for the East of England where she was responsible for developing and supporting partnership working to establish sustainable development activities. At the main office Kathy is also one of two Directors and is in charge of the UK organisation. She has travelled extensively, led expeditions and recceed projects all over the world. She is a qualified off-road driver, divemaster, marathon runner, keen walker, sailor, diver and all-round nature enthusiast.

From group three onwards Jennifer Kraushaar was the expedition leader. Jennifer Kraushaar qualified as a vet at the University of Giessen in Germany. As part of her training, she spent time at various wildlife clinics in Australia and Canada. Her work as a vet also took her to Asia where she spent some months working with injured elephants. Jennifer has also completed a one-year course in safari field guiding in South Africa. Her field work experience includes research on lions in the Greater Kruger National Park and hands-on chimpanzee work with the Jane Goodall Institute. Back in Europe, she has trained and treated sledge dogs in Norway. For Biosphere Expeditions she has been mainly involved with the Namibia big cat expedition, but also with many other projects.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of all ages, nationalities and backgrounds. They were (with countries of residence):

29 July – 10 August 2012: J. Elizabeth Colley (UK), Jonathan Colley (UK), Catherine McCosker (Australia), Brian Fredrich (USA), Kirsty Grant (New Zealand), Giles Heywood (UK), Stacy Hoover (USA), Sanya Krljes (UK), Frank Marks (USA), Robert Marks (USA), Philip Platts (New Zealand), Marilee Potthoof (USA).

12 – 24 August 2012: Jane Bean (Australia), Harald Bendl (Austria), Katie Bunting (UK), Alexandra Edhofer (Austria), John Highet (UK), Michal Nowakiewicz (Poland), Fritz Reichinger (Austria), Heike Saal (Germany), Ilka Schweda (Germany), Ulf Schweda (Germany), Ann Windle (UK), Ben Windle (UK).

2 – 14 September 2012: Hendrik Clasmeier (Germany), Andrew Collins (UK), Julia Collins (UK), Joshua Doherty (Australia), Derek Ho (USA), Terrence Leach (Australia), Sandra Lück (Germany), Brian Oikawa (Canada), John Rawnsley (UK), Ann Winterman (USA).

16 – 28 September 2012: Allyson Bailey (UK), Susan Brenner (USA), Linda Holt (USA), Sylvia Rogers (USA), Ginny Warren (UK).

30 September – 12 October 2012: Jean-Luc Czech (Switzerland), Anja Giles (Germany), Bob Hussey (UK), Susanne Koenig (Germany), Eva Kohl (Germany), Susanne Lichtenberger (Germany), Stefanie Parchmann (Germany), Michael Reitzle (Germany), Julia Stumpf (Germany), Catherine Thebault (France), Serge Thebault (France).

21 October – 2 November 2012: Karlene Bain (Australia), Helen Burling (UK), Susanne Haupt (Germany), Rod McGregor (UK), Michael Mitchell (USA), Jutta Nagel (Germany), Joanna Sanderson (UK), Malcolm Seyderhelm (Australia).

4 – 16 November 2012: Hendrik Duda (Germany), Mirjam Harmtodt (Austria; journalist), Ariane Holzhauer (USA), Jan Kelway (UK), Astrid Natus (Germany), Douglas O´Neill (USA), Christian Pschierer (Germany), Gigi Ragland (USA; journalist), Joerg Schoele (Germany).

1.8. Expedition budget

Each team member paid towards expedition costs a contribution of £1690 per two week slot. The contribution covered accommodation and meals, supervision and induction, all maps and special non-personal equipment, and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses such as telephone bills, souvenirs, etc., as well as visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how these contributions were spent are given below.

Income	£
Expedition contributions	105,994
Expenditure	
Staff includes local & international salaries, travel and expenses, living expenses	26,741
Research includes equipment, animal capture and other research expenses	5,719
Transport Includes bus transfers, fuel, car tax & maintenance	8,893
Base includes board, lodging and other base camp services	39,948
Administration includes office costs, visa & professional fees and miscellaneous costs	3,873
Team recruitment Namibia as estimated % of PR costs for Biosphere Expeditions	6,400
Income – Expenditure	**14,420**
Total percentage spent directly on project	**86%**

1.9. Acknowledgements

This study was conducted by Biosphere Expeditions, which runs wildlife conservation expeditions all over the globe. Without our expedition team members (listed above) who provided an expedition contribution and gave up their spare time to work as research assistants, none of this research would have been possible. The support team and staff (also mentioned above) were central to making it all work on the ground. Thank you to all of you and the ones we have not managed to mention by name (you know who you are) for making it all come true. Biosphere Expeditions would also like to thank Land Rover, Swarovski Optik and the Friends of Biosphere Expeditions for their sponsorship and/or in-kind support.

The author would like to thank the Namibian Government, the Namibian Tourism Board and the Ministry of Environment and Tourism in particular, for giving me the permission to conduct this study. My thanks also go to all expedition team members as well as staff members for their amazing effort. The expeditions in 2012 made a major contribution to the exploration and establishment of the new study site on Okambara. I am grateful to Land Rover for providing essential vehicle support. A special mention goes to staff at Novel Motors, the Land Rover dealer in Windhoek, especially Tony Bassingthwaighte and Martin Nell, for their patient and tireless help in dealing with the vehicles. I would also like to thank *mtc* Namibia for sponsoring SIM cards for the GPS/GSM collars. My thanks also go to Swarovski Optik for providing binoculars and to MOBE Radio for trying to repair equipment in the quickest time. I thank the Institute for Zoo and Wildlife Research in Germany for scientific advice and analysing blood samples. Special thanks go to Uschi and Christian Schmitt, for giving me permission to run the expedition on their property and for their cooperation and allowing me to live on Okambara, and to the lodge managers Maja and German Fug. I thank Jörg Melzheimer, Matthias Hammer, Vera Menges, Adam Stickler and the other reviewers for their comments on various versions of this manuscript. Last but not least, I would like to thank Biosphere Expeditions and every team member for the contribution that this expedition has made to large carnivore conservation in Namibia.

1.10. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Copies of this and other expedition reports can be accessed via www.biosphere-expeditions.org/reports. Enquires should be addressed to Biosphere Expeditions via www.biosphere-expeditions.org/offices.

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2. African leopard ecology on two Namibian game farms

Kristina Killian
Biosphere Expeditions

2.1. Introduction and background

This leopard research project started in 2010 on a game farm, Ongos, in the Khomas (Hochland) Region of central Namibia. Two years of fieldwork were completed (Killian and Hammer 2012) until the farm was sold. In March 2012 the research project moved to Okambara Game Reserve, located in the Khomas Region as well, and the research on free-roaming leopards on game farms continued.

There are many studies of leopards (*Panthera pardus*), but all are of animals inside protected areas such as Kruger National Park (Bailey 1993), the Serengeti (Bertram 1982, Durant 1998) and Etosha National Park (Stander 1997b). However, the majority of leopards in Namibia occur on commercial farmland. Over the past three decades an increasing number of livestock farmers have changed over to game ranching. Since the value of many of the game species kept on game ranches exceeds that of normal livestock by far, many of these ranchers are obviously averse to losses due to predation and are therefore intolerant of big cats and other predators.

There are no detailed studies on the prey preferences of leopards outside protected areas. Farmers often assume that leopards specialise in preying on domestic livestock and take calves, sheep, goats and poultry as easy prey. There are strategies to protect livestock against depredation. Examples are guarding dogs or the use of donkeys inside the herd. In addition, herds can be kept inside kraals overnight or animals can wear bells. However, none of these strategies are practical in protecting game species from predation.

Excessive leopard persecution and their extermination on farmland, often with the aid of questionable or blatantly unethical techniques such as hunting at night with torches, the use of dogs to chase the cats or shooting them in a box trap, is putting the local leopard population under threat.

To determine the status of the leopard population in the study area, the dynamics and abundance of the leopard population and prey species need to be ascertained. The two basic questions that the study focused on were: What is the behaviour and ecology of leopards living on commercial farmland, particularly game farms? Are there any differences to leopards found in protected areas and national parks? Additionally, inter- and intraspecific relationships of different predator species in the study area were considered. For interspecific interactions the following species were included: cheetah (*Acinonyx jubatus*) and brown hyaena (*Hyaena brunnea)*.

2.2. Study site and training of expedition participants

Okambara is situated 85 km southeast of Windhoek's Hosea Kutako international airport (Figure 1.2a). The farm is 150 km² in size and entirely surrounded by an electrified fence (Figure 2.2a). All internal fences have been removed, thus allowing free roaming of wildlife (in Figure 2.2a turquoise lines inside the study area illustrate former fence lines as the study area eight years ago consisted of three different farms – "Frank" in the south, "Bildah" in the centre and "Okambara" in the northwest). The study site has a variety of landscapes (altitude range from 1500 – 2000 m) with many different habitat types ranging from typical African bushveld to hilly areas that contain ideal habitats for all of Namibia's indigenous mammal species, including elephant and rhino. Fairly evenly distributed over the study area are nine dams (man-made lakes), which contain water year-round. Other dams are relatively small and only keep water for a few months after the rainy season. The area has for many years not been used for any commercial farming activity, thus leaving the pasture and bush in good condition. The expedition base camp site (S 22.44308, E 16.96900) is situated close to a man-made waterhole called Gustavposten. Okambara is a good area in which to study leopard ecology in a game ranch setting.

Although the study area is fenced in, the movements of leopards and other felids are not confined as cats (and smaller herbivores) can easily pass underneath the fences.

For the first two days of each two-week group, expedition participants were given talks and practical lessons, learning the use of GPS, compass, range finder and other research equipment and safety techniques, skills and procedures. First excursions into the field were under the supervision of Biosphere Expeditions staff. After a few days, participants were able to navigate around the study site, install camera traps, record tracks and signs of mammals and identify animals. Where necessary, research teams were accompanied by trained local staff to improve the accuracy of data recording or to provide a safe working environment. Data entry and picture downloads were tasks performed at the expedition base.

2.3. Study animal

The leopard *(Panthera pardus)* was the key study species. It has the greatest geographic distribution of all the big cats (Nowell and Jackson 1996), covering a variety of different habitats ranging from desert to rainforest. Density varies with habitat, prey availability and intensity of persecution, from below 1 individual per 100 km² to over 30/100 km², with the highest densities recorded in protected east and southern African environments (Hunter 2011). Nevertheless, the leopard is listed on Appendix I of CITES and is classified as Near Threatened (IUCN 2013), with nine genetically distinct subspecies. Currently wild cats such as leopards, cheetahs and caracals are not listed in the Endangered category (IUCN 2013) although excessive trophy hunting (Berry 1990) combined with a high "problem predator" take-off, and other factors such as habitat loss, fragmentation and local outbreaks of wildlife diseases, may potentially put the leopard (and the other predator species) under threat locally (Bailey 1993).

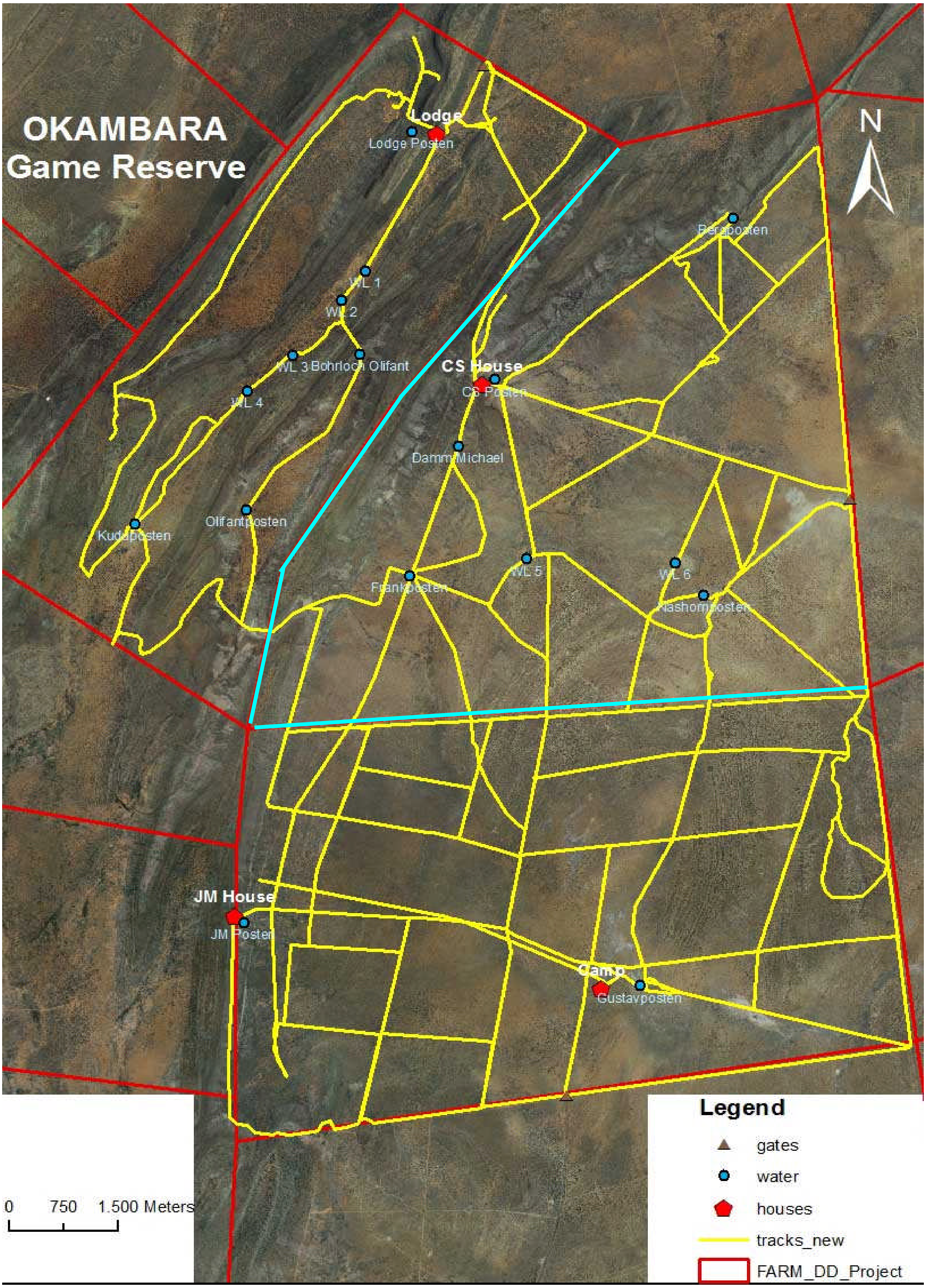

Figure 2.2a. Okambara Game Reserve consists of three former farms as shown by the red lines that surround farm roads (yellow). The outer red line perimeter is an electrified game fence; inner fences (turquoise) have been removed.

Leopards are nocturnal and solitary (Bailey 1993, Stander et. al 1997) stalkers and pouncers; they do not chase their prey over long distances. Both sexes are territorial and defensive against conspecifics of the same sex (Hamilton 1976, Bailey 1993). Bailey (1993) noted at least 92 prey species used by leopards in sub-Saharan Africa, and known prey ranges in size from insects to large mammals, for instance adult male elands (Kingdon 1977). Yet despite this apparent ability successfully to exploit prey spanning such an enormous size range, leopard diet is generally dominated by medium-sized ungulates (e.g. Bailey 1993). A recent analysis of 33 studies on leopard feeding ecology revealed that leopards preferentially prey upon species within a weight range of 10 - 40 kg, even if prey outside this weight range is more abundant (Hayward et al. 2006). The optimum prey weight for leopards derived from this analysis is 23 kg, based on body mass estimates of significantly preferred prey species (Hayward et al. 2006).

2.4. Capturing and collaring

2.4.1. Introduction

To understand the ecological factors that determine demographic trends in carnivores, it is important to study free-ranging populations under natural selection pressure. As most parts of Namibia are under some sort of agricultural management, which very often entails removal of problem animals, the selection pressures include human factors. Demographic parameters such as fecundity, mortality, reproductive success, sex ratio, age structure and social structure will therefore differ from populations in protected areas. These demographic parameters are key elements to estimate long-term viability of populations, and population viability models need to be fed with high-quality data as the output of these models is extremely sensitive to the input. Information on leopards on commercial farmlands is scarce and very often preliminary data are used.

Leopards in protected areas, for example in national parks, are habituated to humans and extended periods of observation are therefore possible. However, leopards living on commercial farmland generally avoid encounters with humans. To obtain high quality data, indirect sampling methods are required. Fitting individual animals with GPS collars is a suitable method to study solitary, elusive and nocturnal felids in their habitats (Seidensticker et al. 1970, Bailey 1974).

2.4.2. Methods

Box traps were baited mainly with antelope and zebra meat and used to capture leopards, and were checked on a daily basis. Once an animal was captured, it was darted and immobilised. Drug choice, dosages and combinations depended on type of species captured and the body weight. Whilst under anaesthesia, animals were placed in a shaded location and a facial cover and eye lubricants were used to prevent damage to the eyes. Noise levels were kept to a minimum. Vital parameters were monitored and an intravenous line was placed to administer fluids if needed and to have access to the bloodstream should an emergency arise. ID pictures were made from different sides of the animal for usage in the camera trap survey (Figure 2.4.2a). Various samples were taken (a range of blood samples, smear of saliva, nasal and conjunctival fluid, faeces and body measurements). While working in the field, blood samples were stored, chilled and processed later in the laboratory. The animal’s age was determined based on tooth wear and general habit. Fully grown animals were fitted with a GPS collar.

Once the anaesthetic was reversed, the animal was kept under observation inside the box trap in the shade to ensure complete anaesthetic recovery prior to its release, to avoid risk of injury or predation.

Figure 2.4.2a. ID picture of female leopard LF05, right side.

Vectronic Aerospace GPS/GSM collars were used (Figure 2.4.2b). These collars provide the GPS position (WGS84) of the animal, a fine-scale ambient temperature, an activity signal (resting, activity and mortality) and notification in the event of mortality. Data were transmitted as text messages via the local GSM network and received through a dedicated internet platform. The weight of the collar was less than 3% of the cat's body weight.

2.4.3. Results

The capture campaign started in August and continued until November 2012. During this period two leopards were captured, a subadult female and an adult male. Additionally, three brown hyaenas were caught (one mature male and two subadults). All individuals were immobilised. The subadult female leopard (about 16 - 18 months) and two subadult brown hyaenas (less than 18 months; male and female) were released after samples and measurements were collected without fitting them with a collar. The mature male leopard was fitted with a GPS/GMS collar. The adult male brown hyaena was collared as well. The two subadult brown hyaenas were caught several times. They were fitted with ear tags for better individual identification. All individuals captured were in good to excellent condition (Table 2.4.3b). The male leopard (LM04) had some injuries to the face and claws, which did not result from the box trap.

During the expedition four box traps were set throughout the study site. Each trap that was set and armed counted as one trap night. One night with four armed box traps was therefore counted as four trap nights. During the study period box traps were active on 109 days with a total of 266 trap nights (Table 2.4.3a).

During the capture campaign traps were moved regularly. In Figure 2.4.3a, the letter “A, B, C” after label “BT01" indicates a new position of a box trap (Figure 2.4.3a; for example box trap 1, BT01, moved to location box trap BT01A).

Figure 2.4.2b. Adult male leopard LM04 with Aerospace Vectronic GSM/GSP collar; monitoring vital parameters.

Table 2.4.3a. Trap nights (24h) effort and success 2012.

	Trap nights	**Open**	**Closed/empty**	**Capture**
2012	266	212	34	20

Table 2.4.3b. Leopard and brown hyaena capture data 2012 (neck circ. = neck circumference in centimetres).

Date	Species	Animal ID	Gender	Estimated Age (months)	Weight (kg)	Neck circ.	GPS collar
03.08.2012	Leopard	LF05	female	18	25	37	no
09.08.2012	Brown hyaena	BHM01	male	48	34		yes
03.09.2012	Brown hyaena	BHF01	female	18	21.5	43	no
06.09.2012	Leopard	LM04	male	86	62	51	yes
25.09.2012	Brown hyaena	BHM02	male	16	19.5	39	no

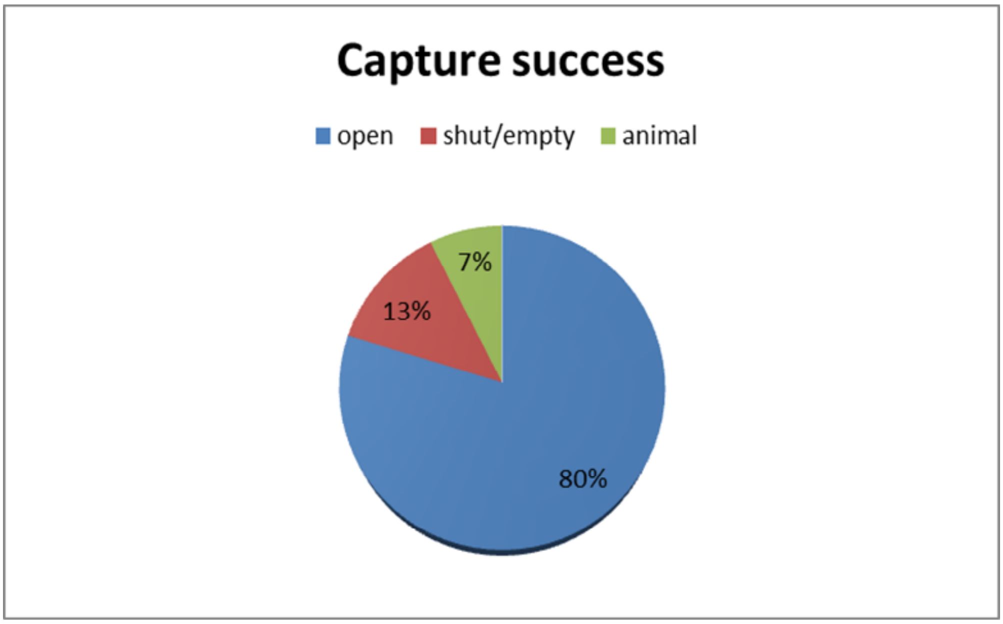

Figure 2.4.2c. Capture success from 266 capture nights (24h) on Okambara in 2012.

When checking the traps, 80% of box traps were found open, 7% had captured an animal and 13% of the traps that had shut were empty (Figure 2.4.2c). Two leopards, one caracal, one baboon, five warthogs, one tortoise and three porcupines were captured. Three different brown hyaenas were captured as well. The young ones were recaptured two times. Traps were set in eleven different locations; the highest capture success was close to the Bergposten waterhole (BT01) in the northeast of the study site (trap position BT01 on Figure 2.4.3a).

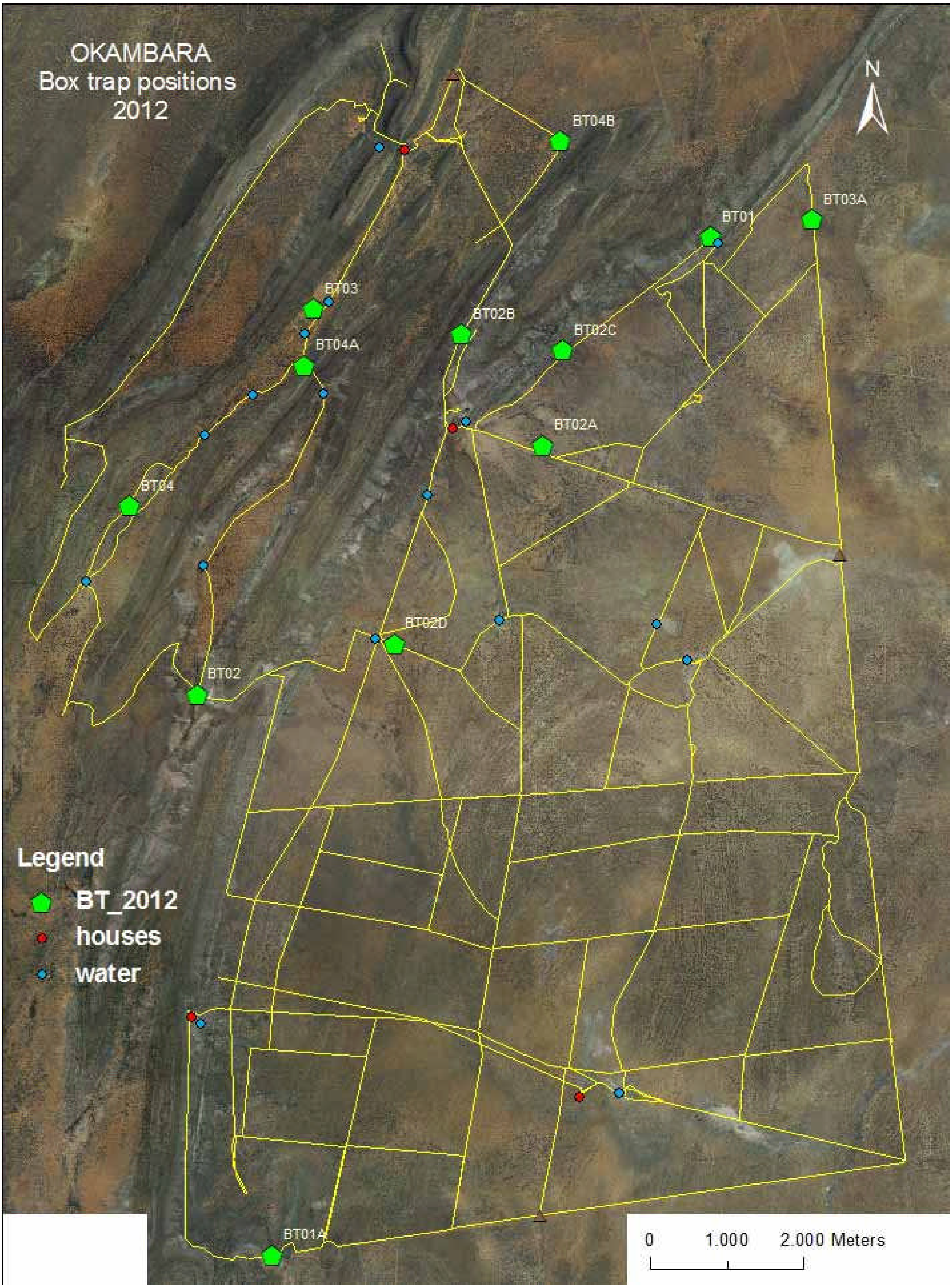

Figure 2.4.3a. Map of Okambara with position of box traps in 2012.

2.4.4. Discussion

Information on leopards is difficult to obtain by visual observations (Bailey 1993). Non-invasive methods were chosen to gain ecological and biological information. With the help of identifying leopard signs, such as tracks and scats (chapter 2.6.), box traps were set up. Several predators were captured and they showed a variety of different carnivore species on commercial farmland. In this study leopards that were captured once did not show any interest in the bait again and passed box traps several times without getting close. This suggests that leopards have an excellent memory of trap location and most likely, and unsurprisingly, develop an aversion to traps (getting trap shy). Interestingly, leopards living in national parks (Bailey 1993) showed no aversion to box traps; researchers captured some individuals up to twenty times during a study period! The subadult and not sexually mature female LF05 was evidently inexperienced and unlikely to have encountered box traps before. She was captured in the first week of capture effort. It is rare to capture an older male leopard in an area where neighbouring farmers (trophy) hunt and/or shoot problem animals (personal observations). The injuries of LM04 indicated that he was likely to have been in fights with other predators, most likely with another adult male leopard whose territory overlapped with that of LM04 (camera trap pictures showed evidence of a second adult male leopard in the same area, see chapter 2.6.2).

The adult male hyaena BHM04 was only captured once, but was photographed several times in front of the box trap after initial capture. It appears that this animal developed an aversion to box traps too. However, both young hyaenas were caught twice, suggesting the appeal of the bait was greater than the fear of getting caught.

No cheetahs were captured because the traps were set particularly for leopards and heavily scented bait was used. Cheetah capture requires different trap positions and settings, e.g. at marking trees or with live bait.

Honey badgers were captured twice, but they were able to escape between the bars, as were genets. Black-backed jackals never went into a box trap. One young caracal was captured and injured so he had to receive medical treatment. He survived, but now lives in captivity.

Blood samples taken during capture and immobilisation were sent to the Institute for Zoo and Wildlife Research (IZW) in Berlin, Germany for further analyses. Results gleaned will be published elsewhere, probably in late 2013 or 2014.

Some leopard samples collected during the study period between 2010 and 2011 have already been used in one paper by Castro-Prieto et al. (2011).

2.5. Monitoring of primary study animals – home range

2.5.1. Introduction

Home ranges (the area regularly used by an individual) of some carnivore species overlap considerably among individuals, depending largely on resource density and distribution and genetic relatedness (e.g. black bear - Moyer et al. 2005). However, overlap occurs more often between individuals of different sex (Arthur et al. 1989). In leopards, certain males defend territories against other prime aged males, but tolerate females, cubs and even dispersing young males within their territories (e.g. leopard - Bailey 1993, Marker and Dickman 2005). Home range sizes average between 30-78 km² (males) and 15-16 km² (females) in protected areas (Bertram 1982, Bailey 1993).

Where prey distribution is constant these territories are often stable, but under other circumstances they drift (e.g. red foxes - Doncaster and Macdonald 1991), move with migrating prey (e.g. wolves - Walton et al. 2001) or are fixed, but temporarily left by individuals to find prey (e.g. spotted hyaena - Hofer and East 1993).

Predators occurring on (game and/or livestock) farmland do not have the problem of prey animals migrating far away because fences block their way. Therefore, home range should be stable. In a spatial-temporal context, data can be used to analyse daily and seasonal movements of each individual and to reveal average distance between daily locations.

2.5.2. Methods

GPS/GSM telemetry (Global Positioning System / Global System for Mobile Communication) was used. Leopards fitted with collars were located by GPS, i.e. the transmitter inside the collar attempts – within defined intervals – to contact at least three satellites in order to determine accurately the animal's position. After taking seven positions, the GSM unit tries to send a text message to the receiving station through the GSM network. The receiving station then sends an email with the information (date, time, location of the collar/animal).

Telemetry data were configured in a special program called GPS Plus. Afterwards data were entered into an Excel database for further processing using ESRI's ArcGIS 9 program extensions such as the Home Range Tool (HRT9) and Hawth's Tools (Version Spatial Ecology 20 1997). Measurements of distance between two locations could be identified. The home range size was calculated using two standard methods: the minimum convex polygon (MCP, Hayne 1949) and the kernel method (Worton 1989).

Results from male (LM01) and female (LF04) leopards caught on the previous research area, Ongos (Killian and Hammer 2012), were analysed too. The female leopard (LF04) provided data since October 2011.

Data analysis

The MCP method is one of the earliest and still a widely used method for calculating home ranges (Harris et al. 1990). In this method the peripheral locations of a given data set are connected so that they form a polygon. The MCP method is very simple and the resulting home ranges are comparable between studies, but it has several disadvantages. For example, the home range is highly correlated to the number of locations and it does not give any information on how the area is used (see Figure 2.5.3b). Studies on habitat utilisation require more sophisticated analyses such as the kernel method. Currently the kernel method is considered to be the most suitable one for home range estimation (Powell 2000, Worton 1995). With this method a probability density function from the locations is calculated in order to determine a utility distribution. Home ranges are then defined by drawing contours around areas with equal intensity of use. The home range looks like a hilly surface. However, occasional exploration trips of an animal may lead to overestimated home range sizes. To correct for this, a certain percentage of the dataset is excluded as outliers (e.g. 5% of the most remote points being excluded results in the 95% kernel or 95%K). From a biological point of view, the kernel method is much more useful than the MCP method (Figure 2.5.3c), but for comparison with previous studies MCP data needs to be considered too.

For analysis, ESRI's ArcGIS (9.3) was used with the following settings (9.3): "WGS 1984" - geographic coordinate system and "Transverse_Mercator" – projection (ESRI).

2.5.3. Results

The first leopard fitted with a GPS/GSM collar was an adult male (LM01) in 2011 on the previous Ongos study site (Killian and Hammer 2012). That animal lived 55 days with the collar before he was shot by a neighbouring farmer as a problem animal. His home range sizes are in Table 2.5.3a.

The second male leopard (LM04; Figure 2.4.2b) was collared on the current Okambara study site and between 9 September 2012 and 24 July 2013, 1008 locations were recorded (Figure 2.4.2a). At the beginning of the survey, 14 locations were recorded in 24 hours. To save battery lifetime this schedule was adjusted in November 2012 to seven locations in 24 hours (five fixes during the night and in daytime). Because of irregular GSM network coverage and GPS reception, text messages with location information were sent at irregular intervals and sometimes locations are missing or incomplete.

Table 2.5.3a. Home range size (km^2; MCP and Kernel) of male (LM04/OKAMBARA) and male (LM01/ONGOS) leopards.

	Home range size (km^2)	
	LM01	LM04
DATA (%)	55 days	318 days
Kernel 50	22.67	20.00
Kernel 90	58.88	72.67
Kernel 95	64.50	95.10
MCP 100	218.25	157.32

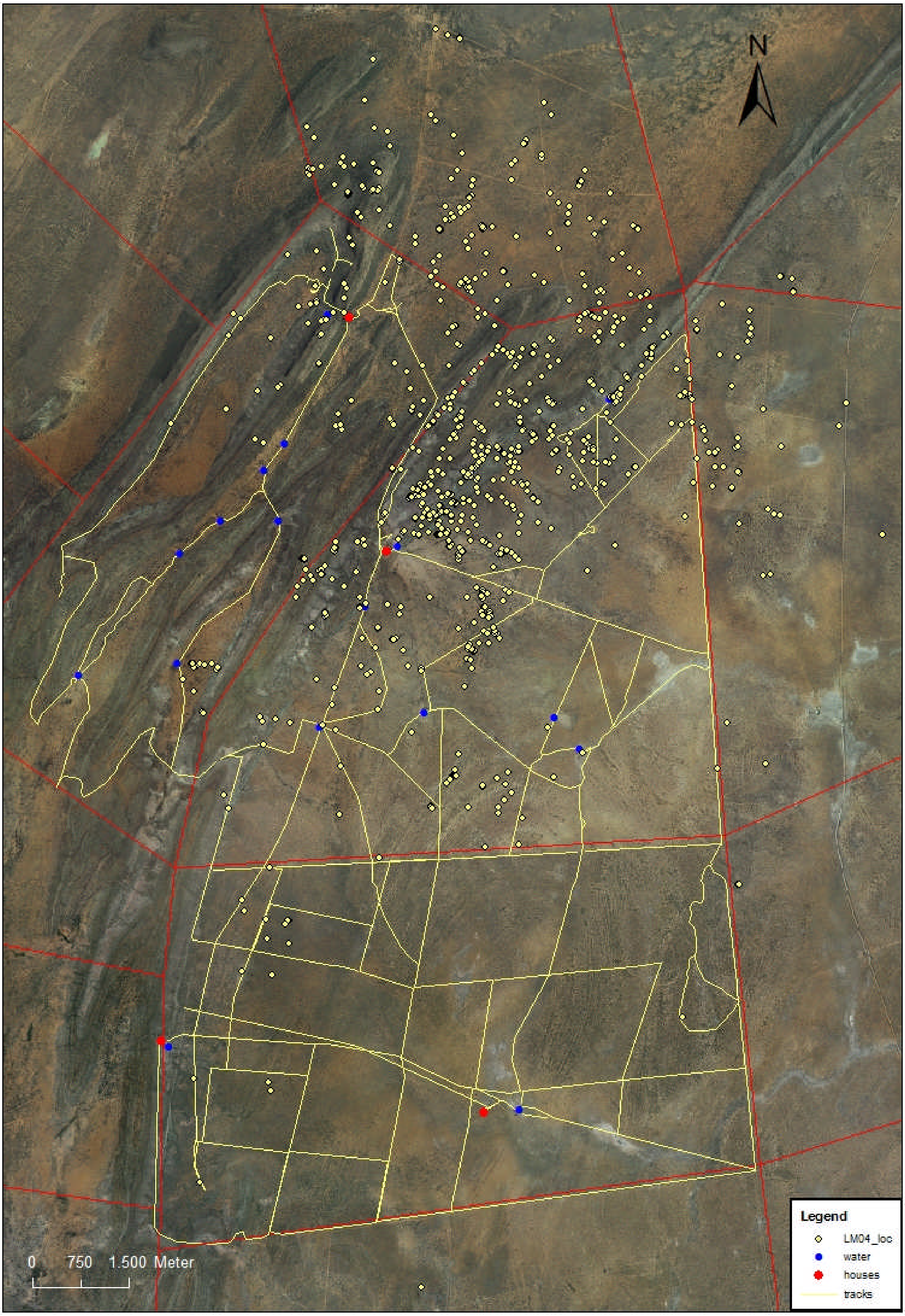

Figure 2.5.3a. Locations of male leopard LM04 between 9 September 2012 and 24 July 2013 on Okambara.

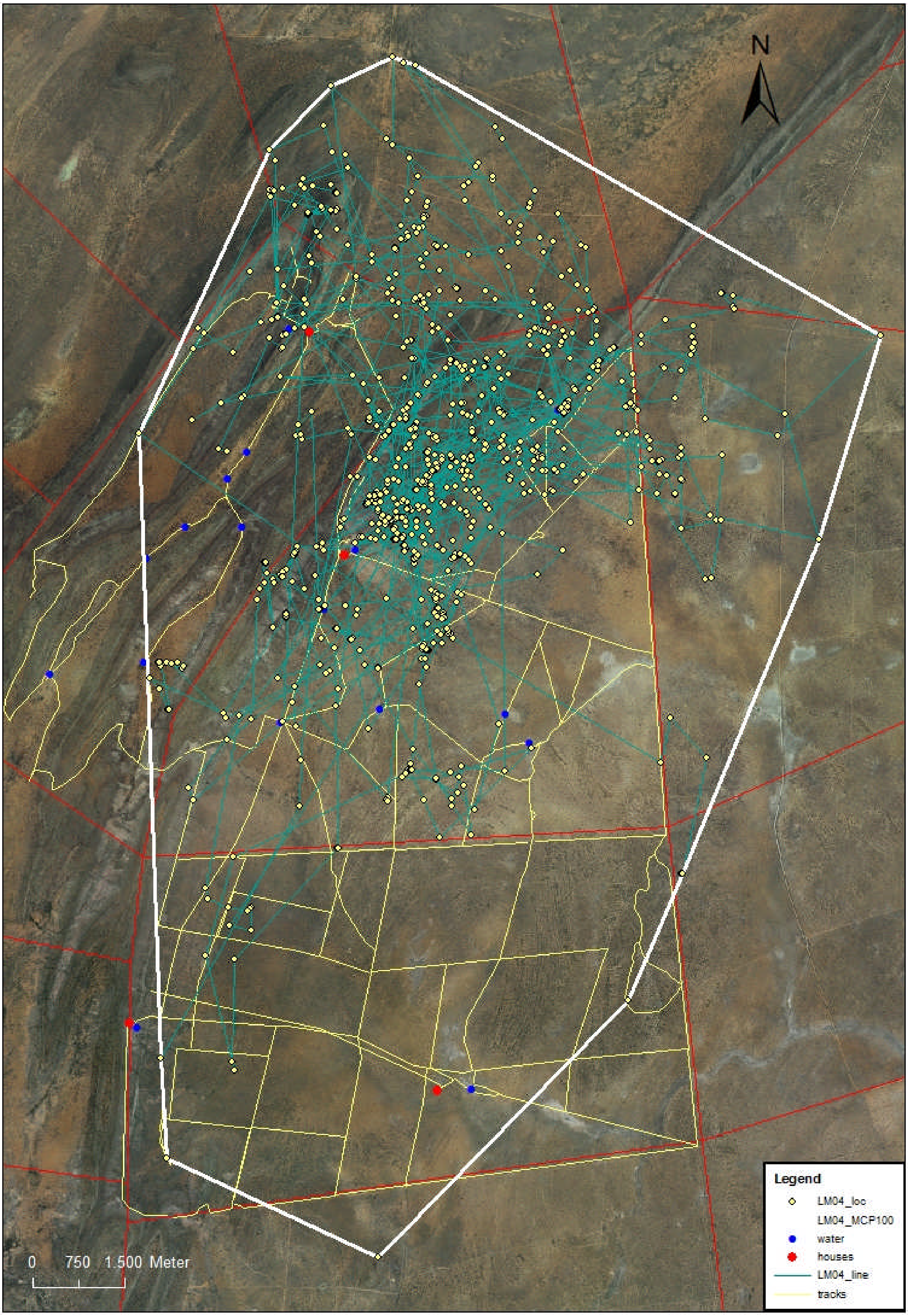

Figure 2.5.3b. Locations and tracks walked by male leopard LM04 between 9 September 2012 and 24 July 2013, MCP (100%) on Okambara.

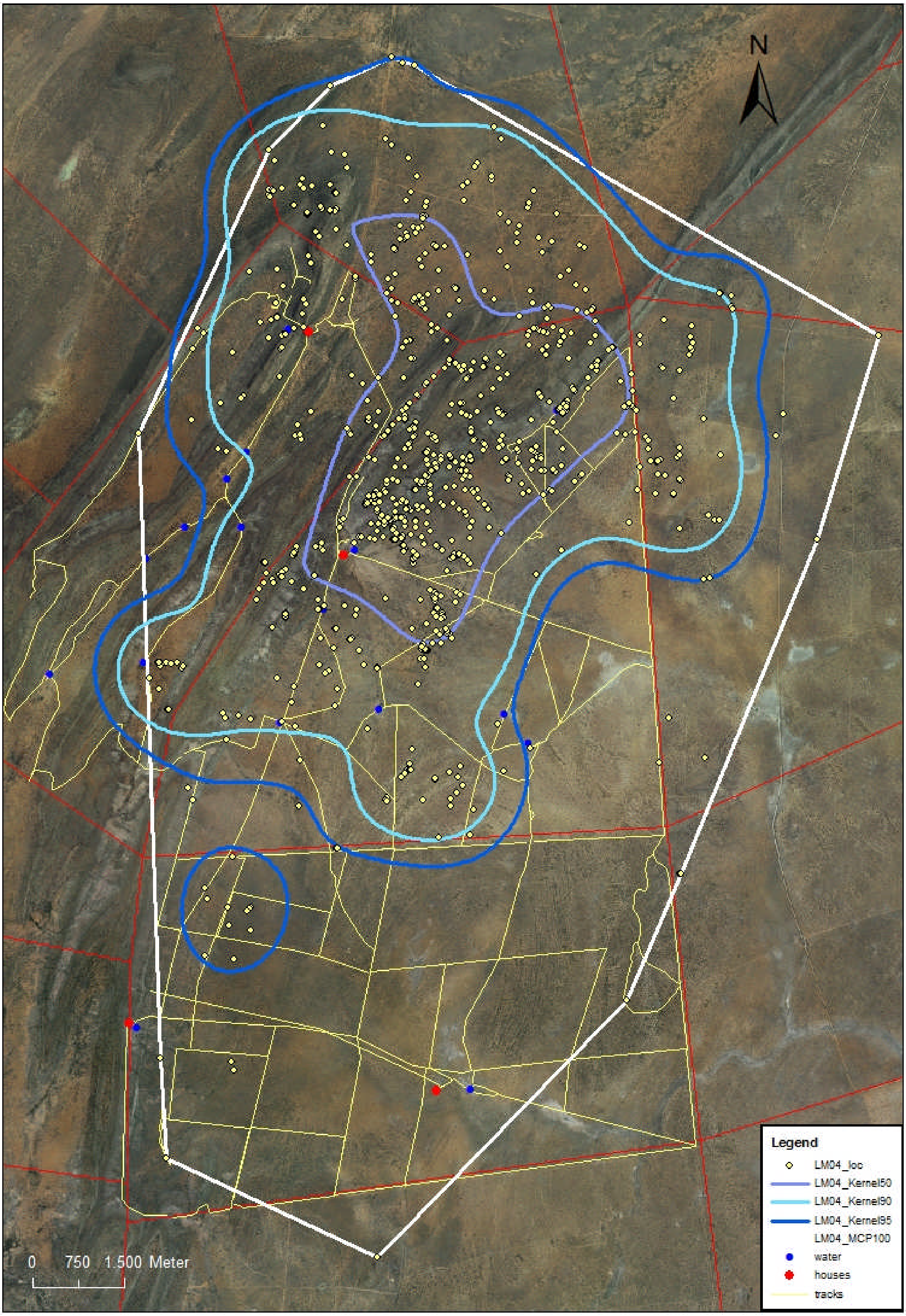

Figure 2.5.3c. Kernel description (50, 90 and 95%) and MCP (100%) of LM04; 9 September 2012 to 24 July 2013 on Okambara.

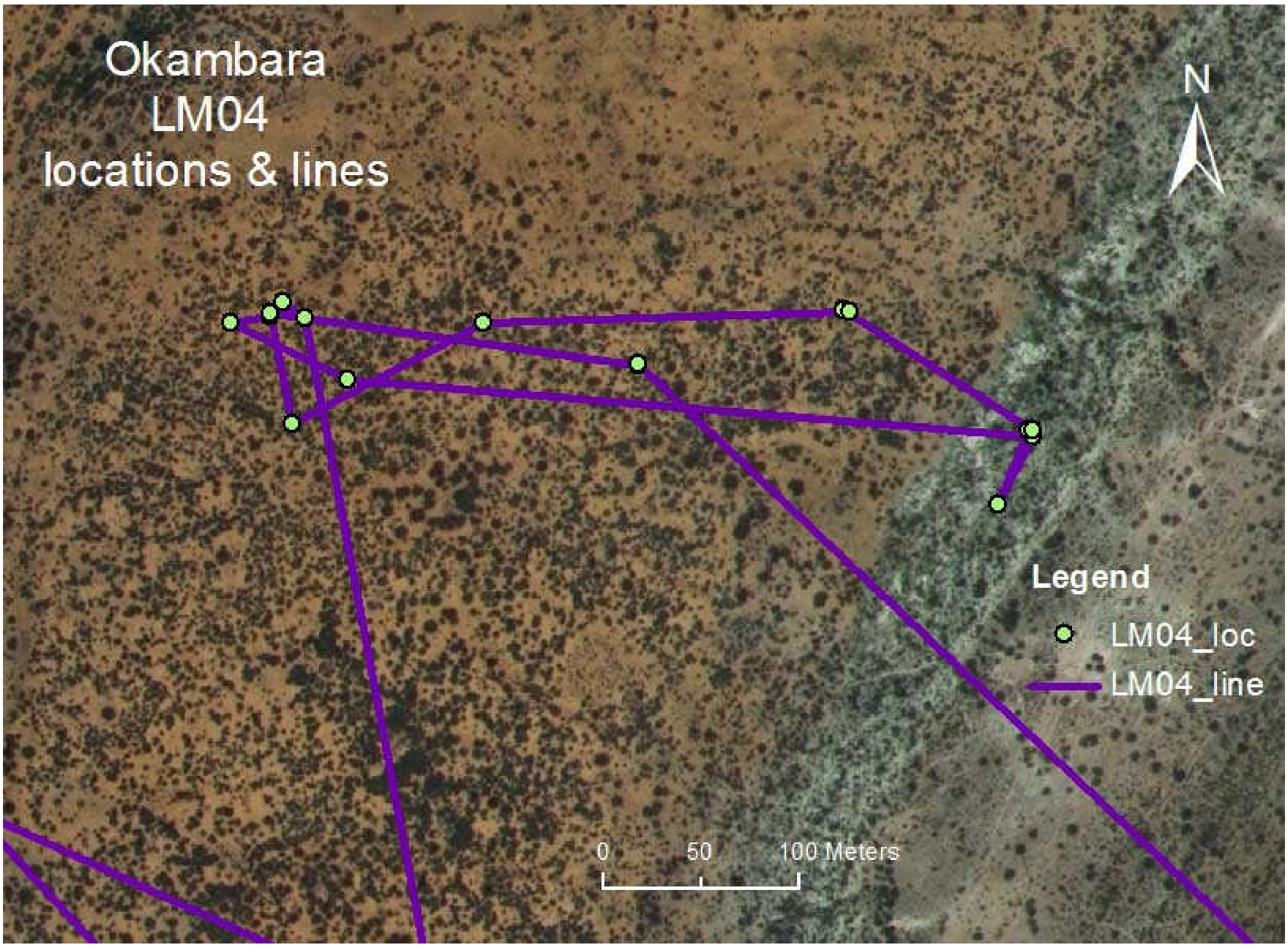

Figure 2.5.3d. LM04 locations and lines of movement in 48 h, utilising an area smaller than 0.02 km^2 (2 ha) on Okambara.

MCP home range sizes of the male leopards varied, but data collection for LM04 was five times longer than for LM01. The activity core centres (Kernel 50%) of the male leopards were nearly the same (see Table 2.5.3a).

Over twenty days of movement, LM01 covered an average of 3.3 km/day. The maximum distance covered was 17.59 km in 24 hours. Exploratory trips by LM01 were eliminated from this calculation. Detailed examination of LM04's spatial data showed that the animal occasionally remained in an area of fewer than 0.03 km^2 (2 ha) for more than 48 h at a time (Figure 2.5.3d). This kind of behaviour appeared several times and is evidence that the animal made a kill. One exploratory trip could be identified for LM04 when the animal was busy walking the southern border of Okambara (Figure 2.5.3b). Figure 2.5.3c shows clearly that LM04 utilises several waterholes on Okambara.

The female leopard (LF04) that was collared on 1 October 2011 was captured on the previous study site, Ongos (Killian and Hammer 2012). When captured, LF04 was approximately five weeks pregnant as determined by a veterinarian. For the following analyses, data until 25 July 2013 were used.

More than 3577 locations were recorded. Figure 2.5.3e shows GPS locations and their connections if they were consecutive. MCP (100%) was included in the figure and more than half of all locations were on the Ongos study site (red line).

Around 25 November 2011 LF04's movements changed abruptly. Until the end of 29 November she stayed almost in the same spot, most likely in her den to give birth. Starting in the evening of 29 November she travelled for 29 hours and returned to the den. She then stayed for up to 21 hours in the den before leaving. On some occasions she spent between 24 and 48 hours in the same spot, leaving only for a few hours during the night. After she had given birth, she travelled again for an average distance of 3.46 km in 24 hours. Her travels were punctuated by short bursts of activity or longer periods at the den site. In December (between 5 and 26 December 2011) there was a conspicuous pattern in that LF04 always came back to a particular area. After a 36-hour period, with a lot of movement, she was found 610 m east of the den. But during the end of January her movements suddenly changed and she spent five days in the same area without leaving it once. She then travelled 15.36 km in 48 hours and remained more or less stationary again for five days in the same spot, 1.9 km away from the previous rest stop. It is unlikely that she took her cubs with her. One of her other journeys lasted 41 hours (with only a few hours of intermittent breaks) and she travelled 13.54 km before she rested for 48 hours. She was seldom found near her cubs' suspected hiding place.

During the first three months of monitoring LF04, she used a core area of 7.08 km^2 (Kernel 50%) (Figure 2.5.3f). Table 2.5.3b shows that there is a considerable difference between the core areas (Kernel 50%; Figure 2.5.3f and Figure 2.5.3g). After more than a year of data collecting, the core area increased nearly twofold.

Table 2.5.3b. Home range size (km^2) of LF04 (Ongos) for different time periods.

	Home range size (km^2) LF04	
DATA (%)	until Jan 2012	until July 2013
Kernel 50	7.08	13.78
Kernel 90	27.16	39.21
Kernel 95	34.52	47.90
MCP 100	35.09	50.19

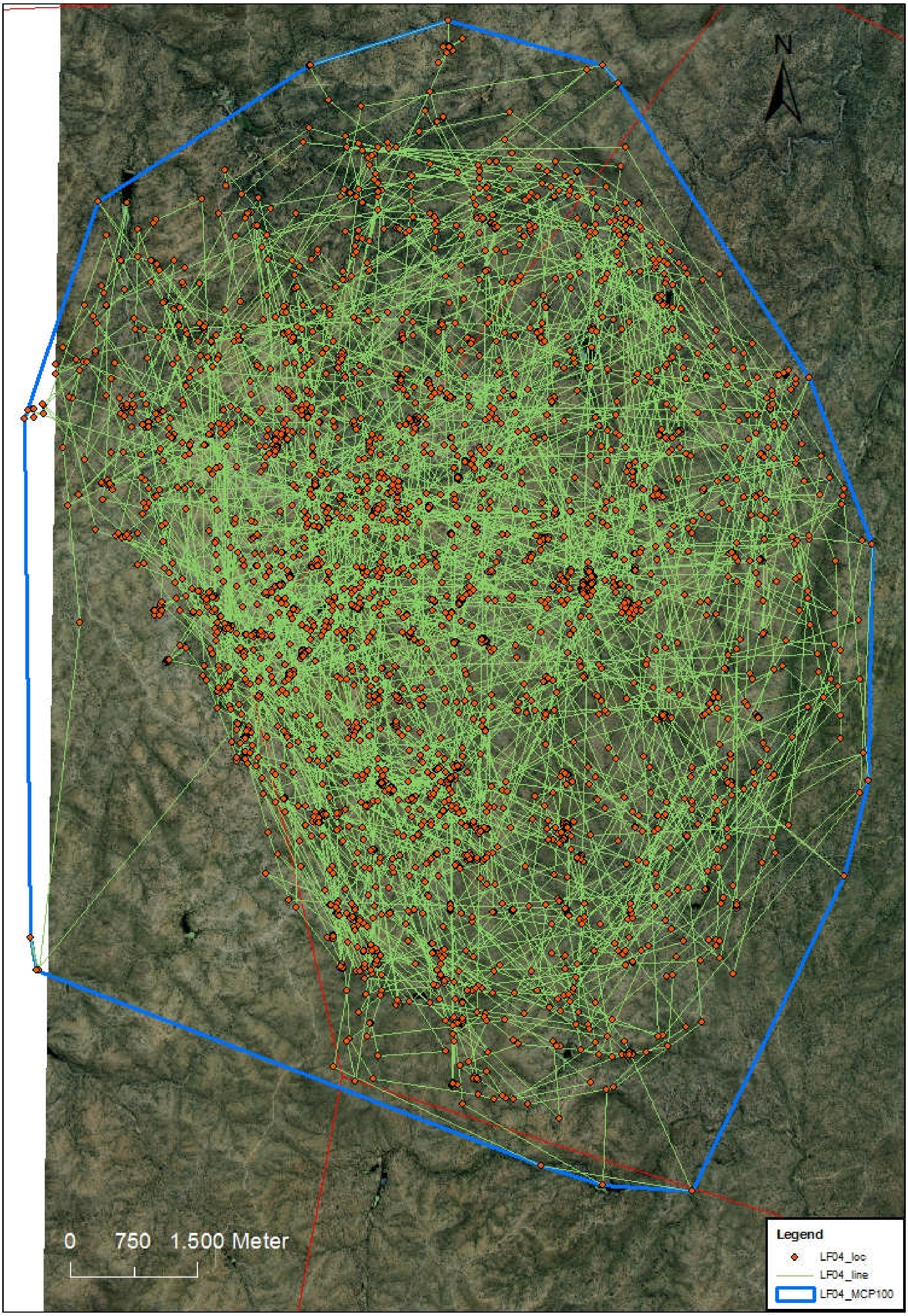

Figure 2.5.3e. GPS locations and walked lines of LF04 for the study period (21 months) on Ongos.

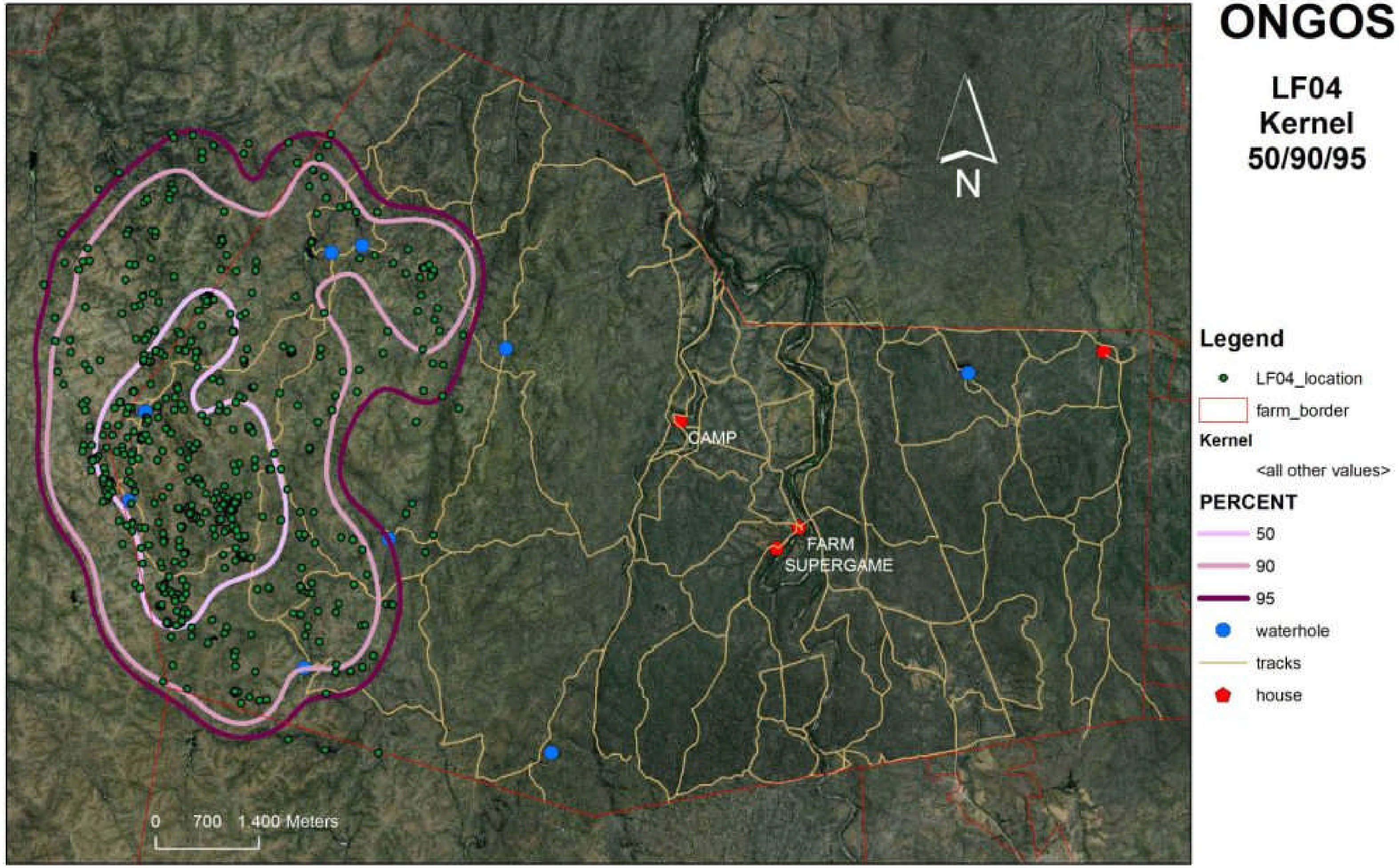

Figure 2.5.3f. Kernel description (50, 90 and 95%) for female LF04 for the first 3.5 months from capture in October 2011 on Ongos.

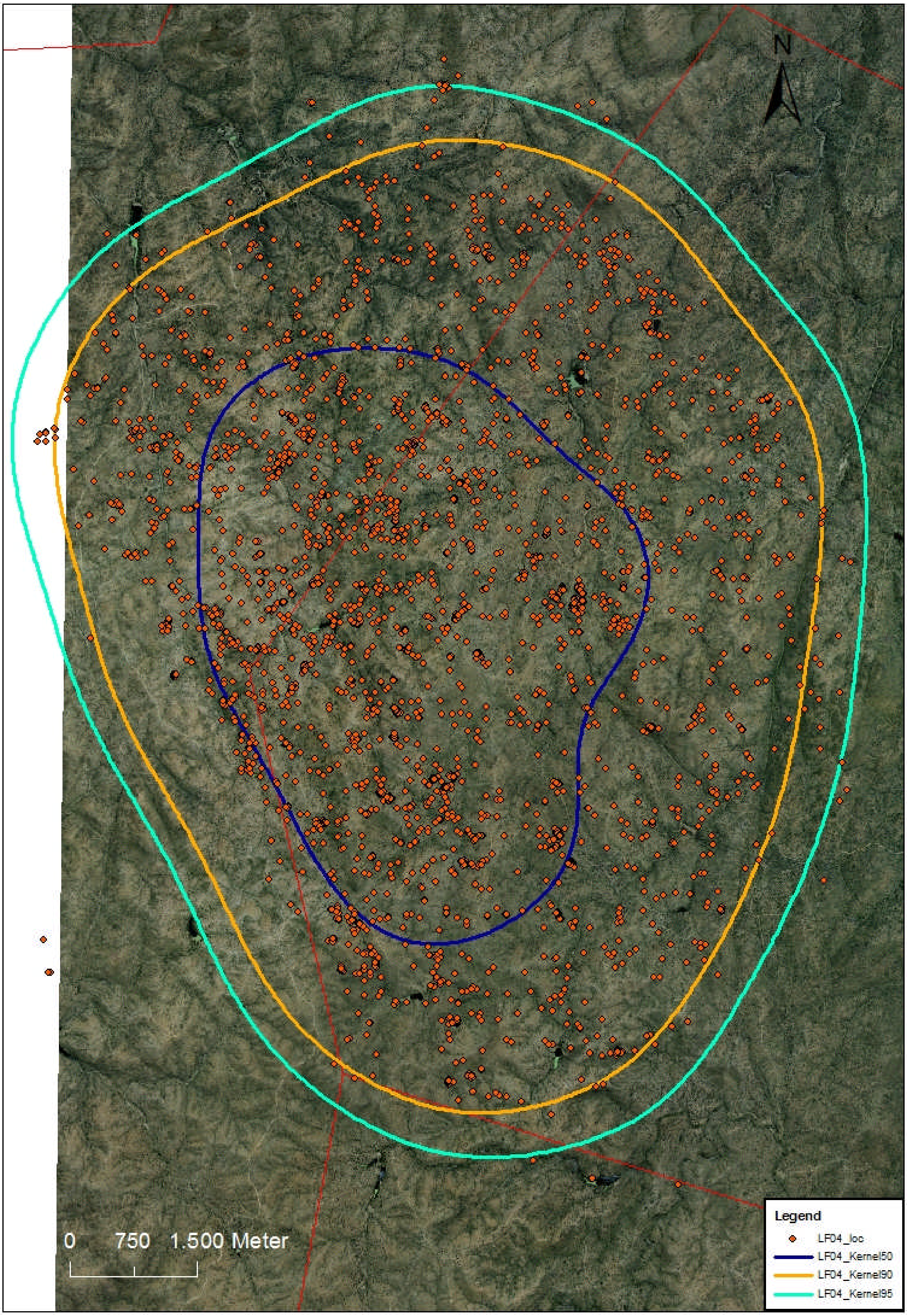

Figure 2.5.3g. Kernel (50, 90 and 95%) for female LF04 (data from October 2011 until July 2013) on Ongos.

2.5.4. Discussion

Under the specific circumstances that prevail on Namibian farmlands (in particular the absence of competition with lions, wild dogs or spotted hyaenas), leopards are the top predator and as such avoiding interspecific competition becomes a less important factor. Eisenberg and Lockhart (1972) found that where leopards are the dominant carnivore, they are often active during the day in open habitat. However, on Namibian farmland they are the top predator, but they still have to fear humans. On both study sites, surrounding farmers occasionally shoot leopards legally for trophy hunting and due to conflict with their livestock and game animals. This will affect the leopards' behaviour.

Many leopard home range data available are from studies that were conducted in protected areas (see Appendix I: Kruger NP, Serengeti NP). In Namibia the sizes of MCP (95%) varied between 108-229 km^2 for males and 53-179 km^2 for females (see Appendix I). A study conducted by Marker and Dickman (2005) on commercial farmland found high home range sizes for male leopards (MCP 95%; 229 km^2) and for females a range of up to 179 km^2. All estimated MCPs (100%) for the present study are of a smaller value than the data from Dickman and Marker, even when MCP (100%) were used (LM01 218 km^2, and 157 km^2 for LM04). The female LF04 yielded a range of 50 km^2, which is small for Namibia farmland and large for protected areas. Home ranges of females are determined mainly by food supply as minimal areas needed for survival and reproduction (Bailey 1993). But the expectation that leopards occurring on farmland have smaller home ranges than leopards in protected areas is not confirmed. The null hypothesis that high prey animal density with restricted movement, as is the case on game farms, results in smaller home ranges for leopards is rejected.

The differences in core area (K50) home range size (MCP) for the male leopards can be explained by their age variance (Table 2.5.3a; about 3 - 4 years for LM01 and 7 - 8 years for LM04). Exploratory excursions were included into the analysis and occasionally LM01 travelled far, moving 28 km away from his core area. Travelling this far is characteristic for younger male leopards (Bailey 1993) in search of a vacant area. Another reason could be a female in oestrus. Game-proof fences, in general, were clearly not a barrier, as LM04 regularly crossed under the fence on Okambara, as did LM01 and LF04 on Ongos (areas outside the yellow track grid are also outside the Okambara fence; Figure 2.5.3c). Leopards seldom remained in the same place on consecutive days; if they do, they are usually feeding on a kill (Bailey 1993). LM04 spent more than 48 h in small areas (Figure 2.5.3d), most probably because the animal had made a kill. In future, if recent data from GPS downloads are available (locations and activity records from a particular animal; GPS cluster analysis, Fröhlich et al 2012), then locations that a collared leopard remains in should be visited and searched for fresh kills, marking areas, sleeping places, etc. This will add another, ecological dimension to studies of leopard movements.

Smaller home range sizes for females correspond with Bailey's studies (1993), which show that female leopards move less than their male conspecifics. The explanation for the behaviour of LF04 described above must be that LF04 lost her litter for some unknown reason in 2012.

During this study, home range overlap could not be analysed with the help of GPS collars because no neighbouring animals were collared. But camera traps showed evidence of other leopards in the study site. For example, two adult male leopards were photographed on the same camera trap (in under 24 hours). One of them was captured and collared; he had several injuries, which could have been the result of fights with other leopards as described by Hamilton (1976).

2.6. Predator abundance, interspecific encounters and identifying individuals

2.6.1. Tracks and scat survey

2.6.1.1. Introduction

Monitoring the abundance and distribution of animals is fundamental to the research, management and conservation of wildlife populations. Large carnivores are particularly difficult to study, as they range widely, occur at low densities, capture probabilities vary between different individuals, and they are often secretive or elusive (Karanth 1995, Boulanger et al. 2004). Direct assessments of population density depend on recognition of individuals and groups and as such they are very expensive and time-consuming (Stander 1998). Indirect sampling methods are cost-effective, objective and repeatable, but the results are scientifically questionable (Norton-Griffiths 1978). In general, recordings of predator tracks are designed to provide presence/absence data only, but by following tracks of foraging cats, a wide range of additional data about behaviour such as prey-encounter frequencies, hunting success, prey species selection, home range use and social interactions can be gathered (Stander et al. 1997). Scats of predators add another piece of evidence of predator occurrence. The hair of prey is relatively undamaged and indigestible in most carnivore scat and can thus be used to identify the prey species eaten (Wachter et al. 2006). Scat analysis is used to understand the prey preferences of leopards and obtain insights into predation habits, thus showing if diet overlap and potential competition among carnivores and even smaller prey occurs. Such findings are very important to demonstrate predator dietary preferences and thus enable game ranchers to optimally manage predators on their land.

2.6.1.2. Methods

Nine different routes were planned for track and scat counts (total 70 km). All of them were located in the flat area of the Okambara study site (Figure 2.6.1.3c). Each day, a route was selected randomly. Occasionally expedition team members needed to reschedule for safety reasons because elephants were utilising that particular area. GPS positions were recorded for all leopard, cheetah and hyaena tracks found. Data such as date, number of animals, sex and age class, age of track (very fresh, fresh, old, not sure) and track size (pad width, pad height, total width, total length), direction of track, start and end point of the track and further comments were recorded.

All leopard, brown hyaena and cheetah scats found on the transects were collected. Scats were collected along the same routes as tracks, and date and GPS coordinates were noted. Scats collected were air dried and stored. Leopard scats can be discerned from scats left by other species by their size, shape, consistency (Stuart and Stuart 2000), odour and adjacent tracks visible. In terms of size, hyaena scats are similar to leopard scats, but easy to distinguish from them, as hyaena scats are much harder and white due to a high ratio of calcium residue of digested bones (Walker 1996). Additionally, in many cases tracks were found in association with scats, which made identification more precise. Scats were sifted with water and hairs, bone fragments and other hard parts were extracted and dried again. Bone fragments, teeth and hooves were used to support the results of the hair examination. Hairs were compared against a hair reference catalogue to determine prey animals.

2.6.1.3. Results

The different routes were monitored between two and seven times each and a total length of 300 km was covered. Six of the routes were in the plains area and three close to ledges (1, 3 & 4). The routes most frequently monitored were numbers 3 and 6 (seven times). Number 5, 7, 8 and 9 were not used regularly (two or three times each), because elephants were in those areas frequently.

Route 4 had very hard, stony surfaces and some of the routes were in deep sand (2, 5 and 6). Weather conditions, for example heavy wind and rain, can destroy tracks easily. Figure 2.6.1.3a shows the probability (p %) per kilometre of predator findings (tracks/scats) for leopard, brown hyaena and cheetah on different routes (T&S 1-9).

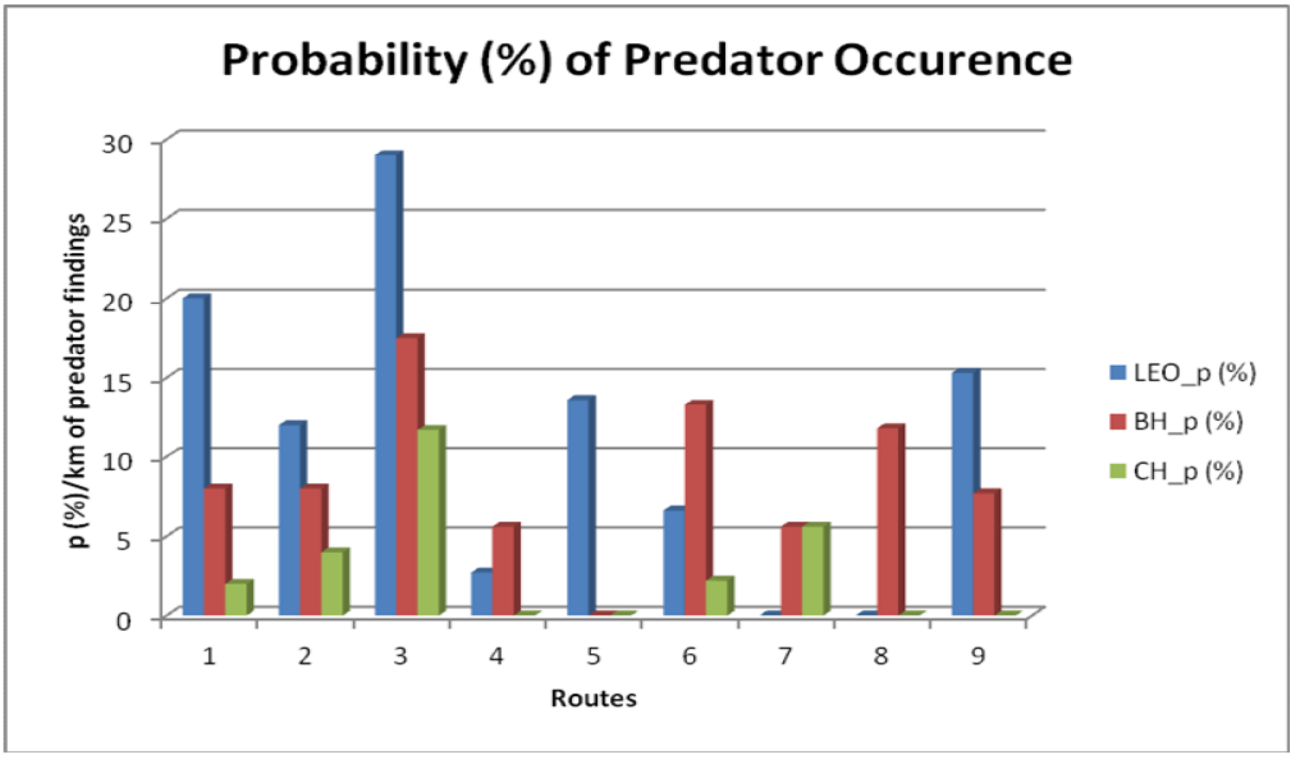

Figure 2.6.1.3a. Probability p (%/km) of predator occurrence on the basis of track and scat findings on particular routes per kilometre. LEO = leopard, BH = brown hyaena, CH = cheetah.

Leopard signs (40) dominate the results over cheetah (11). Hyaena signs (26) were found all over the study site, sometimes several times in the same location. Half of the cheetah signs were found in the plains area. Signs of different predators were recorded in the mountains, but cheetah signs were never found there. Two drag lines and tracks of leopards were found and followed through the bush and fresh impala kills were found.

The largest number of tracks and scats from leopard were found close to the edge of the small mountains in the north and southwest of the study site, where there is also water available (routes 1 & 3). Route 4 along the edge of the mountains in the western part of the study site yielded only a single scat (Figure 2.6.1.3b). Although routes in the plains area were not covered that often (routes 5 - 9), some predator findings were nevertheless detected on 5 and 6, but no scat was found on route 7 to 9.

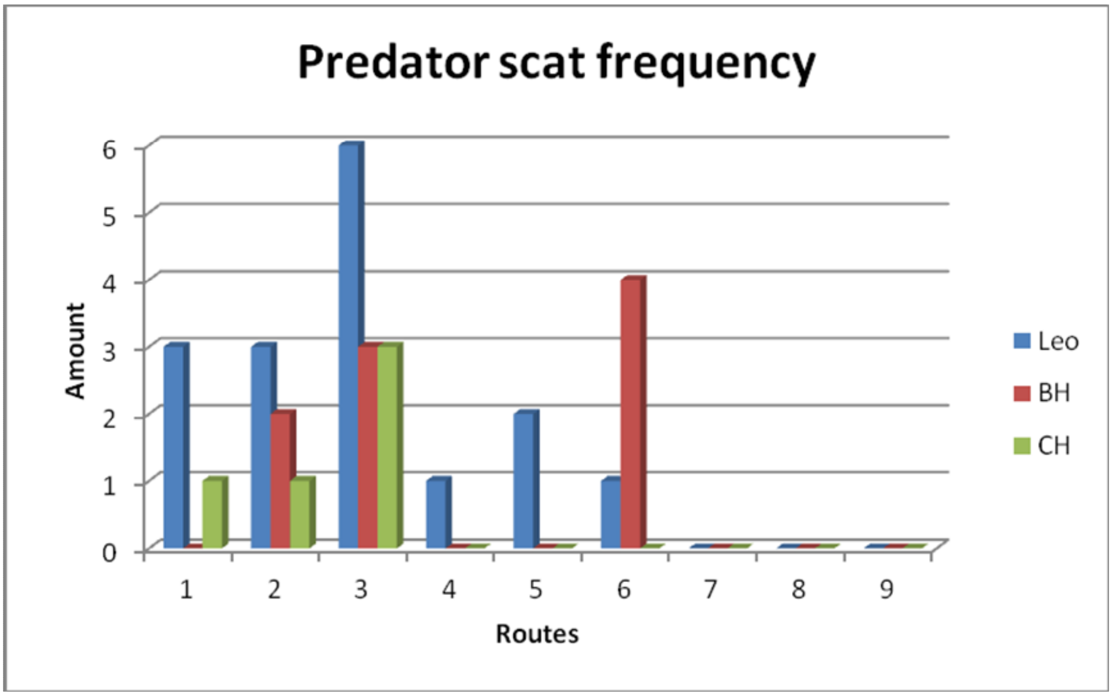

Figure 2.6.1.3b. Frequency of scats from different predators on fixed survey routes, OKAMBARA 2012
Leo = leopard, BH = brown hyaena, CH = cheetah

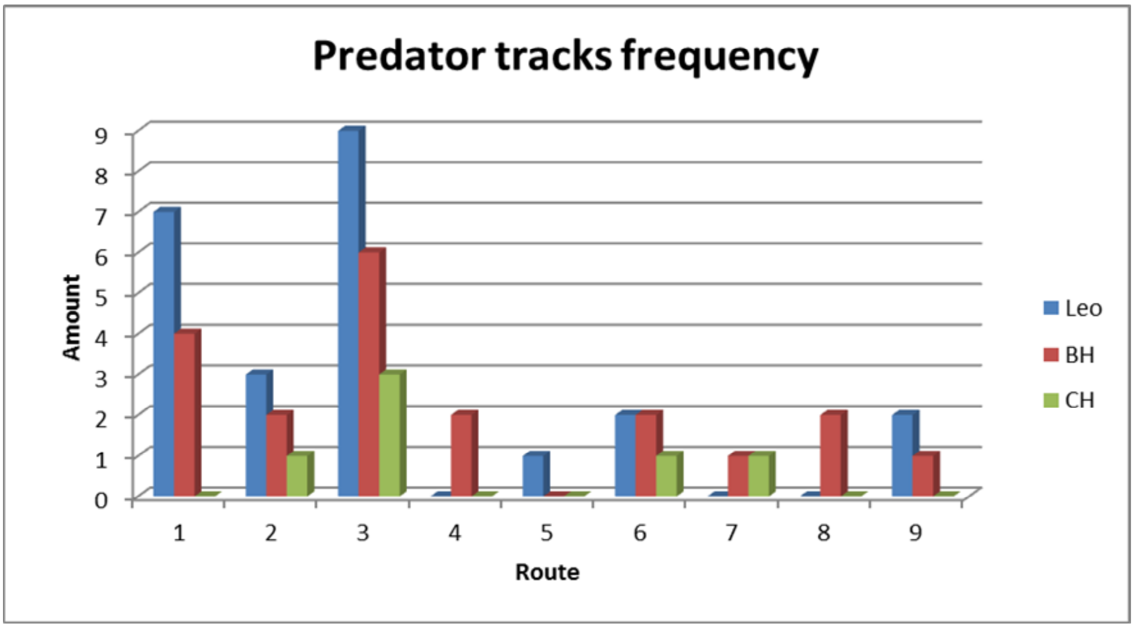

Figure 2.6.1.3c. Frequency of tracks from different predators on fixed survey routes, OKAMBARA 2012
Leo = leopard, BH = brown hyaena, CH = cheetah

Figure 2.6.1.3d. Location of leopard, brown hyaena and cheetah tracks (50) found by the activity "tracks & scats" on nine different routes on OKAMBARA in 2012.

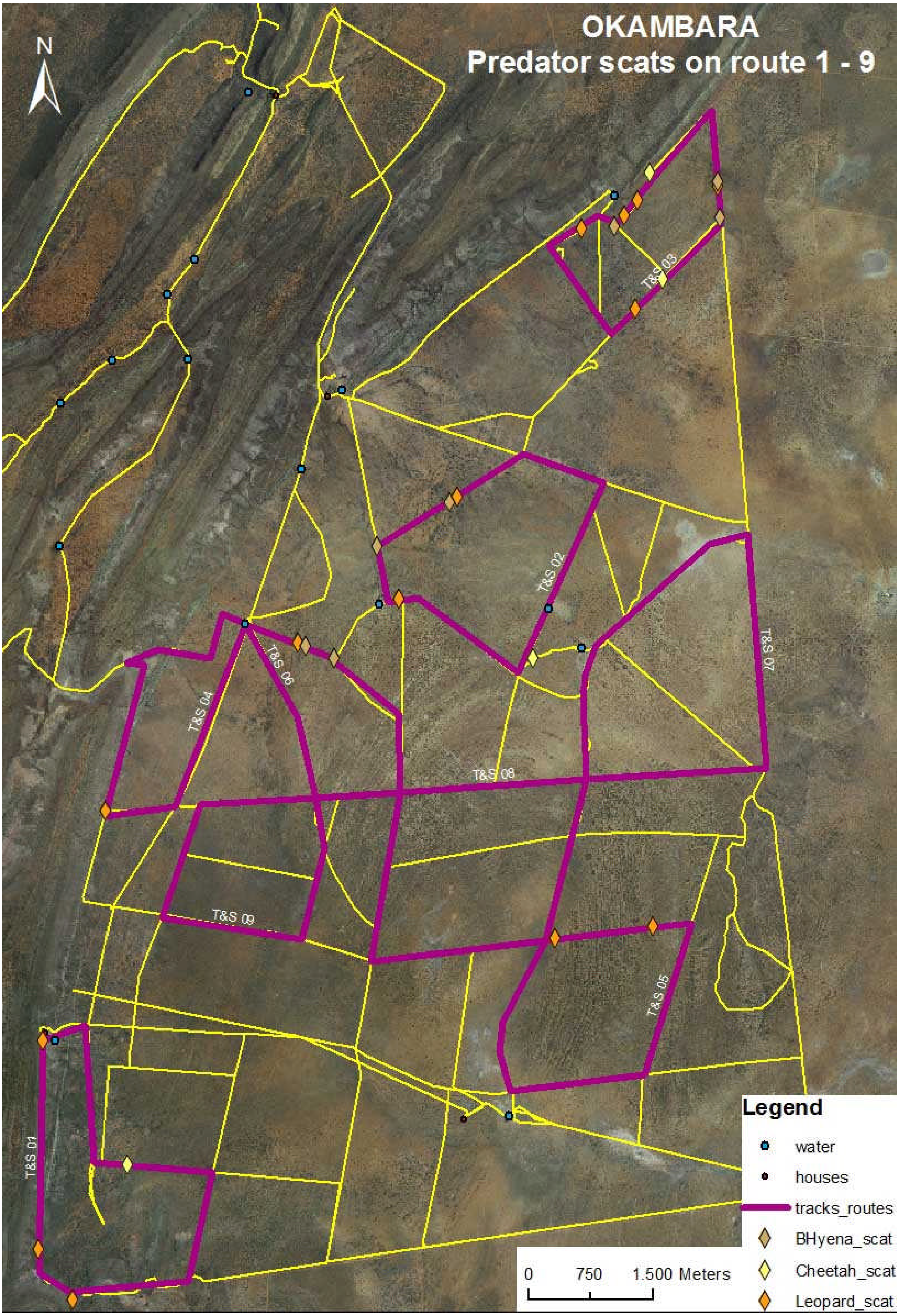

Figure 2.6.1.3e. Location of leopard, brown hyaena and cheetah scats (30) found by the activity "tracks & scats" on nine different routes on OKAMBARA in 2012.

2.6.1.4. Discussion

Results of these non-invasive methods show that different predators occur on Okambara. The focus was on leopard, brown hyaena and cheetah. Their tracks and scats were recorded and camera traps and box traps were installed in those locations that were found to be highly frequented.

Figures 2.6.1.3.d & e show the spatial distribution of leopards. Leopards were often detected close to the mountainous ridge along the western border of the study site Cheetahs were detected more frequently in the open areas of the study site, probably because they want to avoid leopard and brown hyaena and because their hunting technique is more suited to open areas (Caro 1994).

It is notable that all of the tracks found on route 1 were of big adult leopard(s). Route 3 shows a variety of measurements (total length 6 - 10 cm) and camera trap pictures confirm the presence of different adult leopards.

Stony and very sandy parts of the routes might be the reasons why no or only few tracks of predators could be detected (for instance route 4 and 2, 5 and 6).

Scats are important for intra-species and inter-species communication. Brown hyaenas use latrines and secretions from two anal glands to mark their territories (Mills et al. 1980). The reason that brown hyaenas were detected throughout the study site is probably because they are looking for carcasses from other predator kills everywhere and they patrol their home range. Cheetahs are known to leave most of their kill after having eaten their fill and do not usually return (Caro 1994). If leopards do not take their kill up a tree, the probability that hyaenas scavenge on it is high. Photographs taken by camera traps show leopard and hyaena feeding on the same kill or bait, but not at the same time.

In sub-Saharan Africa, 92 prey species of leopard are known (Hayward et al. 2006). They range from small rodents (Mitchell et al. 1965) to large antelope. Bailey (1993), Ray et al. (2005), Sunquist & Sunquist (2002) and others found more than 20 different prey species in leopard scats in studies conducted mostly in national parks, where the prey spectrum is more varied compared to game farms. In the previous study side, Ongos, the prey spectrum of leopards on a game farm reached a plateau at fourteen different species (Killian and Hammer 2012). For the recent study site at Okambara, scat analysis, to determine the prey species, will start soon.

The number of kills recorded over the study period was not large. This is probably because kills of small prey are likely to be eaten almost entirely and/or scattered by scavengers very quickly. It is noteworthy that two adult impala kills were recorded, probably kills made by female leopard LF06. It is difficult to make a reliable statement about kill rates. Bailey (1993) estimates that an average 52.8 kg male leopard must consume 3.8 kg of meat per day and an average 37.5 kg female leopard 3.0 kg per day.

2.6.2. Camera traps

2.6.2.1 Introduction

Another non-invasive method is photo capture through camera trapping. Photographic capture of individual leopards, together with information on date, time and capture location, can provide baseline data for population density analyses (Karanth et al. 2004). Photos obtained can be used to identify individual animals and add valuable information towards population density estimates and population dynamics. Results from the capture/recapture methods can be analysed by the program CAPTURE (Otis et al. 1978, Rexstad & Burnham 1991). This program offers different models to calculate population size. Information gleaned thus can be incorporated into farm management and may help to keep financial losses to a minimum, which in turn makes cooperation by stakeholders more likely.

2.6.2.2. Methods

Two different brands of camera traps (Bushnell Trophy Cam 2010 & 2011) and Reconyx 650) were used during the study. Both were equipped with SD memory cards up to 8 GB (yielding up to 8000 pictures at medium resolution settings). Camera traps were positioned either in wildlife hotspots close to natural or man-made water sources or scattered over the study site mostly alongside farm tracks. The minimum distance between stations was 700 m and the maximum distance was 15 km. No bait or lure was used to attract predators. Camera traps were checked two to three times a week to exchange SD cards, make minor adjustments and verify battery status. Leopard, brown hyaena and cheetah individuals were identified from the pictures taken, as well as a host of other non-target animals (primates, ungulates, etc.). The spot coat of each individual leopard and cheetah is unique and individual animals were identified. Brown hyaenas have stripes on the front legs as well as scars on the face or ears, all of which can be used to identify individuals.

The relative abundance index (RAI) of Jenks et al. (2011) indicates the probability of a particular species being photographed over a period of 100 days (extrapolation). For each camera trap the RAI calculation for leopard and brown hyaena was performed by adding up for each day all detections of a camera trap and multiplying this by 100. The result was divided by the total number of camera trap days. Total number of camera trap days was calculated by adding up all the days when all camera traps were active. Different categories of RAI indices were calculated in this way (Table 2.6.2.2a). Detections were considered independent if the time between successive photographs of individuals of the same species was more than 30 minutes (O'Brien et al. 2003). Recordings with several individuals of a species were listed as a single sighting. Leopards that could not be assigned to any individual were included in the calculation.

The program Camera Base (Version 1.5, Tobler 2010) was used to organise camera trap pictures and run analyses, for example via the program CAPTURE (Rexstad and Burnham 1991), which estimates leopard abundance. CAPTURE offers different models and identifies which model fits the data set best and then generates capture statistics for all models (Jackson et al. 2006). The most important statistical requirement to calculate population size based on mark-recapture data is the assumption that the population is closed (no immigration, no emigration, no mortality and no birth) during the sampling period.

To meet this requirement, a sampling period between 30 and 90 days should be considered, so 50 days was chosen for this study. If an animal was photographed it was noted as an event. In order not to overestimate the research area, a buffer needed to be added (Figure 2.6.2.3b). To estimate the area effectively sampled (A), a convex polygon connecting the outermost camera traps plus a buffer area, where width (W) is an estimate of half the home range length for female leopards in the sampled area, was computed following Karanth and Nichols (2002). Population density was determined by dividing numbers of identified leopards (by CAPTURE) through the sampled area.

Table 2.6.2.2a. Categories of RAI indices.

RAI	Category
0	1
> 0,27	2
0.28 - 0.54	3
0.55 - 1.35	4
1.36 - 2.16	5
2.17 - 2.96	6
2.97 - 4.31	7

2.6.2.3. Results

The study period started at the end of July 2012 but reconnaissance and preparation of the area began in May. At that time, fifteen camera traps were placed at strategic points (based on fresh tracks, kills, scats found) around the study site. Elephants destroyed two camera traps in the plains area during the preparation phase. The study design was adapted accordingly and no further camera traps were placed in areas that could be reached easily by elephants. Baboons and elands damaged a further camera trap in the mountains during the main study period. Overall, between 1 and 15 camera traps were in use. Not all leopards photographed could be identified. From 41 events, 12% of photographs were either too poor in quality (e.g. blurred or overexposed) for the fur pattern to be sufficiently visible, or close-ups showed only small body sections. In total 36 leopard events were recorded, where an event is an individual leopard being captured by a camera trap. This equals one leopard capture for every third night of trapping.

Capture success

A sampling period of 50 days was set and conducted from 21 September to 9 November 2012, yielding 18 events. Three individual adult leopards were identified by their coat patterns (Table 2.6.2.3a). Two adult males were recorded: one of them was captured and collared in September (LM04); the other one did not go into a box trap until the expedition study period had finished in 2012 (LM05). One mature female (LF06) was photographed several times. In May and June pictures of a subadult leopard were taken. In August this animal - subadult female (LF05) - was captured and ID pictures were compared to previous camera trap pictures. After capture, this animal was not photographed again.

Table 2.6.2.3a. Camera-trapping effort and leopard captures 2012.

Year	Sampling period	Trap stations	Leopards	Identified individuals
2012	21 Sep – 9 Nov	11	18	3

During the sampling period, eleven camera traps were active, six of which recorded leopards. Two others recorded brown hyaena. In the plains area, three camera traps took pictures of cheetahs (Figure 2.6.2.3a); two camera traps were placed facing a marking tree. During the study period there was no recapture of cheetahs so no identification and analysis could be made. In the mountains no evidence of cheetahs was found (no pictures, scats or tracks) and most of the pictures taken were of brown hyaena.

One adult male brown hyaena was captured in a box trap and collared. Two subadult brown hyaenas (one male and one female) were captured several times, but not collared. For later identification purposes, both received ear marks with a number and colour. The young male was often seen with the collared male in the mountains where the subadult was caught (Figure 2.4.3a - BT03). The adult male was seen all throughout the site, but not together with the female. The female was seen a couple of times in the same area where she was caught. All predators shown in table 2.6.2.3b avoided areas of high leopard density.

Table 2.6.2.3b. Camera trap pictures of different predators.

Year	Sampling period	Brown hyaena	Cheetah	Honey badger	Caracal	Jackal
2012	July - November	42	6	7	5	31

Estimates of leopard capture probability, population size and density

The CAPTURE test for closure supported the assumption of population closure (i.e. no immigration, emigration, births or deaths) during the survey. CAPTURE selected the null model (M_0) for the survey. A relatively high capture probability of 0.3667 was recorded (the probability that a leopard in the sampled area is photographed on a single sampling occasion) (Table 2.6.2.3c).The sample population was estimated to be three leopards (SE +/- 0.1831, 95% CI 3–3 individuals). When computing the 95% confidence interval, CAPTURE converts the values to the nearest integer, rather than printing decimals (Jackson et al. 2006).

For the survey three individual leopards (excluding subadults) were estimated to occupy an area of 77.69 km^2 (Figure 2.6.2.3g). The buffer width (half of the home range length of a female home range) was 4.4 km. The estimated effective area sampled was 226.37 km^2. A density of 1.3 individuals per 100 km^2 was calculated.

Table 2.6.2.3c. Results of population closure, capture probability, estimated abundance, standard error and 95% confidence interval of leopards sampled on a Okambara game farm, Namibia 2012.

Year	Test for closure	Null Model (M_0)		95% CI
		Capture probability	Abundance (SE)	
2012	z = 0.609 P = 0.729	0.3667	3 +/- 0.1831	3-3

Figure 2.6.2.3a. Three cheetahs (two subadults) walking in front of camera trap 5 (and subsequently passing under the fence in the background).

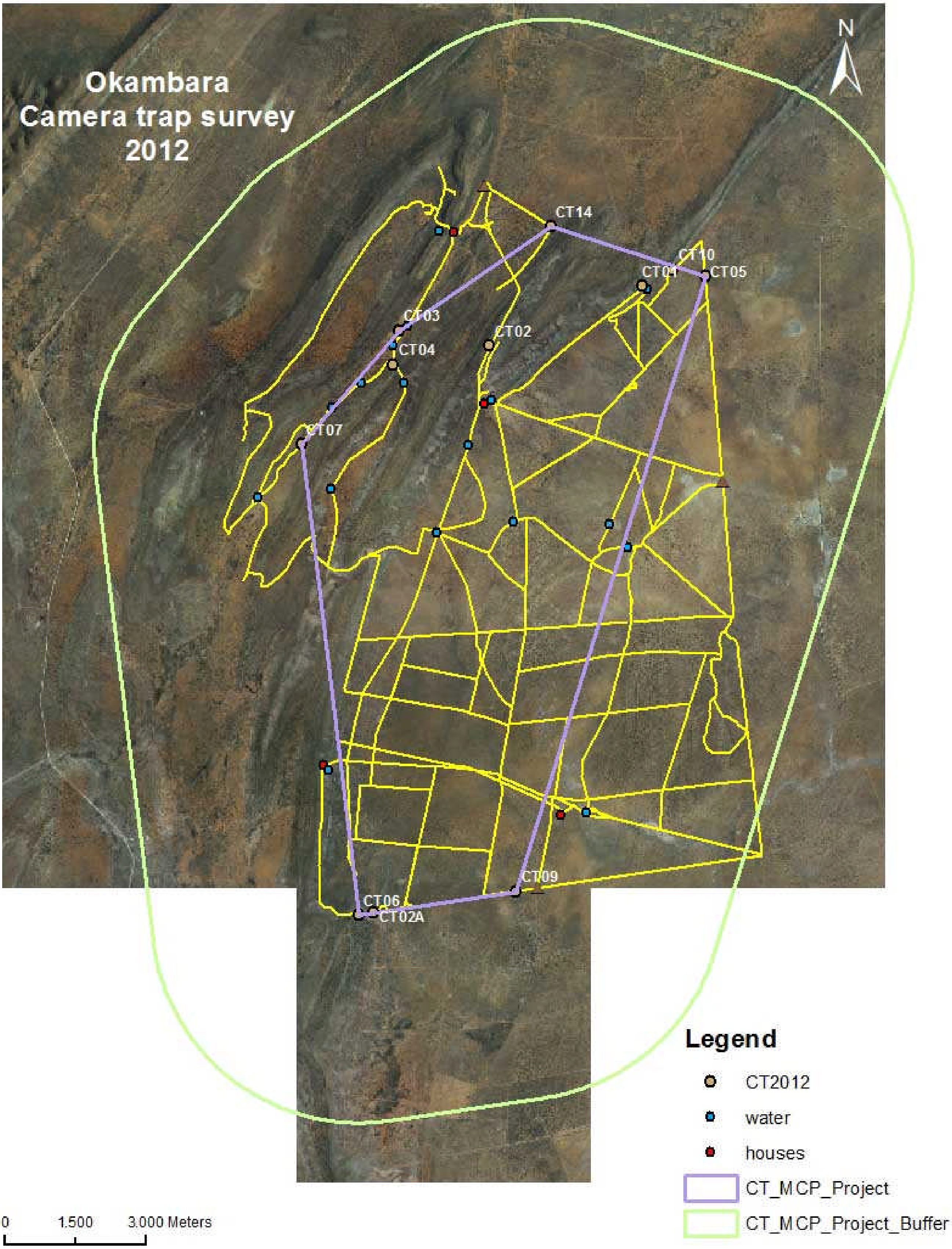

Figure 2.6.2.3b. Effectively sampled area of camera trap survey 2012 (camera trap polygon and buffer), OKAMBARA.

Relative abundance index (RAI)

The program ArcGIS 9.3 (ESRI 2010) was used to visualise the relative abundance index of leopards and brown hyaenas for each camera trap in the study site. Seven different categories were created based on values of the relative abundance indices (Table 2.6.2.3d). Each camera trap was represented within a circle, wherein the size of the index related to the size of the circle. The larger the circle, the larger the value of the relative abundance index (Figure 2.6.2.3c).

Table 2.6.2.3d. Categories of RAI indices for leopard (Leo) and brown hyaena (BH); location ID (same location & name of camera trap).

Location ID	Events Leo	RAI	Events BH	RAI
CT01	2	0.54	4	1.08
CT02	5	1.35	X	X
CT02A	X	X	6	1.62
CT03	X	X	11	2.96
CT04	1	0.27	16	4.31
CT05	8	2.16	5	1.35
CT10	1	0.27	X	X
CT14	1	0.27	1	0.27
CT 06	0	X	0	X
CT 07	0	X	0	X
CT 09	0	X	0	X

Figure 2.6.2.3c visualises the spatial distribution of the leopards and brown hyaenas in the research area. The leopards' RAIs go up to five; brown hyaena to seven categories. Leopards were generally photographed only in the northern region of the study site and in the mountains in the east. Camera traps 1 and 5 were visited by leopards and hyaenas equally; they fitted in the same category (Table 2.6.2.2a). In the south only brown hyaena was photographed. Six camera traps did not record any leopard or hyaena images (category 1; Figure 2.6.2.3c).

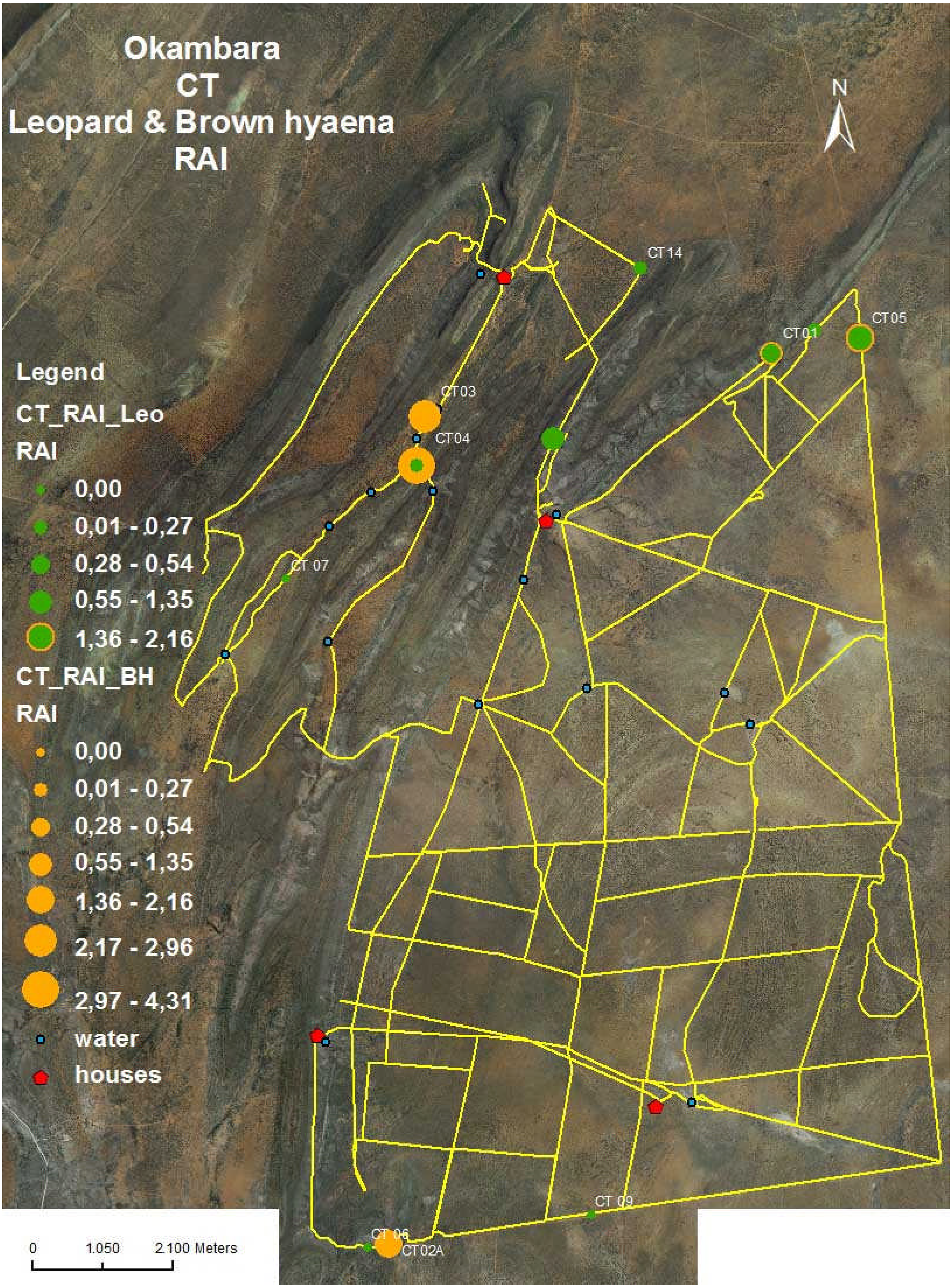

Figure 2.6.2.3c. Visualisation of the leopard and brown hyaena RAI values for camera trap survey in the research area, OKAMBARA 2012.

2.6.2.4. Discussion

Camera traps are very useful tools in wildlife research, collecting a variety of data sets and allowing for undisturbed observation of species in their habitats to explore their natural behaviour patterns and movements, and to determine population sizes.

During the four months of the expedition, 132 pictures of all large predator species present in the area (leopard, cheetah, jackal, caracal, brown hyaena and honey badger) were recorded. Caracal, honey badger and most of the jackal pictures were made after sunset. Adult brown hyaenas were never active/photographed before 21:00; subadults started to become active two hours earlier, but none of them were seen after 05:00. Several studies show that leopards are active between sunrise and sunset (Nowell and Jackson et al. 1996, Hamilton 1976, Bailey 1993, Sunquist & Sunquist 2002). This is confirmed by most pictures taken during this study, with leopard active after 17:00 and in the middle of the night and only a few records after sunrise, when temperatures are not too high. In semi-arid savannah regions mammals are active at night to avoid the heat of the day and associated heat stress and energy loss (Bothma & Bothma 2005). There is evidence that, unsurprisingly, the activity patterns of leopard prey have an influence on leopard hunting behaviour (Bothma and Bothma 2005, Sunquist & Sunquist 2002, Jenny and Zuberbühler 2005). Leopards avoid the heat and prefer shady places to rest (Bothma and Le Riche 1984, Walker 1999, Sunquist and Sunquist 2002). Another reason to be active during the night is to avoid humans.

A high percentage of the predator pictures were of brown hyaenas and jackals. Three different brown hyaenas could be identified. Jackals were not identified individually. Due to their greater strength, size and stealth, leopards are the dominant predator. No persecution of predators occurs on Okambara so predator ratios should be close to natural. In general, on Namibian farmland, the leopard is the only competitor for brown hyaena and cheetah, and it is likely that the latter will avoid areas where many leopards occur. Brown hyaena and leopard do coexist in space, but they try to avoid each other in time (Killian and Hammer 2012). Generally, leopard and brown hyaena are opportunists and better adapted to poorer habitat conditions (Estes 1991). Findings from Hansen and Stander (2004), who reported 2.5-3.8 individuals per 100 km^2 as a high value, demonstrate that the previous study site Ongos was located in a high leopard density area. On Ongos there was scant evidence of cheetah (one picture taken in two years) and a high density of leopards with 2.7 individuals per 100 km^2 (Killian and Hammer 2012). Stein et al. (2011) determined that on farmland in central Namibia leopard population density is 3.6 leopards per 100 km^2. Marker and Dickman (2005), on farmland in north-central Namibia, found that the average density of leopards in protected areas is 2.1 leopards per 100 km^2. On the current Okambara study site, the estimated leopard density of 1.3 individuals per 100 km^2 was lower than expected. This result and the presence of their preferred plains area habitat explain why more cheetahs were detected. Cheetahs favour open terrain with few bushes for their well-known high-speed prey captures (Estes 1991) and avoid mountains and their edges, where the chance of encountering a leopard is much higher.

The relative abundance index (RAI) is a measurement of the distribution of the abundance of species. Considering the RAI of brown hyaenas and leopards, the abundance of brown hyaenas is higher. Note that juveniles must not be included into calculations here as they will disperse on maturing. Leopards were not captured on all camera trap locations; for instance, there was no leopard evidence in the plains, but there were many photographs of leopards close to the edge of mountains and in the mountains. This shows clearly that leopards prefer mountainous habitat, as reported by Bailey 1993. Still, further studies on habitat preference would be useful.

Female leopard LF06 was regularly detected by camera traps positioned at fresh impala kills. This female and the collared male leopard LM04 were recorded within 30 minutes of each other at the same kill in September (see Figure 2.7.3c). Two adult leopards without collars were sighted on the edge of the mountains in the beginning of October, probably the female (LF06), which was photographed several times in that area, and the male leopard LM06. On 18 November 2012 the male leopard without collar (LM06) was camera-trapped in the northeast of the study site and followed by LF06 a few seconds later. The reason why subadult LF05 was not seen again on camera traps until November, when the camera trap survey ended, might be that she had started to extend her home range. If she is a relative of LF06 she might not roam too far from her mother’s territory (Bailey 1993), which was not completely covered by camera traps.

To meet the statistical assumption of the population being “closed” during the camera trap study period (no immigration, no emigration, no birth, and no death), a period of 50 days was selected. The null model (M_0) assumes that capture probability is the same for all individuals and is not influenced by behavioural response, time or behavioural heterogeneity among individuals. The camera trap survey produced meaningful results, but small sample sizes from low-density, cryptic carnivores makes precise analysis difficult. Karanth and Nichols (1998) noted that CAPTURE performs poorly with population sizes of 20 or fewer individuals. Therefore, the statistical analyses performed here and based on just three recaptured individuals can only serve as an indication.

Even with the result of a low density of leopards, overall results suggest that local conditions are particularly favourable for different predators such as leopard, brown hyaena and cheetah. The area possesses abundant prey, good habitat features and minimal competition, and no persecution from humans. All species were recorded to have offspring.

The camera trap placement design was not ideal, because few traps could be placed in the plains area where destructive elephants and baboons were active. For future studies elephant-proof housing should be constructed so that camera traps can be spread more equally around the study site. In addition, for each camera trap station two camera traps should be placed to photograph animals from both sides for better identification. In the new study season, many camera traps should be installed close to Frank, to identify more resident leopards in that area.

Additional studies, particularly on the neighbouring farms, would yield a more detailed picture of the distribution of individuals and the size of their home ranges.

2.7. Game animals

2.7.1. Introduction

The management of game on game farms is the most important factor in securing income. Where wild ungulates are utilised by people for either consumptive utilisation (commercial hunting and game farming) or non-consumptive utilisation (safari tourism), competition and conflict may occur between game ranchers and large predators. With the advent of game ranching, game prices for most species have increased by more than 50% over the last 20 years. Many game farms are stocking up with rare and valuable species such as roan (*Hippotragus equinus*) and sable (*Hippotragus niger*) antelope, resulting in a large increase in the antelope value over recent years. People's attitudes to and tolerance of predation by wild felids varies widely. Antipathy towards carnivores may be a result of historical or cultural attitudes, as well as based on past experiences and personal perceptions.

The typical game farm is fenced to keep the valuable game species on the property of the owner. Historically, game migrated perennially from one grazing ground to another. This gave the grass time to regrow, bloom and reproduce. Fences hinder these dynamics and game farms run the risk of severe degradation and desertification due to overgrazing. Management therefore becomes crucial in fenced-in area and many pieces of information are needed for successful management, e.g. game density, reproduction rate, primary production and sustainable stocking rates.

For that reason vehicle game counts and waterhole observations were conducted on Okambara over a four-month period. Of primary interest was population demographic data (e.g. male:female ratios, age composition of herds, number of sexually mature females with calves, etc.).

2.7.2. Methods

Distance sampling is one of the best methods to estimate wildlife populations accurately (Buckland et al. 2008). For this purpose the study area was divided into line transects following Buckland et al. (2008). The area was classified into two easily discernable vegetation types: dense and open.

Vehicle game counts were conducted on farm tracks. The three transects of between 10 and 15 km each were driven along at a very low and relatively constant speed (about 15-20 km/h) and observers on the back of the vehicle counted all animals they detected on both sides of the road. All game animals within a 1000 m semi-circle (the average viewing distance on foot) in front of the observers were counted and fed into the computer program DISTANCE (Buckland et al. 1993). Equipment used included rangefinder, binoculars, angle measurer, clipboard, datasheet, pen and different African mammal identification field guides. Species, number(s), distance and angle of the detected animal(s) were recorded, as well as the GPS position of the observer, plus, if possible, any notes about species age and sex. Ostriches were the only birds noted; other birds and reptiles were not recorded. Observers then identified and counted all animals detected and recorded the distance to the vehicle, the angle from the transect (vehicle midline), the number of individuals and, if possible, sex and age composition (Figure 2.7.2a).

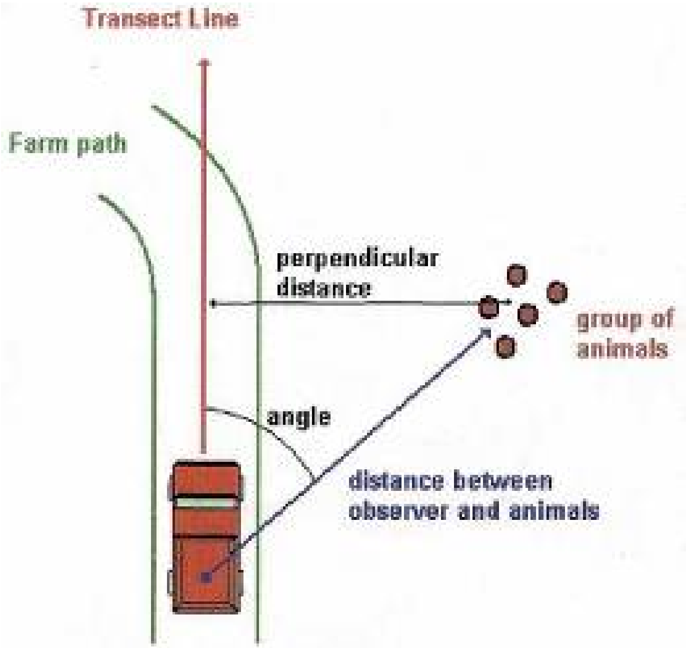

Figure 2.7.2a. View distance sampling method / vehicle game count.

At waterholes, game species were also recorded. At the beginning of the study, expedition participants had to construct several hides at each waterhole so that viewing positions could be taken up in depending on the wind direction. Observations took place during the day to study animal behaviour such as duration of stay at the waterhole, and whether animals were drinking or not. Gender, age class and herd composition were also recorded.

2.7.3. Results

Vehicle game counts were conducted during daylight hours between August and November 2012 using three line transects (see Figure 2.7.3b) and distance sampling methods. All routes were driven from south to north and started at the same time in the morning (at sunrise). There was a tracker or scientist on each game count vehicle to provide some standardisation of observations and detection probability.

The three transects lengths were VGC 1 = 10.8 km, VGC 2 = 14.9 km and VGC 3 = 12.7 km. Twenty-four game counts were conducted, yielding 3319 animals over 668 sightings and 301 km driven. The program DISTANCE (Buckland et al. 1993) was used to calculate species densities per square kilometre and total number of individuals present (6104) on the entire study site (150 km^2) (Table 2.7.3a). Accuracy was relative to the rate of sightings of species, where higher sight rating results in a lower standard deviation. Values with covariance over 60% were not accurate enough for analysis. For all estimates DISTANCE indicated a 90% confidence interval.

As all game counts were carried out during the day, nocturnal animals such as aardvark were not detected.

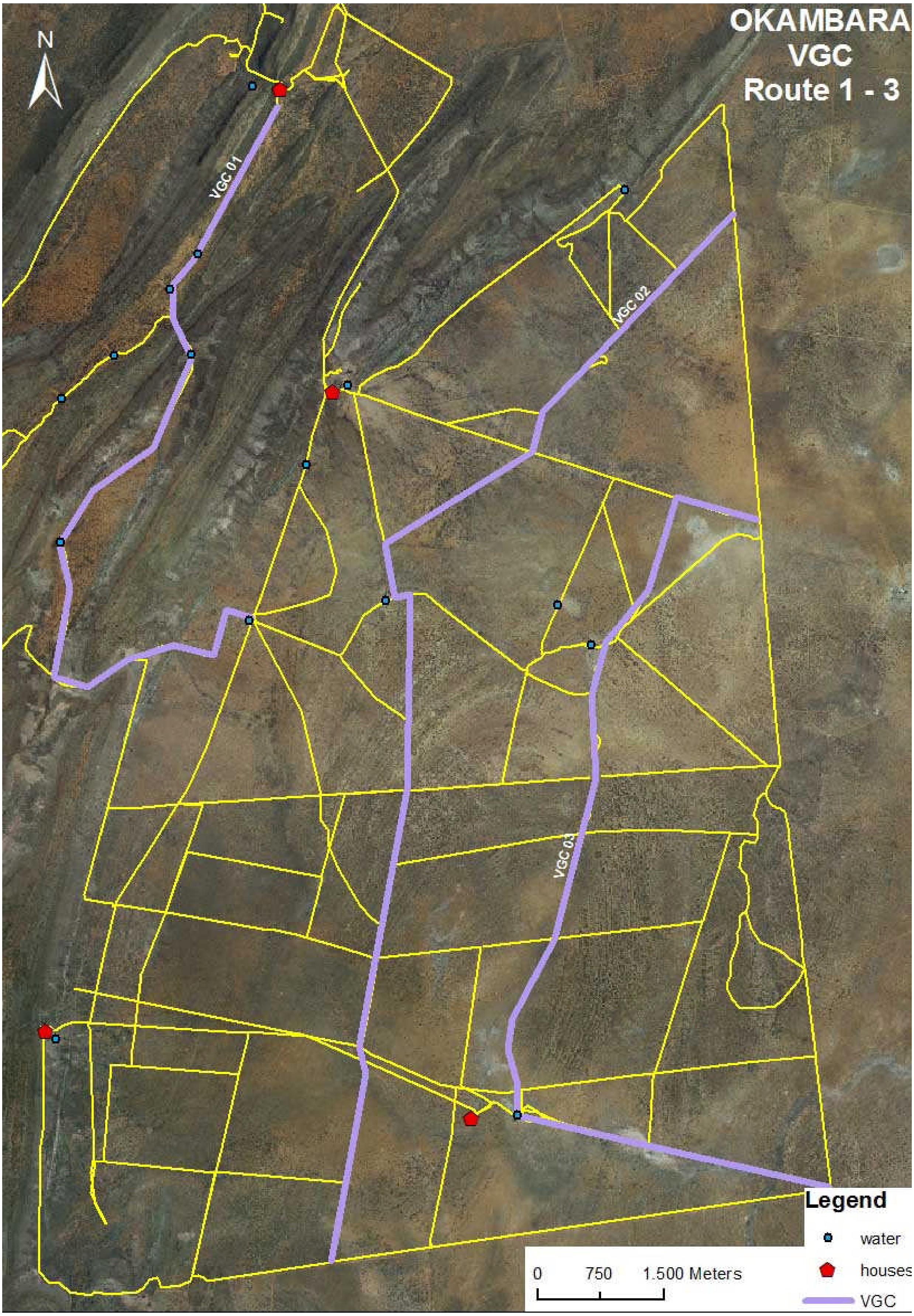

Figure 2.7.3a The three vehicle game count routes on Okambara.
VGC 1 = 10.8 km, VGC 2 = 14.9 km and VGC 3 = 12.7 km.

Table 2.7.3a. Numbers of game species estimated by DISTANCE, density/km^2, covariance and 90% confidence interval, OKAMBARA 2012.

Species	No. of individuals	density/km^2	Covariance	90% confidence interval
Warthog	48	0.3	47.6	16 - 148
Oryx	1310	8.7	23.3	808 - 2124
Springbok	137	0.9	99.4	14 - 1327
Hartebeest	102	0.7	71.6	18 - 579
Eland	241	1.6	92.6	35 - 1642
Kudu	764	5.1	59.6	166 - 3518
Steenbok	44	0.3	56.6	11 - 186
Ostrich	87	0.6	91.0	10 - 730
Waterbuck	115	0.8	63.0	35 - 376
Common duiker	6	0.4	56.2	2 - 19
Zebra	606	4.0	46.1	197 - 1864
Giraffe	131	0.8	59.8	34 - 500
Impala	700	4.6	82.1	98 - 5033
Klipspringer	29	0.2	97.2	3 - 296
Black wildebeest	1397	9.3	92.4	152 - 12864
Blue wildebeest	387	2.6	57.2	96 - 1559
Total	6104			

Results of counted animals from the three transects were examined over the entire area (150 km^2). Livestock animals such as cattle, horses and donkeys were not counted. Enormous variations in the coefficient results were visible with black wildebeest, impalas, eland and springbok. The two zebra species (mountain and plains) were not distinguished and lumped into one 'zebra' category.

Over time, the same groups, e.g. black and blue wildebeest, were observed repeatedly in certain areas of the farm (e.g. on VGC 3). Animals were simple to detect, because they prefer to stay in large groups in open areas to feed on grass.

Results of the waterhole observations at three different waterholes (Figure 2.2a; Bergposten North, Frankposten West and Nashornposten East) produced 1116 animals over 257 sightings. The percentage of juveniles was 11.6%. The study period was between August and November 2012. Most of the time animals noticed the observers in the hide, but more than 80% did not flee.

The greater kudu and black wildebeest were seen most often. Both species occur in herds of females and juveniles accompanied by a dominate male, or in bachelor herds. During the mating season, male black wildebeest defend territories and occur solitarily (Estes 1991). During the observation period at the Bergposten waterhole, in the north of the study site, no impala, springbok or blue wildebeest were seen. That area is very dense with bushes and trees and the waterhole is located at the bottom of a small mountain. Impala, springbok and blue wildebeest prefer open areas for foraging and are recorded more often at the other waterholes, which are located in open areas. The species with the most juveniles recorded was the warthog. Births are usually in the dry season, about four to five months after the end of the rainy season (Skinner and Chimimba 2005).

A few carcasses were found during the study period. One half eaten and dried out zebra foal was found in the mountains. It was used as bait for one box trap and a brown hyaena was able to take it out of the kraal.

An adult impala carcass was also found and a drag line on the road into the bush ended at another dead impala. Teeth marks on the throats and claw marks on the bodies of both animals pointed towards leopard as the predator. Camera traps were placed close to it and one kill was visited by the female leopard LF06 and the collared brown hyaena (BHM01) for a whole week. The second kill was visited by the same LF06 female and the LM04 adult male collared leopard (see Figure 2.7.3c).

Figure 2.7.3b Female leopard LF06 approaches a fresh male impala kill (above). Three hours later the same kill is visited by male leopard LM04 (below).

2.7.4. Discussion

The study period for game counts was conducted in late winter and the beginning of spring, and finished in early summer. Results from the DISTANCE analysis have to be interpreted with caution. About half of all records had covariances of over 60% and could thus not be used. One problem is that a larger dispersion of data occurred if animals were found and counted either in herds or solitarily; for instance, wildebeests occur in big herds but solitary males defend their territories and were counted singly. Another issue is the determination of a particular species over a long distance: for example, the classification between mountain and plains zebras. Because of an error in recording zebras, the two zebra species on Okambara were lumped together and the total number of zebras was estimated at 600 individuals with a covariance of under 50%. However, because of the lumping error this result is questionable. More secure and conclusive results were calculated for kudu and oryx with a density of 5.1 and 8.7 per km^2, respectively. Data from solitary animals or those living in pairs such as steenbok were difficult to analyse, because the animals can easily be overlooked in dense vegetation. Data collected in this first study period did not yield conclusive results.

It is likely that the dense vegetation over large distances reduced the sample size for most species. From this fact, an enormous increase in the sampling effort (counts should be continued over the whole year) could generate accurate numbers to determine reliable population sizes.

For some species the expedition data collection period coincided with their mating and reproduction periods. For example, impala females gave birth during the data collection period and are known to leave their calves hidden for protection (Skinner and Chimimba 2005). Suckling juveniles do not need to go to waterholes during the first weeks of life, resulting in underestimations.

It was found that observers at the waterhole by and large did not disturb the animals visiting. Animals were alert, but not fleeing and this gave researchers time to collect data. The data collected during the expedition should form the baseline for further data collection, which should include data collection during dry and wet seasons. If data over all seasons is collected, important statements for farm management about population growth and other population parameters can be made in future.

Bothma (2005) recommends using a combination of several methods for wildlife censuses in southern Africa. Distance sampling from the ground and air, combined with a camera trap survey, should yield meaningful results about game numbers. With the help of camera traps, nocturnal species can be detected and a useful addition to studies would be waterhole observations at night (during full moon, for example). Further hides should be built as necessary and game counts should be conducted more frequently across all seasons to develop a standardised method useful for management purposes.

On Ongos (previous study site) leopards were the only predators able to kill large antelopes (Killian and Hammer 2012). As the results of that study showed, large ungulates such as oryx and eland were rarely killed by leopards, probably because of the danger involved in tackling a large animal. Leopards preferred to kill medium-sized antelopes (47%; 15 - 30 kg), which occur in small herds, in dense habitat and present minimal risk of injury during the hunt. These findings are corroborated by the current study and Hayward et al. (2006) who cite an average prey mass of 23 kg. For Okambara the conclusion of this study is that leopards favour hunting impalas and springbok.

On the previous study site, prey abundance and prey catchability hypotheses were tested. The first hypothesis is that leopards kill prey that are most commonly available (prey abundance hypothesis, Hopcraft et al. 2005), whereas the second catchability hypothesis postulates that leopards hunt prey that is easier to capture, regardless of its frequency (Balme et al. 2007). Results of the previous study showed that the prey catchability hypothesis is the one that applies on Ongos, where leopards predominantly hunt species that represent easy prey (Killian and Hammer 2012). The results presented in the previous report corroborate results by Hayward et al. (2006) and Balme et al. (2007), who found that leopards prefer prey with (a) a solitary lifestyle, who (b) present a low risk of injury when being hunted and (c) live in dense vegetation. Therefore springbok, steenbok and common duiker are significantly (Chi^2-test) preferred, contributing over 55% of the leopard's diet on Ongos. Findings presented also indirectly corroborate Bailey (1993) who cites that impala is an important ungulate prey species of leopards throughout southern Africa, because the species yields the greatest return of energy for that expended in locating and killing its individuals. There were no impala on Ongos; their closest relatives present on the farm were springbok, which is one of the preferred prey species. The null hypothesis is that on Okambara leopards will follow the same habit; here impalas occur and they represent easy prey. This null hypothesis can only be confirmed or dismissed depending on the results of the scat analysis.

2.8. Discussion and conclusions

2.8.1. Discussion

The expedition’s research has shown that different carnivore species coexist. Species included leopard, brown hyaena, cheetah, caracal and black-backed jackal. The habitat quality present is sufficient to ensure the survival of the different carnivore species if no other threats arise. In contrast to the previous study site, Ongos, where a relatively high occurrence of leopards (2.7. individuals per km^2) was found, on Okambara a medium occurrence of 1.3 individuals per 100 km^2 was calculated. Home range size of a captured, collared and monitored male leopard (LM04) was smaller than that of the investigated leopard captured in 2011 on Ongos; only the core areas were of similar sizes. Home ranges of all three investigated and collared leopards in the last three years were found to be bigger than those in protected areas. The null hypothesis that due to the farm fence, which limits prey movement, leopards do not have to roam as widely as in fenceless national parks to find enough food to survive is not proved. The expectation that leopards occurring on farmland have smaller home ranges than leopards in protected areas is not confirmed. This is a very interesting result, which deserves further study into the underlying reasons.

Camera trap pictures, as well as the investigation of scats and tracks, confirmed coexistence of leopard, brown hyaena, caracal, African wildcat, Cape fox and jackals. Using camera trap pictures, several leopard individuals could be identified. A subadult female (LF05) was photographed during the expedition preparation phase (May to July 2012) and at the beginning of the expedition phase (August). Later on, no more evidence of this individual could be detected. This animal was also captured in a box trap on 3 August 2012, but not collared because of her young age. Another female (LF06), mature, was not captured but with the help of photographs (several ones between August and November 2012) her gender could be identified. She was seen together with an uncollared male leopard (LM05) (direct observation by farm owner Christian Schmitt and photos from camera traps in October and November), which might be an indicator that she was in oestrus. Two subadult brown hyaenas (BHM02 and BHF01) were captured and photographed several times during the study period. Female cheetahs with cubs were captured by different camera traps and observed directly. All these strands of evidence show that the habitat is suitable for the different predator species mentioned above, and their reproduction.

The scat investigation is still in progress and no propositions can be made as to what kind of species leopards prefer to hunt on Okambara. In general, leopards prefer to hunt prey that weighs between 15 and 30 kg, a finding corroborated by results from the previous Ongos study site. Two impalas killed by leopards were found. It is assumed that impala is one of the favourite leopard prey species on Okambara too. If this is confirmed by the scat investigation, a high density of less expensive game such as impala and springbok could decrease the probability of losses of more valuable game species.

The Okambara study site is surrounded by livestock farmers, who primarily farm cattle. The collared male leopard (LM04) roams on neighbouring farms in the north and east of the study site and it will be interesting to follow his movements more intensely to discover, for example, more details of habitat use and movements. Additional camera traps should be set up on neighbouring farms to extend the study area. Communication with neighbouring farmers should continue so that emerging problems such as leopard attacks on cattle can be recorded and discussed with the neighbouring farmers and non-lethal solutions can be found.

The 55-day GPS-based “life story” of LM01 from the previous Ongos study site showed that leopards can develop a taste for livestock if presented with easy prey options such as readily available, unprotected calves (Killian and Hammer 2012). Under such circumstances, leopards are very likely to become “problem predators” and the familiar pattern of predator-farmer conflict resulting in the death of the predator is the likely scenario that is undoubtedly played out all over Namibia and Africa time and time again. These scenarios result in the loss of top predators and with them, loss of biodiversity and potential revenue streams for farmers. Besides, removing a leopard will make its territory available to other, young leopards roaming the area in search of a territory. Killing a leopard is therefore likely to do nothing or even exacerbate the situation as one (or more) leopards will be attracted to the area and simply take over.

The results presented here provide information to assist wildlife managers and conservation bodies on predator carrying capacity and predator-prey interactions. Understanding the human-carnivore relationship is central to rural and commercial carnivore conservation and management and ultimately to the possibility of sustainable coexistence.

We hope that science-based results such as the ones presented here, translated into readily understandable management advice, will promote coexistence of stakeholder farmers and predators by reducing conflict and pointing towards revenue streams such as ecotourism. Biosphere Expeditions itself working on a Namibian game farm with international volunteers is a showcase of the oft-quoted win-win situation. Income for the farm through low-impact ecotourism helped provide useful scientific results that translated into sound management advice and predator/biodiversity conservation.

In the end, successful management of carnivores will require modifying both human and wildlife behaviour. Long-term success can only be attained by changing human behaviour, especially people’s attitudes towards, and tolerance of, human/predator conflict situations.

2.8.2. Management recommendations for stakeholder farmers

On game farms, game species are prevented from migrating by fences and have to adapt to farm conditions. Therefore good farm management is required to maintain stocks of healthy game animals, especially if an extreme drought occurs. With good management, fenced areas can be very good conservation tools, for rare species in particular.

Leopards are likely to become problem animals if presented with easy options to make a kill. Such easy options are inexperienced, weak and essentially defenceless large antelope as well as livestock juveniles.

To protect valuable game species from leopard depredation, farm managers should ensure that their farm is well stocked with low-value species (less expensive than sable and roan antelopes), particularly impala and springbok. Leopards are likely to then concentrate on these preferred easy target species and stay away from larger, more valuable species. Managers should also ensure that the entire game population is in a good, healthy condition and that the fenced areas are not overgrazed resulting in weakened game populations.

2.8.3. Outlook and recommendations for further work

To develop effective conflict resolution strategies, more about leopard biology on game farms must be known. Okambara is surrounded by cattle farms. All of them should be included in the next study period to investigate how leopards behave on these properties. Capturing and collaring of further predators is a high priority in order to monitor individual animals and their social units. Conducting further research on prey animals continuously over the whole year is another priority area. Furthermore, vegetation surveys should be performed.

2.9. Literature cited

Arthur, S., Krohn, W., and Gilbert, J. (1989): Habitat use and diet of fishers (*Martes pennanti)*. Journal of Wildlife Management 53: 680-88.

Bailey, T.N (1974): Social organization of a bobcat population. Journal of Wildlife Management 38: 435-46.

Bailey, T.N. (1993): The African leopard, Ecology and behaviour of a solitary felid. The Blackburn Press, New York.

Balme, G., Hunter, L., and Slotow, R. (2007): Feeding habitat selection by hunting leopards *Panthera pardus* in a woodland savanna: Prey catchability versus abundance. Animal Behavior 74: 589-598.

Berry, H. (1990): Large-scale commercial wildlife utilization: Hunting, tourism and animal production in Namibia. In: Wildlife Research for Sustainable Development, 45-49.

Bertram, B.C.R. (1982): Leopard ecology as studied by radio tracking. Symposia of the Zoological Society of London 49: 341-352.

Bothma, O., and le Riche, N. (1984): Aspects of the ecology and the behaviour of the Leopard (*Panthera pardus*) in the Kalahari Desert. Koedoe Supplement 27(1): 259-79.

Bothma, J., and Bothma, M. (2005): Activity patterns in southern Kalahari leopards. African Zoology 41(1): 150-152.

Bothma, J. du P., Knight, M.H., le Riche, E.A.N., and Van Hensbergen, H.J. (1997): Range size of southern Kalahari leopards. South African Journal of Wildlife Research 27(3): 94-99.

Boulanger, J., Himmer, S., and Swan, C. (2004): Monitoring of grizzly bear population trends and demography using DNA mark-recapture methods in the Owikeno Lake area of British Columbia. Canadian Journal of Zoology 82: 1267-1277.

Buckland, S., Anderson, D., Burnham, K., and Laake, J. (1993): Distance sampling: Estimating abundance of biological populations. Chapman and Hall, London.

Buckland, S., Anderson, D., and Burnham, K. (2008): Advanced distance sampling: Estimating abundance of biological populations. Oxford University Press, Oxford.

Brown, C. J. (1992) Namibia's green plan (environment and development) Ministry of Environment and Tourism, Windhoek, Namibia

Caro, T. (1994): Cheetahs of the Serengeti plains. University of Chicago Press, Chicago.

Castro-Prieto, A., Wachter, B., Melzheimer, J., Thalwitzer, S., and Sommer, S. (2011): Diversity and evolutionary patterns of immune genes in free-ranging Namibian leopards (*Panthera pardus pardus*). Journal of Heredity 102(6): 653-665.

Doncaster, C., and Macdonald, D. (1991): Drifting territoriality in the red fox (*Vulpes vulpes)*. Journal of Animal Ecology 60: 423-39.

Durant, S. (1998): Competition refuges and coexistence: an example from Serengeti carnivores. Journal of Animal Ecology 67: 370-386.

Eisenberg, J., and Lockhart, M. (1972): An ecological reconnaissance of Wilpattu National Park, Ceylon. Smithsonian Contributions to Zoology 101: 1-118.

ESRI – ArcGIS 9.3 http://www.esri.com/software/arcgis

Estes, R. (1991): The Behavior Guide to African Mammals: Including Hoofed Mammals, Carnivores, Primates. University of California Press, Berkeley and Los Angeles, California.

Fröhlich, M., Berger, A., Kramer-Schadt, S., Heckmann, I., and Martins, Q. (2012): Complementing GPS cluster analysis with activity data for studies of leopard (*Panthera pardus*) diet. South African Journal of Wildlife Research 42(2): 104-110.

Hamilton, P. (1976): The movements of leopards in Tsavo National Park, Kenya, as determined by radio tracking. M.Sc. thesis, University of Nairobi.

Hansen, L., and Stander, F. (2004): Namibian Large Carnivore Atlas, Full book. http://www.catsg.org/catsglib/recordetail.php?recordid=8646

Harris, S., Cresswell, W., Forde, P., Trewhella, W., Wollard, T., and Wray, S. (1990): Home-range analysis using radio-tracking data - A review of problems and techniques particularly as applied to the study of mammals. Mammal Review 20: 97-123.

Hayne, D. (1949): Calculation of size of home range. Journal of Mammalogy 30: 1-18.

Hayward, M., Henschel, P., O'Brian, J., Hofmeyer, M., Balme, G., and Kerley, G. (2006): Prey preferences of the leopard (*Panthera pardus*). Journal of Zoology 270: 298-313.

Hofer, H., and East, M. (1993): The commuting system of Serengeti spotted hyaenas: how a predator copes with migratory prey. I. Social organization. Animal Behaviour 46: 547-557.

Hopcraft, J., Sinclair, A., and Parker, C. (2005): Planning for success: Serengeti lions seek prey accessibility rather than abundance. Journal of Animal Ecology 74: 559-556.

Hunter, L. (2011): Carnivores of the world. Princeton University Press.

IUCN (2013): IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>; Panthera pardus (2008) http://www.iucnredlist.org/details/15954/0

Jackson, R., Roe, J., Wangchuk, R., and Hunter, D. (2006): Estimating snow leopard population abundance using photography and capture-recapture techniques. Wildlife Society Bulletin 34(3): 772-781.

Jenks, K.E., Chanteap, P., Damrongchainarong, K., Cutter, P., Cutter, P., Redford, T., Lynam, A.J., Howard, J., and Leimgruber, P. (2011): Using relative abundance indices from camera-trapping to test wildlife conservation hypotheses – an example from Khao Yai National Park, Thailand. Mongabay.com Open Access Journal – Tropical Conservation Science 4(2): 113-131.

Jenny, D. (1996): Spatial organization of leopards *Panthera pardus* in Tai National Park, Ivory Coast: Is rainforest habitat a ‘tropical haven’? Journal of Zoology, London 240: 427-440.

Jenny, D., and Zuberbühler, K. (2005): Hunting behaviour in West African forest leopards. African Journal of Ecology 43: 197-200.

Karanth, K. (1995): Estimating tiger (*Panthera tigris*) populations from camera-trap data using capture-recapture models. Biological Conservation 71: 333-338.

Karanth, K., and Nichols, J. (1998): Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79: 2852-2862.

Karanth, K., and Nichols, J. (2002): Monitoring tigers and their prey: a manual for researchers, managers and conservationists in tropical Asia. Centre for Wildlife Studies, Bangalore, India.

Karanth, K., Chundawat, R., Nichols, J., and Kumar N. (2004): Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture–recapture sampling. Animal Conservation 7: 285-290.

Killian, K., and Hammer, M. (2012): Studying leopards (*Panthera pardus*) on a game farm in the Khomas Hochland, Namibia. Biosphere Expeditions, Norwich. Expedition report available via www.biosphere-expeditions.org/reports.

Kingdon, J. (1977): East African mammals: An atlas of evolution in Africa, Vol. 3(A). Carnivores. Academic Press, New York.

Marker-Kraus, L., Kraus, D., Barnett, D., and Hurlbut, S. (1996): Cheetah survival on Namibian farmlands. Cheetah Conservation Fund, http://www.cheetah.org/ama/orig/con_prot.pdf.

Marker, L., and Dickman, A. (2005): Factors affecting leopard (*Panthera pardus*) spatial ecology, with particular reference to Namibian farmlands. South African Journal of Wildlife Research 35: 105-115.

Mendelsohn, J. (2009): Atlas of Namibia. Ministry of Environment and Tourism, Sunbird Publishers, Cape Town.

Mills, M.G.L., Gorman, M.L., and Mills, E.J. (1980): The scent marking behaviour of the brown hyaena (*Hyaena brunnea*). South African Journal of Zoology 15: 240-248.

Mitchell, B., Shenton, J., and Uys, J. (1965): Predation on large mammals in the Kafue National Park, Zambia. African Zoology 1: 297-318.

Moyer, M., McCown, W., Eason, T., and Oli, M. (2005): Does genetic relatedness influence space use pattern? A test on Florida black bears. Journal of Mammalogy 87(2): 255-261.

Norton-Griffiths, M. (1978): Counting animals. Second edition. African Wildlife Leadership Foundation, Nairobi.

Norton, P., and Lawson, A. (1985): Home range and movements of male leopards in the Cedarberg Wilderness Area, Cape Province. South African Journal of Wildlife Research 17: 41-48.

Nowell, K., and Jackson, P. (1996): Wild cats, Status survey and conservation action plan. IUCN/SSC Cat Specialist Group, Switzerland.

Otis, D., Burnham, K., White, G., and Anderson, D. (1978): Statistical inference from capture data on closed animal populations. Wildlife Monographs 62, 135pp.

Powell, R. (2000): Animal home ranges and territories and home range estimators. In: Boitani, L. & T.K. Fuller (eds) Research techniques in animal ecology - Controversies and consequences: 65-110. Columbia University Press, New York.

Ray, J., Kent, H., and Steneck, R. (2005): Large carnivores and the conservation of biodiversity. Island Press, Washington D.C.

Rexstad, E., and Burnham,K. (1991): User’s guide for Interactive Program CAPTURE. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins.

Schaller, G.B. (1972): The Serengeti lion. University of Chicago Press, Chicago.

Seidensticker, J., Hornocker, M., and Knight, R. (1970): Equipment and techniques for radio-tracking mountain lions and elk. Forest, Wildlife and Range Exp. Station Bulletin, no. 6.

Skinner, J.D., and Chimimba, C.T. (eds). (2005): The mammals of the southern African subregion. Cambridge University Press. 3rd Edition, UK.

Stander, P., Ghau, II., Tsisaba, D., OMA, II., and VI, II. (1997): Tracking and the interpretation of spoor: scientifically sound methods in ecology. Journal of Zoology 242: 329-341.

Stander, P.E. (1997b): Field age determination of leopards by tooth wear. African Journal of Ecology 35: 156-161.

Stander, P. (1998): Spoor counts as indices of large carnivore populations: the relationship between spoor frequency, sampling effort and true density. Journal of Applied Ecology 35: 378-85.

Stein, A. (2008): Ecology and conservation of the leopard (*Panthera pardus* Linnaeus 1758) in northcentral Namibia. *Electronic Doctoral Dissertations for UMass Amherst.* http://scholarworks.umass.edu/dissertations/AAI3325271

Stein, A.B., Fuller, T.K., DeStefano, S., and Marker, L.L. (2011): Leopard population and home range estimates in north-central Namibia. African Journal of Ecology 49: 383-387.

Stuart. C., and Stuart, T. (2000): Tracks and signs of southern and East African wildlife. Struik Publishers, Cape Town.

Sunquist, M.E., and Sunquist, F. (2002): Wild cats of the world. University of Chicago Press, London.

Tobler, M. (2010): Camera Base, Version 1.5, http://www.gnu.org/licenses.

Wachter, B., Jauernig, O., and Breitenmoser, U. (2006): Determination of prey hair in faeces of free-ranging Namibian cheetahs with a simple method. Cat News 44: 8-9.

Walker, H. (1996): Signs of the wild. Struik publishers, Cape Town.

Walton, L., Cluff, H., Paquet, P., and Ramsay, M. (2001): Movement patterns of barren-ground wolves in the central Canadian Arctic. Journal of Mammalogy 82: 867-876.

Worton, B. (1995): Using Monte Carlo simulation to evaluate kernel-based home range estimators. Journal of Wildlife Management 59: 794-800.

Worton, B. (1989): Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70(1): 164-168.

Zeiss, B. (1997): Waterberg leopard project. Albert-Ludwigs-Universität Freiburg, Germany and the Ministry of Environment and Tourism, Namibia.

3. Elephant study

Jörg Melzheimer
Biosphere Expeditions

3.1. Introduction

Safari tourism is a rapidly growing industry and an increasing number of farmers are changing their cattle farms to game farms. This may sound ecologically favourable, but is in fact only so under certain circumstances. Most farmers buy in valuable game and erect high, game-proof fences to keep their valuable (re-)introduced game on their property. As in other industries, owners and managers of game farms and safari lodges have to compete for customers and do so by offering unique sales points. In this context, the bigger the variety of African mammals on their property, the higher the chance of attracting visitors. This results in a variety of rare and/or exotic game species being kept on privately owned land, namely the lion farms in South Africa (offering activities such as lion walks), rare antelopes (e.g. sable antelopes, waterbuck) on many farms outside their historic range, breeding albino or other rare mutations of antelope species (golden oryx, golden wildebeest, black springbok), hippos in artificial waterholes in arid areas, and also elephants on small game farms. In Namibia, only a handful of private game reserves keep elephants, but increasing numbers are applying for permits at the Ministry of Environment and Tourism (MET) to keep elephants.

Elephants are known to have various and significant impacts on the ecosystem. Known as ecosystem engineers (Jones et al 1994), they very significantly change the environment they live in by pushing over trees, digging large holes and leaving behind large piles of dung.

Very little data exist on either the effect of elephants as ecosystem engineers within a game ranch setting or their ecology and ethology when confined to relatively small fenced-in areas. This study therefore aims to investigate the impact of and on elephants that are kept on the 15,000 ha (150 km^2) Okambara game ranch. The herd comprises three females and six juveniles and it is always found together.

3.2. Methods

From August to December 2012 the herd of elephants on Okambara was located 63 times. Usually one group of expedition participants located the elephants early in the morning and a second group followed them in the afternoon. The herd was located using a VHF radio signal and, once located, the GPS position was recorded. Researchers then followed the herd and recorded feeding behaviour (n=155 with total of 25.8 hours observation time). During feeding, the vegetation category (grass, shrub, tree) being eaten was recorded, as was the number of trees knocked over and killed.

3.3. Results

The positions where the elephants were found are shown in Figure 3b. Among the three different vegetation categories, shrubs were preferred over grass and trees (see Figure 3c). In the 25.8 hours of observation, two trees were knocked over and ultimately killed.

Figure 3a. Elephant feeding on *Acacia mellifera* in early spring 2013.

3.4. Discussion

The first study of elephant spatial and feeding ecology on Okambara revealed some interesting facts. During spring, the elephants preferred to feed on the abundant *Acacia mellifera* tree. About half of their diet consisted of *Acacia mellifera* followed by grass and other trees. We hypothesise that this is because during spring, *Acacia mellifera* is one of the earliest trees to flower and therefore provides the first fresh plant biomass in the vegetation period. Accordingly, the elephant were almost always found on small slopes with dense *Acacia* thickets at the beginning of the expedition. As the expedition progressed and temperatures increased, shrubs in the plains started flowering with the herd following and being encountered in the plains more.

Two trees were killed during 25.8 hours of observations. This frequency sums up to a total of 680 trees killed per annum, which explains the high number of knocked-over trees on Okambara and the high impact just one herd can have on the environment.

These first results are interesting and further studies are needed to obtain a more comprehensive picture over the course of the year. As direct observation is typically very labour-intensive, it is the Biosphere Expedition teams that make this research possible. Expeditions should be run more often and across all seasons, if possible. The herd's lead cow should also be fitted with a GPS collar to make tracking the herd easier and quicker.

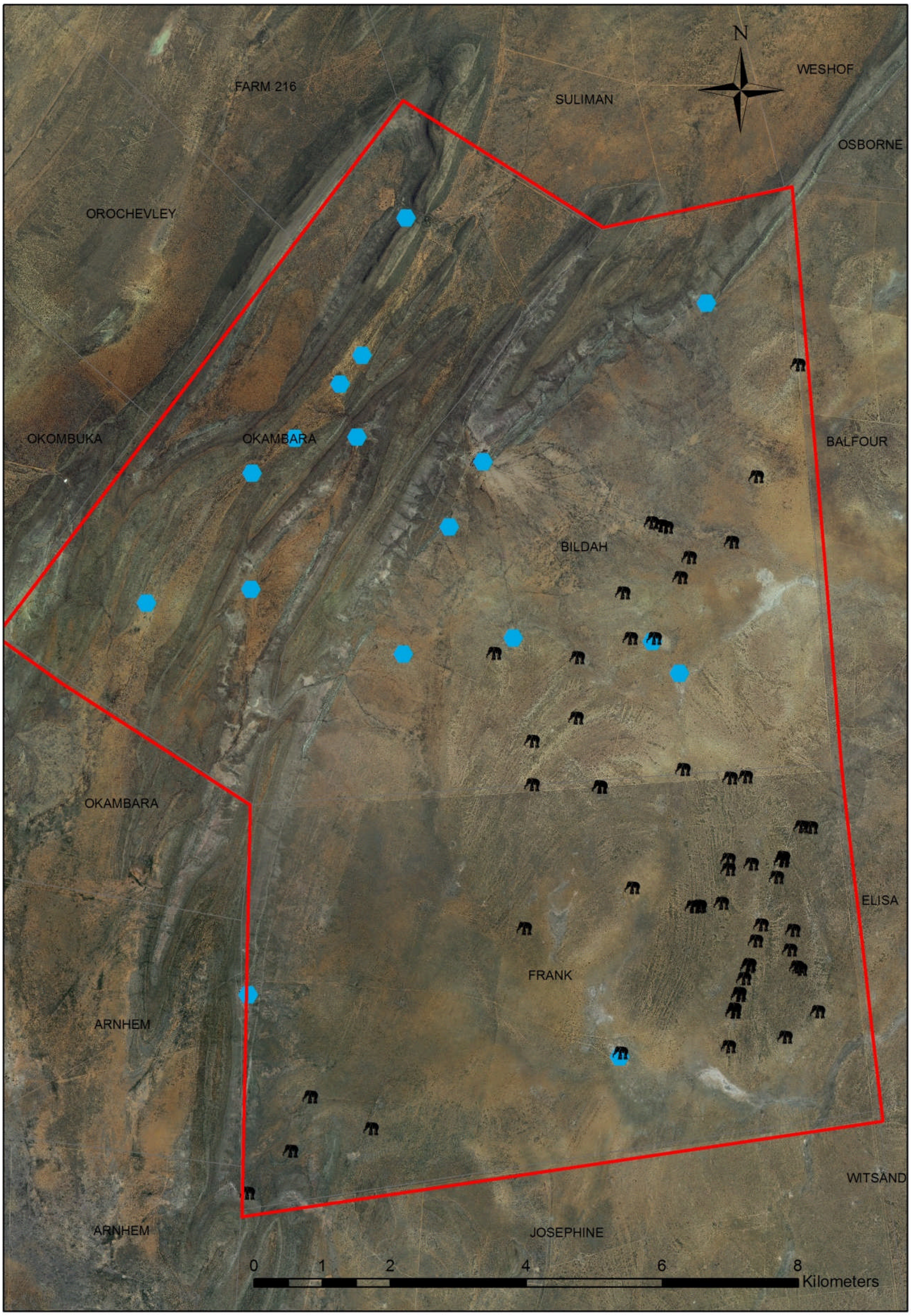

Figure 3b. Position of the elephant herd (black elephants) during the 63 observations from August 2012 to December 2012. Blue hexagons represent waterholes.

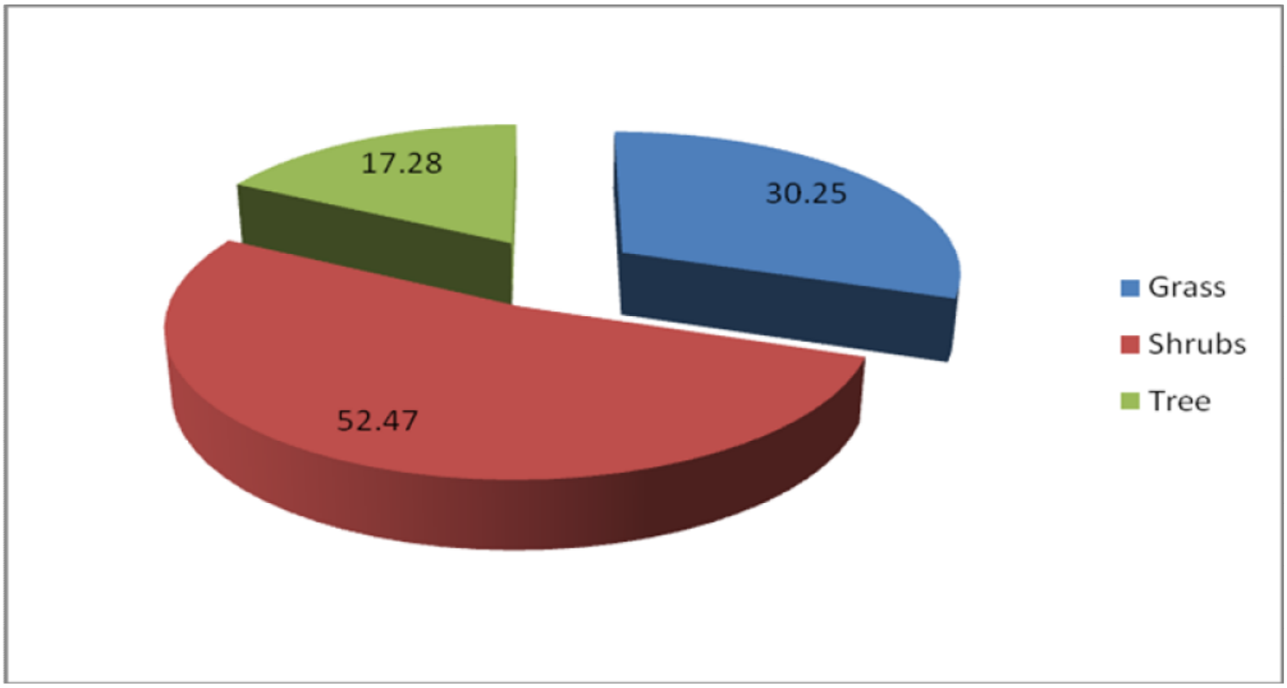

Figure 3c. Percentage of vegetation classes consumed by elephants on Okambara from August to December 2012.

3.5. Literature cited

Jones, C.G., Lawton, J.H., and Shachak, M. (1994): Organisms as ecosystem engineers. Oikos 69: 373-386.

Appendix I: Studies reporting mean home range sizes (95% minimum convex polygons) and densities of leopards in sub-Saharan Africa.

Study Area	Home range size (km^2)		Density (no. per 100 km^2)	Reference
	Male	Female		
Serengeti National Park, Tanzania	18	16	10.40	Schaller 1972; Bertram 1982
Kruger National Park (SRSA), SA	28	18	16.40	Bailey 1993
Tsavo National Park, Kenya	36	14	10.80	Hamilton 1976
Kruger National Park (NRSA), SA	76	15	9.5	Bailey 1993
Tai National Park, Ivory Coast	86	25	9.5	Jenny 1996
North central Namibia	108	53	4.5	Stein 2008
Waterberg Plateau Park, Namibia	119	64	1.3	Zeiss 1997
North-eastern Namibia	217	128	0.6	Hanssen & Stander 2004; Stander et al. 1997
North-central Namibia	229	179	3.2	Hanssen & Stander 2004; Marker & Dickman 2005
Cape Province, SA	388	487	0.9	Norton & Lawson 1985
Kalahari Desert, Botswana	2,182	489	0.6	Bothma & Le Riche 1984

Appendix II: Expedition diaries & reports.

A multimedia expedition diary is available on http://biosphereexpeditions.wordpress.com/category/expedition-blogs/namibia-2012/

All expedition reports, including this and previous expedition reports, are available on www.biosphere-expeditions.org/reports.