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EXPEDITION REPORT

Expedition dates: 3 August – 7 November 2014
Report published: September 2015

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

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Authors:
Vera Menges
Biosphere Expeditions

Matthias Hammer (editor)
Biosphere Expeditions

Abstract

This research project started in 2012 and was based on Okambara Elephant Lodge, a game farm located 85 km south of Windhoek's international airport, in the Khomas region of central Namibia. Okambara is game-fenced and comprises an area of 150 km^2. This report covers the survey work conducted during the period of August–November 2014. The key study species was the African leopard (*Panthera pardus*).

Leopards are protected animals and listed as Near Threatened by the IUCN (International Union for Conservation of Nature). 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.

This study focussed on the spatial ecology and prey preferences of leopards on Namibian farmland. Invasive as well as non-invasive methods were used; invasive methods included trapping and collaring of leopards, whilst non-invasive methods included camera traps, track counts, search for prey remains and faeces collection.

Data collected on Okambara showed differences in the ecology of leopards living on farmland and in protected areas. Home range sizes on farmland were bigger than those of leopards living in protected areas, most likely due to habitat preferences, variation in prey availability and lower predator densities compared to protected areas.

The camera trap surveys on Okambara yielded a density of 1.8 individuals per 100 km^2, a lower density compared to protected areas, thereby confirming the assumption that home range size is related to density. The camera trap surveys, as well as the monitoring of carnivore tracks and scats, also revealed the existence of additional carnivores and related interspecific behaviour showing that predators seem to avoid each other, thereby reducing 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 survival and reproduction of different predator species.

Zusammenfassung

Im Jahr 2012 startete dieses Forschungsprojekt auf der Okambara Elephant Lodge, einer Wildtierfarm etwa 85 km südlich von Windhoeks internationalem Flughafen, in der Khomas Hochland Region in Zentral-Namibia. Okambara ist von einem Wildtierzaun umgeben und deckt ein Gebiet von 150 km² ab. Dieser Bericht befasst sich mit Untersuchungen, die dort im Zeitraum August-November 2014 durchgeführt wurden. Im Fokus der Studie stand der Leopard (*Panthera pardus*).

Der Leopard ist eine geschützte Art und als "potenziell gefährdet" von der IUCN (International Union for Conservation of Nature) eingestuft. Jedoch kommt ein Großteil der namibischen Leopardenpopulation auf kommerziell genutztem Farmland und somit außerhalb geschützter Gebiete vor. Dadurch ist die Erhaltung dieser Art in Namibia nicht gesichert. Ihr Status als "Problem-Beutegreifer", ein hoher Trophäenwert, fortschreitender Verlust von Lebensraum und Wildtierkrankheiten sind ihre stärksten Bedrohungen. Diese Bedrohungen sowie der Mangel an wissenschaftlichen Daten machen es sinnvoll und notwendig, diese Spezies im Lebensraum Farmland besser zu erforschen.

In dieser Studie standen die räumliche Ökologie von Leoparden auf nambianischen Farmland sowie deren Beutepräferenzen im Mittelpunkt. Sowohl invasive als auch non-invasive Methoden wurden angewandt; invasive Methoden beinhalteten den Fang und die Besenderung von Leoparden, während non-invasive Methoden die Nutzung von Kamerafallen und die Suche nach Kot, Spuren und Überresten von Beutetieren umfassten.

Die auf Okambara aufgenommenen Daten zeigten, dass sich die räumliche Ökologie von Leoparden auf namibianischen Farmland von der in geschützten Gebieten vorkommenden Leoparden unterscheidet. Streifgebiete waren größer als in Schutzgebieten und dies ist vermutlich auf Habitatpräferenzen, variierende Beutetierdichte, sowie geringere Beutegreiferdichte im Vergleich zu geschützten Gebieten zurückzuführen.

Der Kamerafallenstudie zufolge weist Okambara eine Leopardendichte von 1,8 Tieren pro 100 km^2 auf. Die Leopardendichte auf Farmland ist somit geringer als in geschützten Gebieten und unterstützt die Vermutung eines Zusammenhangs von Streifgebietsgrößen mit vorkommender Dichte. Weiterhin zeigte der Einsatz von Kamerafallen, sowie die Aufnahme von Karnivorspuren und -kot das Vorkommen weiterer Beutegreifer auf Okambara, sowie damit verbundenes interspefizisches Verhalten, da sich die verschiedenen Arten in Raum und Zeit zu meiden scheinen, um Konflikte zu vermeiden. Damit ist Okambara ein geeignetes Habitat für den Fortpflanzung und Bestand verschiedener Beutegreifer.

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 3 August to 7 November 2014. 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*) 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 African elephants (*Loxodonta africana*) 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" reduction, 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. In 2011, the Ministry of Environment and Tourism conducted a leopard population density estimate (national estimate: 14,154 leopards) throughout Namibia on which the hunting quota for leopards was based (250 individuals per annum) (Stein & Aschenborn 2012). However, the removal through human-wildlife conflict is poorly monitored and currently no reliable numbers are accessible.

1.2. Research area

At 825,418 km^2 Namibia is the world's 34th largest country (Figure 1.2a). However, after Mongolia, it 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 make up the remaining 20% (Berry 1990). 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.

Flag 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 Okambara 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.

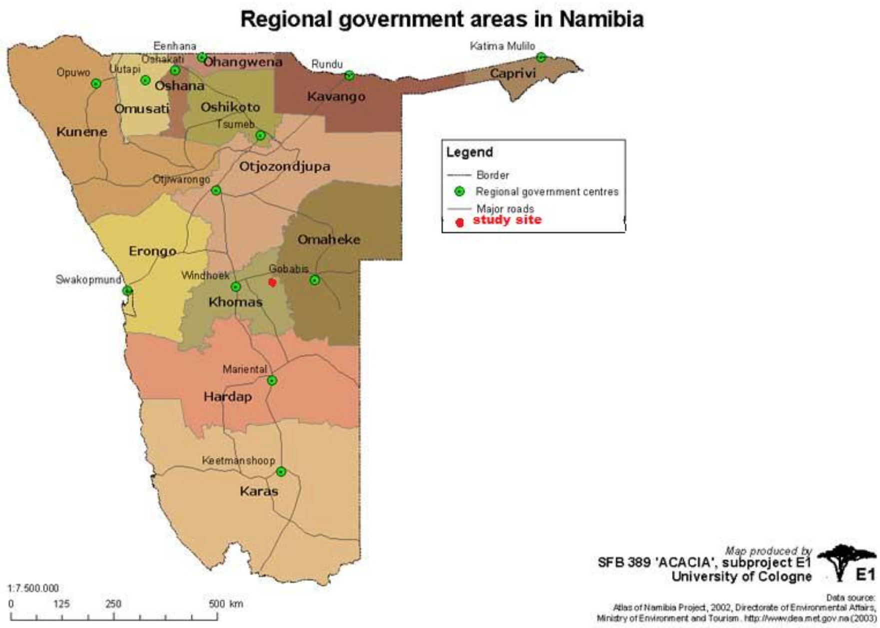

Figure 1.2b. Regional government areas and study site (red dot) in Namibia.

1.3. Dates

The expedition ran from August to November 2014, split into seven two-week groups:

3 - 15 August | 17 - 29 August || 7 - 19 September | 21 September - 3 October || 12 - 24 October | 26 October - 7 November 2014.

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 40ºC 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 August 2014. Annual rainfall was highly variable, but in general rainfall in 2014 was higher compared to the previous year. Average daily temperatures during the expedition ranged from 18 to 38.3ºC.

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.

Cars used during the expedition were Toyota Landcruisers, provided by Christian Schmitt, the owner of Okambara Game Reserve. Team members wishing to drive the cars 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 located in Windhoek. All team members were required to carry adequate travel insurance covering emergency medical evacuation and repatriation. Emergency procedures were in place, but did not have to be invoked. There were some minor medical issues such as a hurt thumb and minor dehydration, but no serious medical incidents during the expedition.

1.5. Expedition scientist

Vera Menges, born and educated in Germany, joined Biosphere Expeditions in 2013. After spending a couple of years abroad (UK & New Zealand), she graduated from the Westphalian Wilhelms-University Muenster in Germany with a Bachelor's Degree in Biology and from Edinburgh Napier University in Scotland with a Master's Degree in Conservation and Management of Protected Areas. The latter was based on research of brown bears in Sweden in collaboration with the Scandinavian Brown Bear Research Project. Since then, she has worked for this bear project as well as for a lynx/roe deer research project in the Bavarian Forest National Park, Germany. Now she is putting her skills and passion for wildlife research and conservation towards pursuing a PhD on leopard ecology within the spatial ecology working group of the Leibniz Institute for Zoo and Wildlife Research in Berlin, as well as mitigating the local human–wildlife conflict by working on the big cat project in Namibia.

1.6. Expedition leader

Alisa Clickenger was born in the United States and educated at Bennington College in Vermont. After many successful years in the corporate world, she fell in love with the path less travelled. She now lives a life of travel and adventure, and writes about it for several magazines. An experienced overlander on two and four wheels, Alisa has a love of nature and foreign cultures which in 2009 brought her on a seven-month solo journey through Central and South America seeking wildlife and wild places. An experienced tour guide in the adventure travel field, at Biosphere Expeditions Alisa realises a dream – that of combining her love of people with her love of wildlife and conservation.

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 (in alphabetical order and with countries of residence):

3 - 15 August 2014

Sebastian Deiber (Austria), Simona Duranti (Qatar), Paula Malesa (USA), Polly Marti (USA), Eva Schoenmakers (Austria), Heinrich Staudigl (Germany), Eric Stockeyr (Belgium), Christine Tschynylo (Belgium), Marco Zanferrari (Qatar).

17 - 29 August 2014

Valerie Boquet (USA), Leung Siu Han (China), Lynne Ogilivie (Canada), Lesley Oliver (Australia), John Rawnsley (UK), Glenn Woodford (Australia).

7 - 19 September 2014

Diane Bateman (UK), Barbara Buchter (Germany), Monika Monn (Switzerland), Rebekka Thalmann (Switzerland).

21 September - 3 October 2014

Edward Durell (USA), Volker Hegemann (Germany), Jeff Holten (Canada), Sonja Krezmer (Germany), Keryn Lewis (Australia), Nerys Lewis (Australia), Sue McVerry (UK), Jan Moore (Canada), James Smith (USA), Rebekka Thalmann (Switzerland), Renate Winderl (Germany).

12 - 24 October 2014

Helen Bartholomew (UK), Emma Charles (UK), John Cotton (UK), Paul Gent (UAE), Martina Gruben (Germany), Bruce Hambour (Australia), Louize Hermitage-Holt (UK), Vibeke Jensen (Denmark), Ashley O'Brien (Australia), Mara Schiff (USA), Mark Schiff (USA), Diane Williamson (UK).

26 October - 7 November 2014

Sabine Brandstetter (Austria), Markus Cudaj (Germany), Astrid Eglitis (USA), Sandra Kraetschmer (Germany), Stuart McDonald (UK), Heidemarie Moser-Sturm (Austria), Karen Smith (UK), Christiane Stalschus (Germany).

Also: Guides Jesaja (slot 1 and 2), Legius (Slot 1 to 6), William (Slot 3), Paul (Slot 5 and 6).

1.8. Expedition budget

Each team member paid towards expedition costs a contribution of £1,750 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., or 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	102,701
Expenditure	
Staff includes local & international salaries, travel and expenses, living expenses	16,234
Research includes equipment, animal capture and other research expenses	15,370
Transport includes bus transfers, fuel, car tax & maintenance	16,721
Base includes board, lodging and other base camp services	29,153
Administration includes office costs, visa & professional fees and miscellaneous costs	222
Team recruitment Namibia as estimated % of PR costs for Biosphere Expeditions	6,525
Income – Expenditure	**18,476**
Total percentage spent directly on project	**82%**

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 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 and their contribution to the research on Okambara. My thanks also go to Swarovski Optik for providing binoculars and range finders. I thank the Institute for Zoo and Wildlife Research in Germany for scientific advice, help with handling and immobilisation of animals and analysing blood samples. My 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. Also, I would like to thank Alisa Clickenger for running the expedition on the ground and her support on numerous occasions. I thank Matthias Hammer and the other reviewers for their comments on various versions of this manuscript. Last but not least, I would like to thank Biosphere Expeditions 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 a Namibian game farm

Vera Menges
Biosphere Expeditions

2.1. Introduction and background

Given the steady decline in biodiversity, it is of increasing importance to connect nature conservation with science-based management (Lawler et al. 2006, Soulé & Orians 2001). Research not only serves to broaden scientific knowledge, but is also essential for predicting the success of management plans for species. This is especially true for large carnivores as they are at the top of the food chain in terrestrial ecosystems, but at the same time represent its most vulnerable elements (Schipper et al. 2008). Studies indicate that carnivores play an essential role as they structure as well as preserve the existing biodiversity through their prey choice (Miller et al. 2001). The elimination of carnivores can lead to a chain of negative consequences, starting with the demographic explosion of herbivores and meso-carnivores and unsustainable grazing pressure, leading to biodiversity loss at all levels of the food chain, and it can even result in a collapse of the ecosystem (Estes & Duggins 1995, Henke & Bryant 1999). It is therefore crucial to protect apex predators, in order to preserve biodiversity as well as the ecosystems that host them.

Research on carnivores is usually not very practice-oriented and management guidelines are often intuitive and subject to trial-and-error methods, rather than relying on scientific facts (Ray et al. 2005). However, species-specific knowledge of ecology and biology of a species is required for the successful implementation of wildlife conservation and management (Frankham et al. 2002). Thus the probability of success of the applied methods increases and important resources, such as time and finances, are used more effectively. In Africa, human–wildlife conflicts are among the three main threats to the existing biodiversity; in particular for large cats such as the leopard (*Panthera pardus*) (Nowell & Jackson 1996, Ray et al. 2005, Treves & Karanth 2003, Woodroffe 2000).

Several studies on leopards (*Panthera pardus*) exist already, but they were usually carried out in protected areas such as Kruger, Serengeti and Etosha National Parks (Bertram 1982, Bailey 1993, Stander 1997, Durant 1998, Mizutani 1999, Ray et al. 2005). However, the majority of leopards in Namibia occur on commercial farmland. There, the local farmers are often accused of persecuting big cats to protect their livestock. Such behavioural patterns are primarily due to the absence of basic strategies to avoid conflicts with these animals in the first place (Linnell et al. 2001, Marker et al. 2003). Namibian farmers are organised locally into so-called conservancies in which they develop and agree on management guidelines. Since there is often a lack of information on the ecology and biology of the big cats, these management guidelines are often neither sustainable, nor do they solve problems comprehensively. Most of the local farmers are engaged in breeding cattle and also use the locally abundant wildlife for their own consumption as well as for trophy hunting. Losses due to predators are reported regularly; some farmers have particularly high losses, which put them under high economic pressure, and are therefore intolerant of big cats and other predators (Shwiff & Sterner 2002, Hughey et al. 2003). 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. Persecution of leopards and their extermination on farmland with methods 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 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 can 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.

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). Leopards in protected areas, for example in national parks, are habituated to humans. Therefore extended periods of observation are 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 and elusive mammals in their habitats (Seidensticker et al. 1970, Bailey 1974) as the data obtained provide information on home range sizes, movement patterns and habitat use. 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.

Also, monitoring the abundance and distribution of animals is fundamental to the research, management and conservation of wildlife populations. Estimating animal numbers is often a basic requirement for determining the status of species. However, this task is deceptively simple and no single best approach exists; techniques that work well in some situations are useless in others (Caughley and Sinclair 1994). Many terrestrial mammals such as the leopard are nocturnal, cryptic in appearance, and, in the case of leopards on farmland, generally adept at avoiding being seen, which limits well-developed methods of direct observation (Duckworth 1998, Chiarello 2000, Lopés and Ferrari 2000, Jachmann 2001). These challenges leave indirect observation, for example via animal tracks or remote photography, as often the only realistic option. 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. 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 indigestible and undamaged 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.

In addition, prey preferences can further be evaluated through GPS cluster analysis. This is a fairly new method to detect potential kill sites of carnivores and has been applied only in a few studies (Krofel et al. 2012, Pitman et al. 2012, Fröhlich et al. 2012). Leopards revisit kill sites for up to several days in order to fully consume their prey, thereby leading to a specific pattern of GPS locations ("clusters"). Remains found at these locations can be used to identify prey species and therefore provide information on individual prey preferences of leopards. Such findings are very important to demonstrate predator dietary preferences and thus enable game ranchers to manage predators on their land.

The abundance and density of prey species are influencing factors on predator occurrence, densities and prey preferences and therefore need to be investigated as well. In addition, the management of game species on game farms is an important factor in securing income. In areas where wild ungulates are utilised by people for either consumptive purposes (commercial hunting and game farming) or non-consumptive purposes (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. 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 areas and many pieces of information are needed for successful management, such as game density, reproduction rate, primary production and sustainable stocking rates.

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 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? What is the local prey availability and abundance?

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 a game fence (height 4 m) (Figure 2.3a). All internal fences have been removed, thus allowing free roaming of wildlife (in Figure 2.3a 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 (altitudes range from 1,500 to 2,000 m) with many different habitat types ranging from typical African bushveld to mountainous areas, and it contains 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 not been used for any commercial farming activity for many years, 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 farm setting.

Although the study area is fenced in, the movements of leopards and other felids are not confined as cats (as well as other predators 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 one individual to over 30 per 100 km², with the highest densities recorded in protected eastern 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 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 (Berry 1990, Bailey 1993).

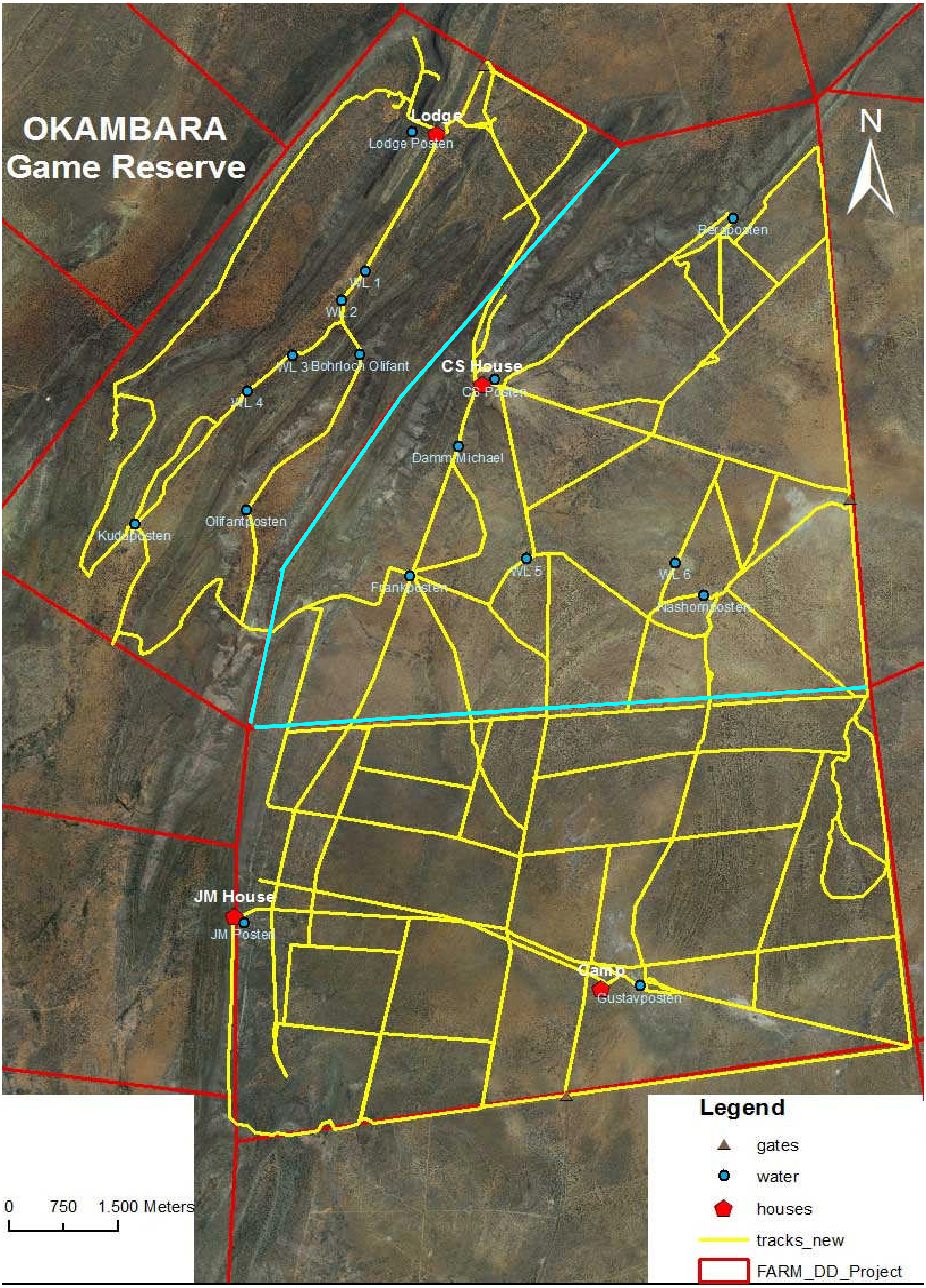

Figure 2.3a. Okambara Game Reserve consists of three former farms as shown by the red lines that surround farm roads (yellow). The outer red line perimeter is an electrified game fence; inner fences (turquoise) have been removed.

Leopards are solitary, nocturnal carnivores with spacious home ranges, but only occur in low densities (Spong et al. 2000). Both sexes are territorial and defensive against adult conspecifics of the same sex; they mark their territory with scent, faeces and scratch marks (Hamilton 1976, Bailey 1993). Leopards are very good climbers; they often hide their prey in trees to avoid scavengers. Their hunting strategy consists of stalking and pouncing; thus they do not chase their prey over long distances (Bailey 1993, Stander et. al 1997). Leopards have a vast range of prey; Bailey (1993) noted at least 92 prey species used by leopards in sub-Saharan Africa, varying from species as small as the dung beetle up to large mammals such as adult male eland antelopes (Kingdon 1977). Yet despite this apparent ability to successfully exploit prey spanning such an enormous size range, the leopard's 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. Methods

2.4.1. Capturing and collaring

Box traps were baited mainly with antelope as well as zebra meat and were checked twice a day (morning and late afternoon). Once a target animal, i.e. a predator, was captured, it was darted and immobilised. Drug choice, dosages and combinations depended on the 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 both sides of the animal for usage in the camera trap survey (Figure 2.4.1a). 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. Only fully grown animals were fitted with a GPS collar.

Once the anaesthetic was reversed, the animal was placed at a location in the shade near the handling site and observed from a safe distance to ensure complete anaesthetic recovery.

Both e-obs GPS-collars (Figure 2.4.1b) and Vectronic Aerospace satellite collars were used. These collar types provide the GPS position (based on the coordinate system "WGS84") of the animal, a fine-scale ambient temperature and an activity measurement; the Vectronic collars also send a notification in the event of mortality. Data collected by the collars were downloaded at regular intervals via airplane telemetry. The weight of each collar was less than 3% of the animal's body weight.

Figure 2.4.1a. ID picture of female leopard L074, left side.

Figure 2.4.1b. Taking samples of adult female leopard L074.

2.4.2. Monitoring animals – home range

GPS (Global Positioning System) telemetry was used to monitor the animals' home ranges. 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.

Telemetry data were uploaded to movebank.org and converted into ESRI shape files and csv-files for further analysis. Afterwards data were entered into the statistical program R and the geographical processing program ESRI ArcGIS 10.1 to calculate and display home range sizes. The home range size was calculated using two standard methods: the minimum convex polygon (MCP, Hayne 1949) and the kernel method (Worton 1989).

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. Studies on habitat utilisation require more sophisticated analyses such as the kernel method. Currently this method is considered to be the most suitable one for home range estimation (Powell 2000, Worton 1995). With it 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 data set is excluded as outliers (e.g. 5% of the most remote points being excluded results in the Kernel 95). From a biological point of view, the kernel method is much more useful than the MCP method, but for comparison with previous studies MCP data needs to be considered too.

2.4.3. Track counts and scat collection

Twelve different routes were planned for track and scat counts (total 70 km) (Figure 2.6.4a). 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 they are 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.

2.4.4. Camera traps

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.

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 8,000 pictures at medium resolution settings). Camera traps were either positioned 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. Camera traps were checked once 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 fur pattern 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 program Camera Base (Version 1.6, 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 90 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. 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) by the sampled area.

2.4.5. GPS cluster analysis

Based on temporal high-resolution GPS data of collared leopards, a GPS cluster analysis was performed (Pitman et al. 2012, Fröhlich et al. 2012). Leopards feed from their prey repeatedly, thus returning to the carcass (i.e. hiding place where the prey is located) over a period of up to several days. This causes a cluster pattern in the data, meaning numerous GPS positions (of consecutive days) in the same location (see Figure 2.4.5). Detected clusters were visited in the field and searched for prey remains such as hair and bones, which were then used to identify the prey species.

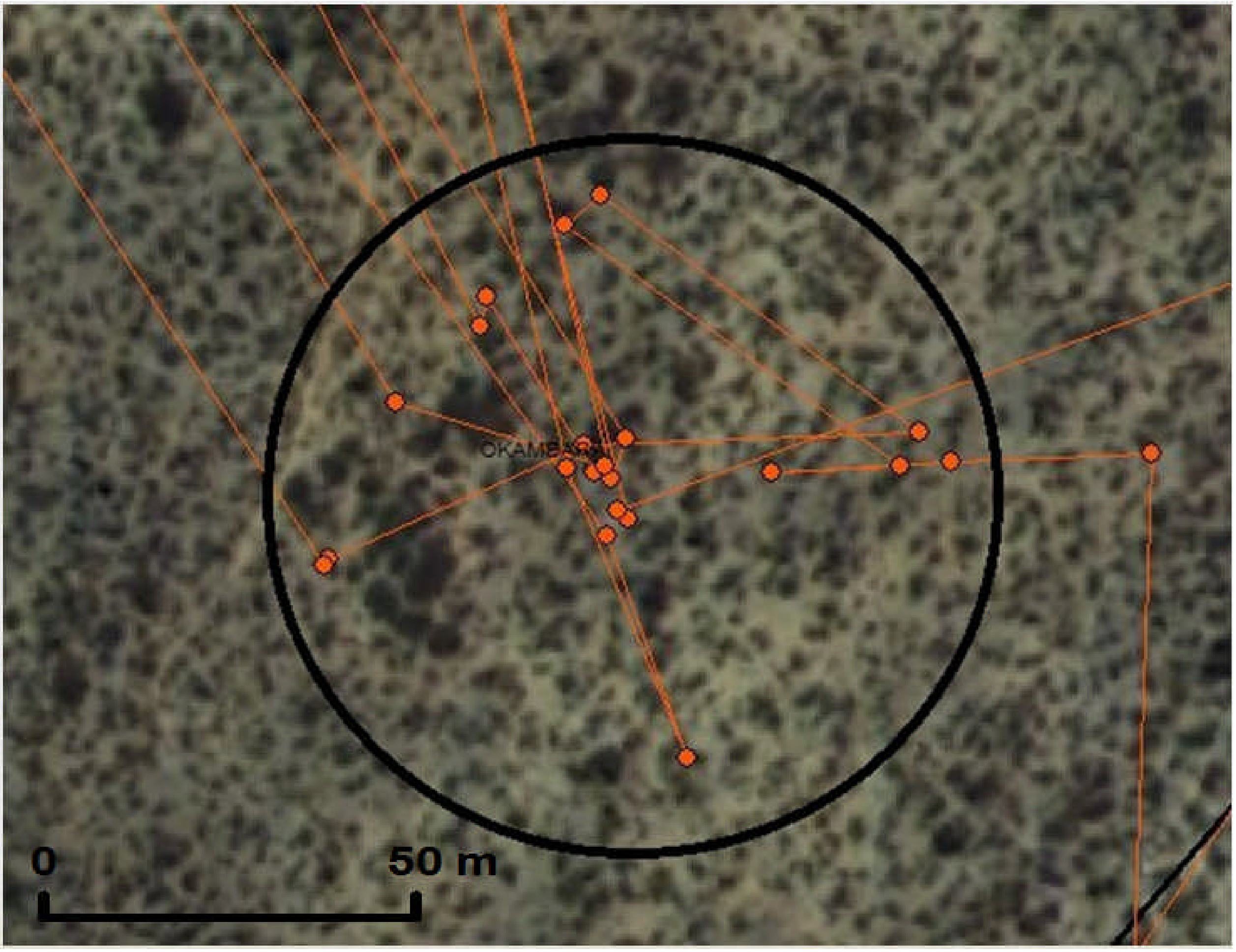

Figure 2.4.5a. GPS positions, movements and cluster (yellow circle) of L055 as an example.

2.4.6. Game counts

Vehicle game counts and waterhole observations were conducted 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.). 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 (see Figure 2.4.6) 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 1,000 m semi-circle (the average viewing distance on foot) in front of the observers were counted. Equipment used included range finder, binoculars, angle measurer, clipboard, datasheet, pen and different African mammal identification field guides. Species, number(s), distance to the vehicle and angle of the detected animal(s) from the transect (vehicle midline) were recorded, as well as the GPS position of the observer, plus, if possible, any notes about the species' age and sex.

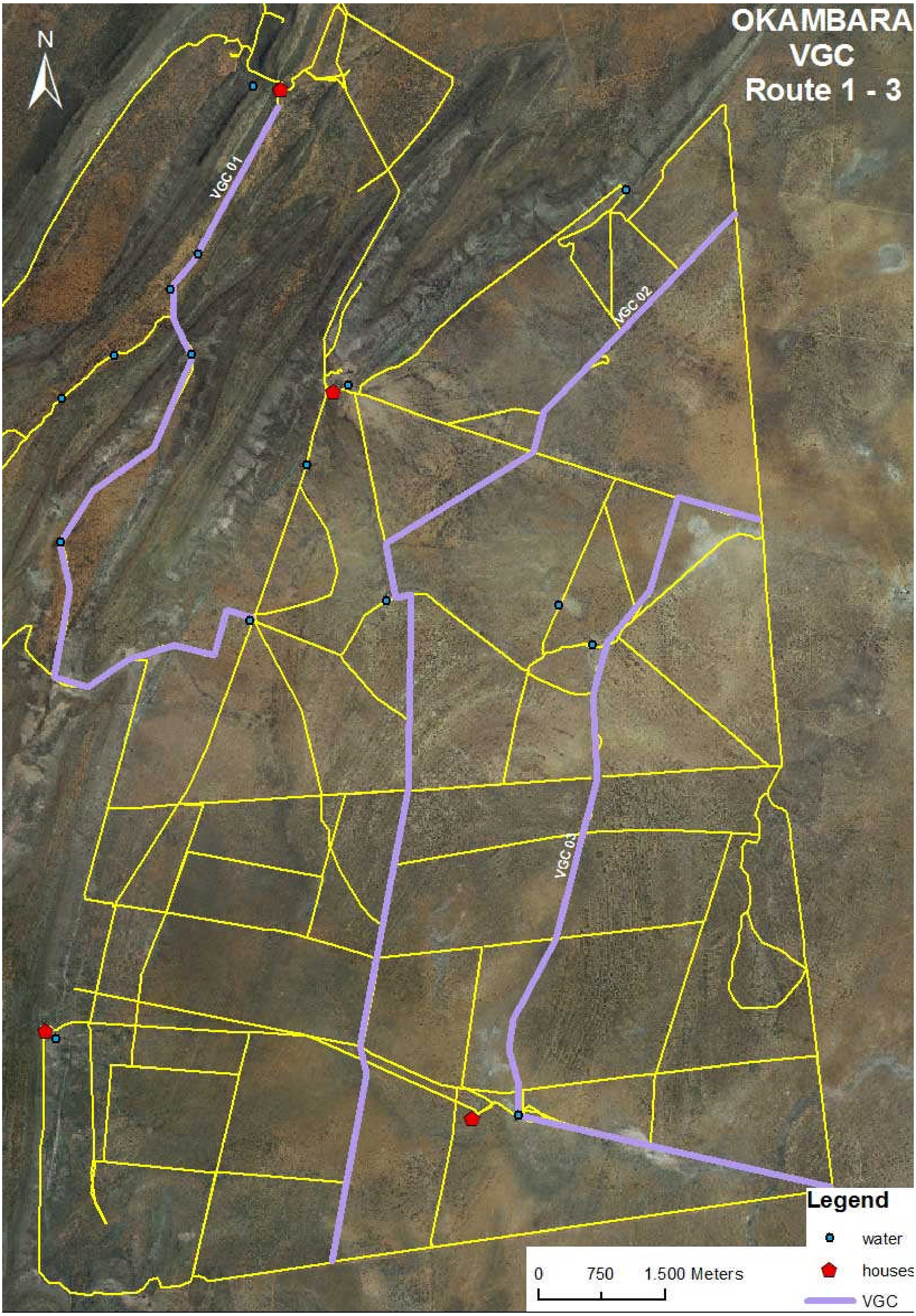

Figure 2.4.6a. The three vehicle game count routes on Okambara.
VGC 1 = 10.8 km, VGC 2 = 14.9 km and VGC 3 = 12.7 km.

Game species were also recorded at waterholes. At the beginning of the study, expedition participants had to construct several hides at each waterhole so that viewing positions could be taken up 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.

2.5. Results

2.5.1. Capturing/collaring

The capture campaign started at the beginning of August and continued until the beginning of November 2014. During this period one juvenile male leopard, one adult female leopard and one adult male leopard were captured (L073, L074, L075 respectively). All leopards where captured in baited box traps and immobilised. The female leopard was fitted with an e-obs GPS collar and the adult male leopard was fitted with the Vectronics satellite collar. The juvenile male leopard was too young to be collared. All individuals captured were in good condition (Table 2.5.1a).

During the expedition four to six box traps were set throughout the study site. Since the fifth and the sixth box trap were a loan of the IZW, their availability was dependent on the needs of the insititute and were therefore not available throughout the whole expedition. Each trap that was set counted as one trap night. One night with four, five or six armed box traps was therefore counted as four, five or six trap nights, respectively. During the study period box traps were active on 94 days with a total of 586 trap nights (Table 2.5.1b). When checking the traps, 88% of box traps were found open, 5% had captured an animal and 7% of the traps that had shut were empty (Figure 2.5.1b). Three leopards, one honey badger (*Mellivora capensis*), one small-spotted gennet (*Genetta genetta*), one slender mongoose (*Galerella sanguinea*), two African savannah hares (*Lepus microtis*), two warthogs (*Phacochoerus africanus*), twelve crested porcupines (*Hystrix cristata*), one rock monitor (*Varanus albigularis*) and one red-billed francolin (*Pternistis adspersus*) were captured. Traps were set in eight different locations; the highest capture success was close to the farmhouse of the farm owner (BT02) in the northern middle of the study site (trap position BT04 on Figure 2.5.1b).

Table 2.5.1a. Predator capture data 2014.

Capture date	Species	Animal ID	Gender	Estimated age	Weight (kg)	Neck circ. (cm)	Collar
24.08.2014	Leopard	L073	Male	10 months	18	30	no
25.08.2014	Leopard	L074	Female	5	40	40.5	yes
27.09.2014	Leopard	L075	Male	5	63	58	yes

Table 2.5.1b. Trap nights (24h) effort and success 2014.

Trap nights	Open	Closed but empty	Capture
586	*516*	*42*	*28*

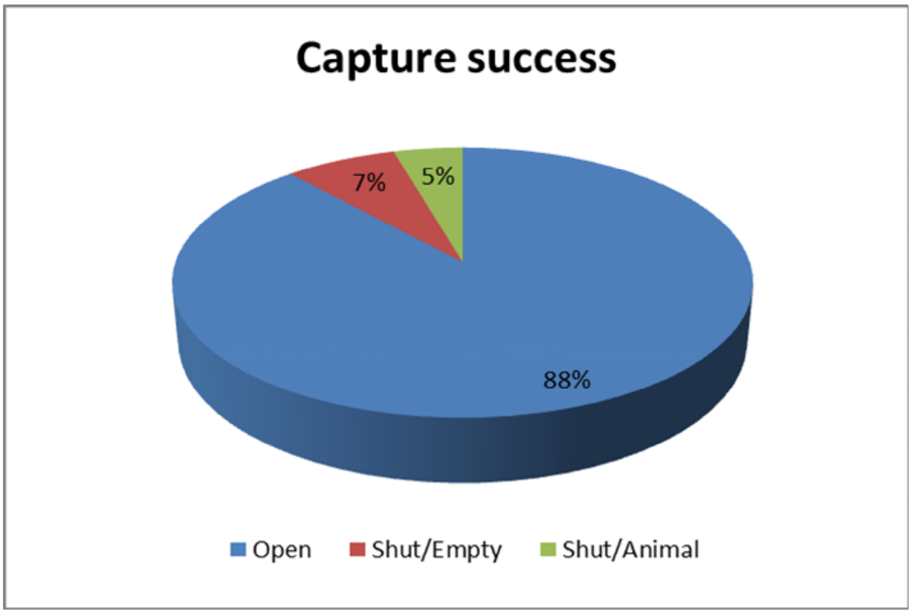

Figure 2.5.1a. Capture success from 584 capture nights (24h) on Okambara in 2014.

During the capture campaign traps were moved regularly. In Figure 2.5.1b, the letter "A" after labels of box traps (e.g. BT01) indicates a new position of a box trap (Figure 2.5.1b; for example, box trap 1, BT01, moved to location box trap BT01A).

2.5.2. Home range size

Data from leopards collared in 2013 is included.

The MCP of L051 covered an area of 413.72 km²; Kernel 95 consisted of 383.73 km², Kernel 90 of 356.18 km² and Kernel 50, the core area of the home range, was 119.75 km². L052 had an MCP of 269.29 km² whilst Kernel 95 and Kernel 90 covered an area of 202.45 km² and 174.82 km², respectively. The core area of L052 (Kernel 50) consisted of 65.84 km². The MCP of L055 was 172.63 km²; Kernel 95 covered 145.01 km² and Kernel 90 entailed 119.38 km². The size of the core area of the home range of L055 was 53.31 km². The MCP of L074 covered an area of 37.91 km²; Kernel 95 consisted of 34.72 km², Kernel 90 of 29.63 km² and Kernel 50, the core area of the home range, was 12.04 km². L075 had an MCP of 89.63 km² whilst Kernel 95 and Kernel 90 covered an area of 82.29 km² and 73.82 km², respectively. The core area of L075 (Kernel 50) consisted of 49.56 km² (see Table 2.5.2).

Table 2.5.2. Home range size (km^2; MCP and Kernel) of the leopards collared on Okambara.

	Home range size (km^2)				
	L051	L052	L055	L074	L075
DATA	256 days	343 days	253 days	59 days	37 days
Kernel 50	119.75	65.84	53.31	12.04	49.56
Kernel 90	356.18	174.82	119.38	29.63	73.82
Kernel 95	383.73	202.45	145.01	34.27	82.29
MCP 100	413.72	269.29	172.63	37.91	89.63

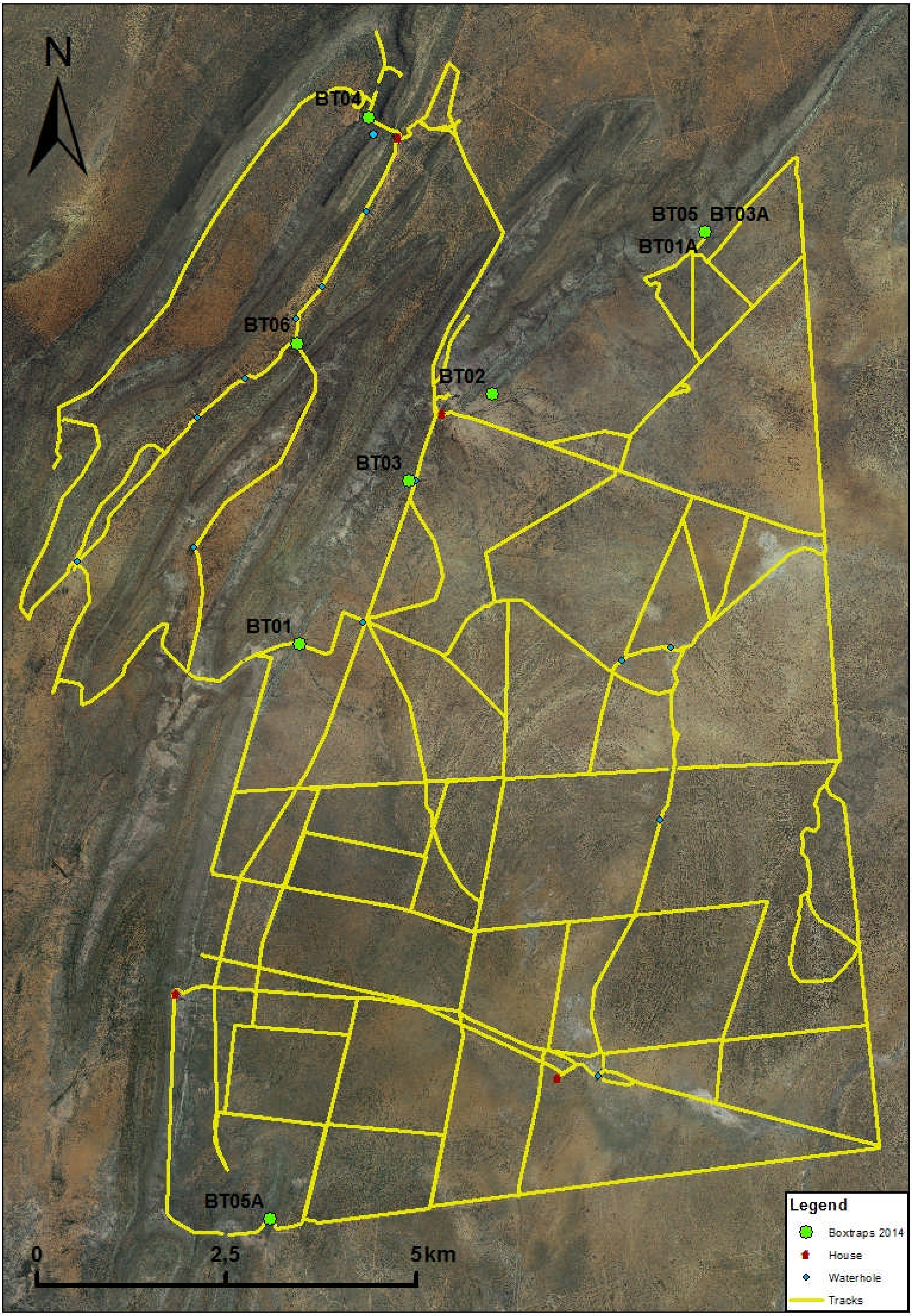

Figure 2.5.1b. Map of Okambara with position of box traps in 2014.

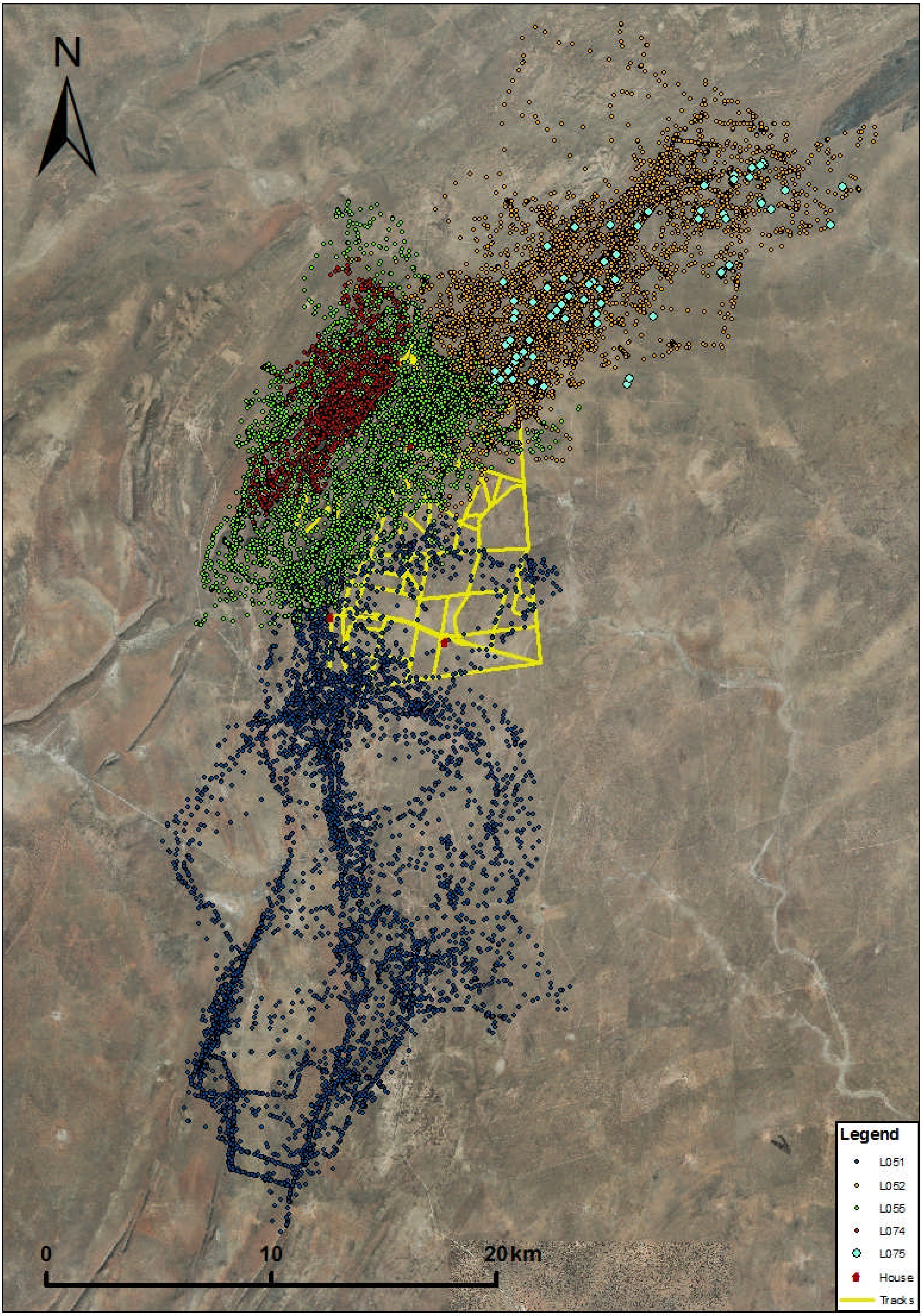

Figure 2.5.2a. Locations of all collared leopards on Okambara and surrounding farms since collaring.

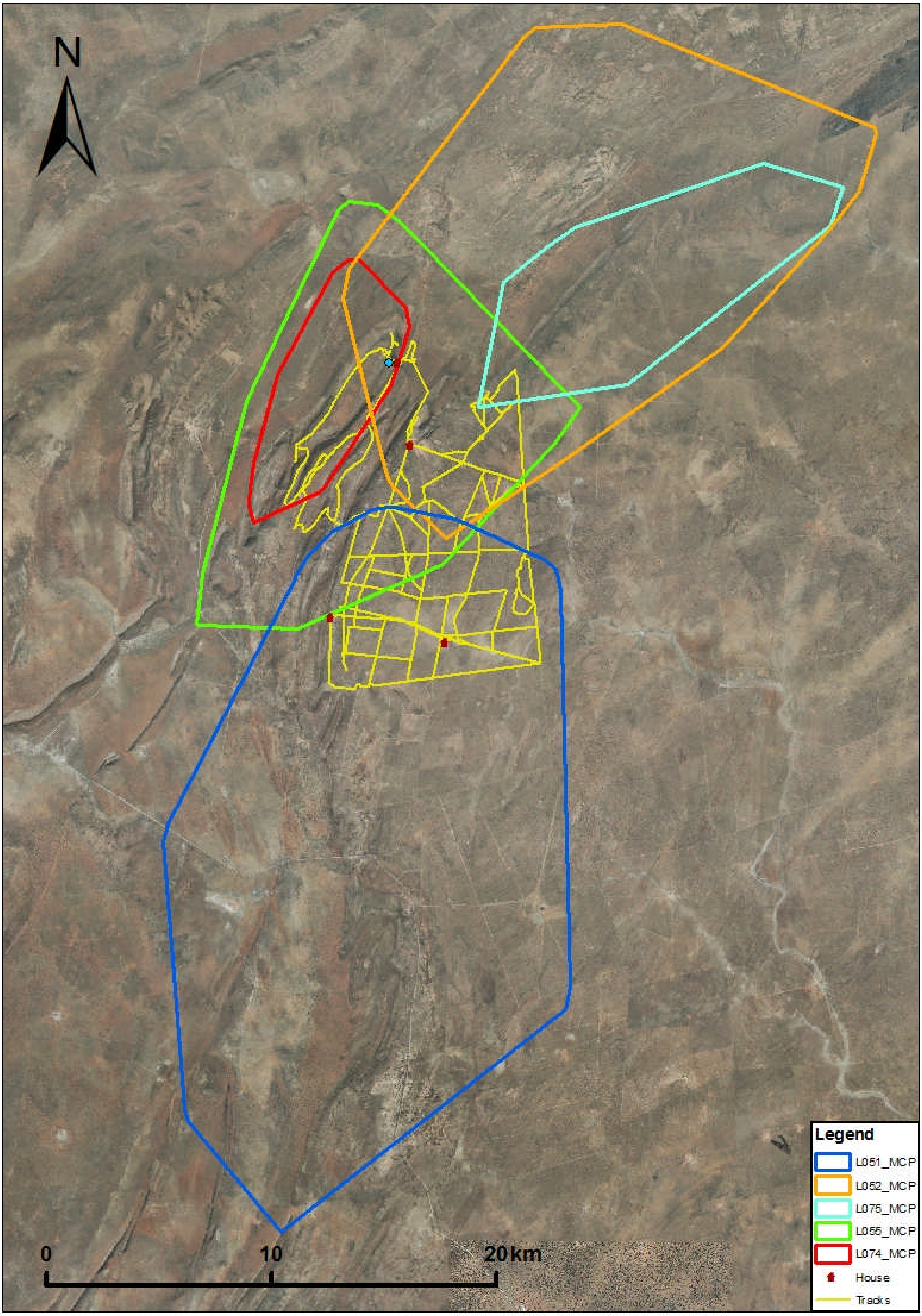

Figure 2.5.2b. MCPs of all collared leopards on Okambara.

2.5.3. Track counts and scat collection

Track and scat routes were monitored between one and 6 times each and a total length of 294.2 km was covered. Eight of the routes were in the plains area (2, 5, 6, 7, 8, 9, 10 & 11) and five in mountainous areas (1, 3, 4, 12 & 13). The routes most frequently monitored were numbers 3, 4, 6 and 9. Numbers 2, 7 and 11 were not monitored regularly, because elephants were in those areas frequently.

Figure 2.5.3a shows the probability (p %) per kilometre of predator findings (tracks/scats) for leopard, brown hyaena and cheetah on different routes (Tracks & Scats Route No. 1–13).

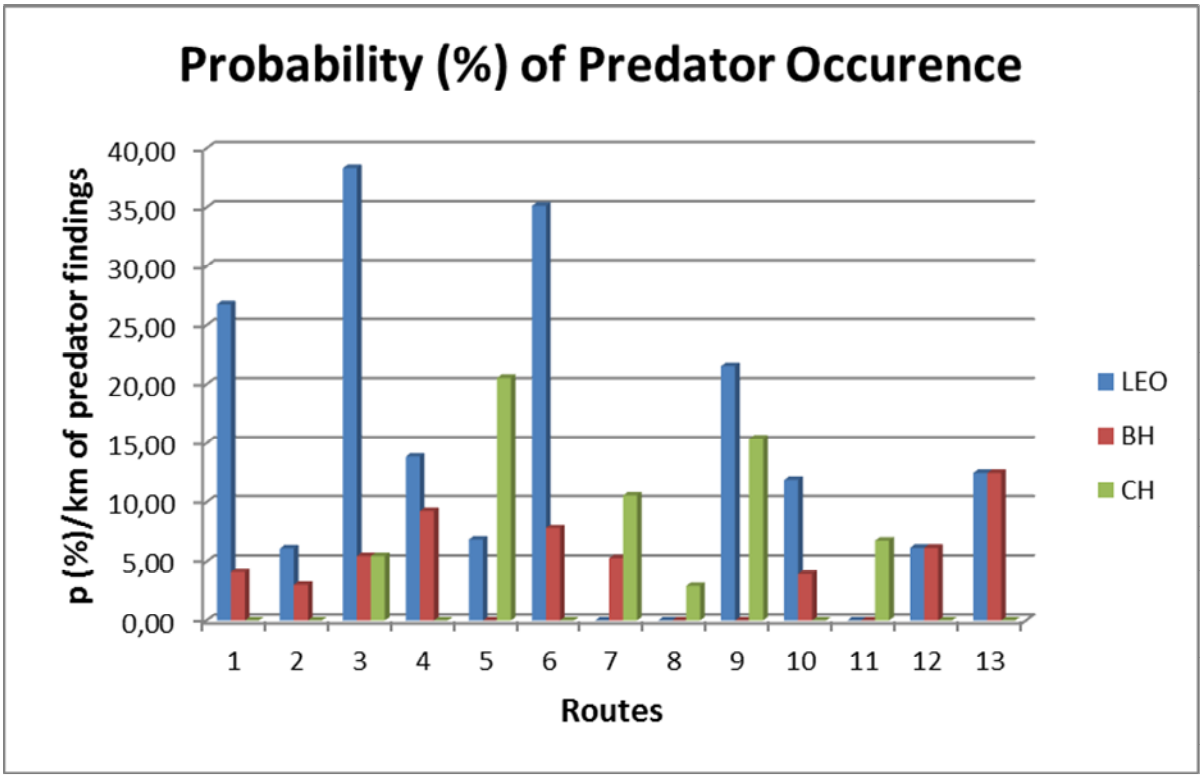

Figure 2.5.3a. Probability p (%)/km of predator occurrence on the basis of track and scat findings on particular routes. LEO = leopard, BH = brown hyaena, CH = cheetah.

Leopard signs (43) dominated the results over cheetah (10). Hyaena signs (18) were found all over the study site, sometimes several times in the same location.

The largest number of tracks and scats from leopards 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 3 & 6). Also, on route 1 and 9 several signs of leopards were found. Few signs of leopard occurrence were detected on routes 2, 4, 5, 10, 12 and 13. No signs of leopards were found on routes 7, 8 and 11, all of which are situated in the plains (see figures 2.5.3a, 2.5.3b and 2.5.3c).

Signs of hyaena were found mostly on routes 4, 6, 12 and 13; few signs were detected on routes 1, 2, 3, 7 and 10. No signs of hyaena were found on routes 5, 8, 9 and 11. Only on routes 3, 5, 7, 8, 9 and 11 were signs of cheetah occurrence detected (see figures 2.5.3.a, 2.5.3b and 2.5.3c).

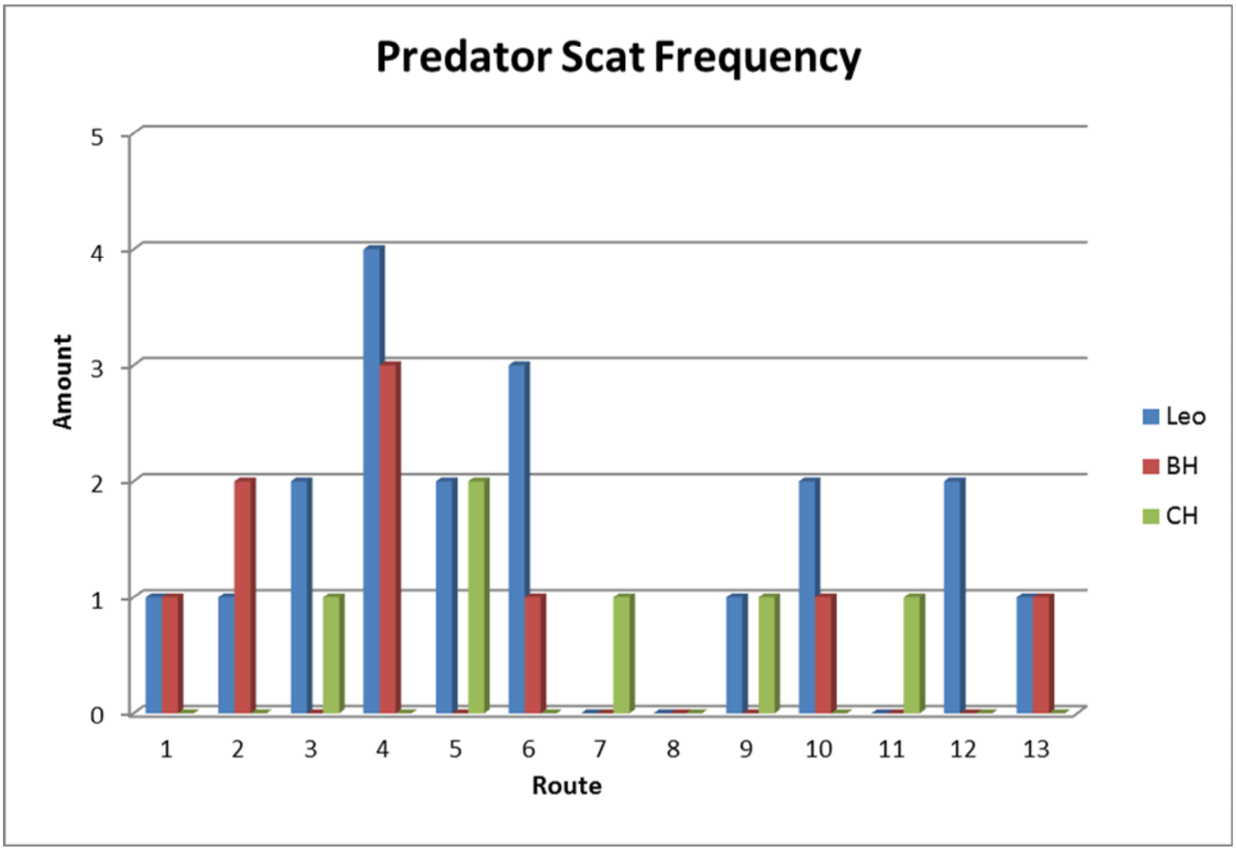

Figure 2.5.3b. Amount of scats from different predators on fixed survey routes, Okambara 2014. Leo = leopard, BH = brown hyaena, CH = cheetah.

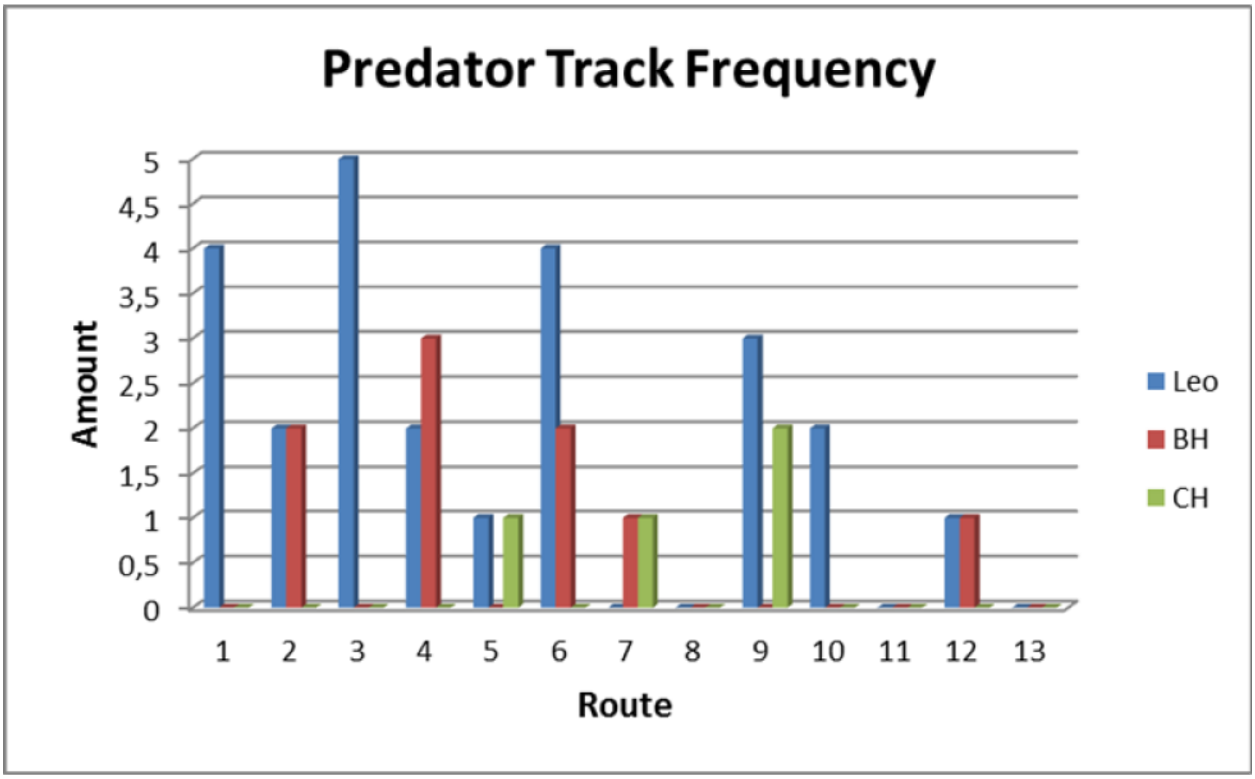

Figure 2.5.3c. Amount of tracks from different predators on fixed survey routes, Okambara 2014. Leo = leopard, BH = brown hyaena, CH = cheetah.

2.5.4. Camera traps

The study period started at the beginning of August 2014. Fifteen camera traps were placed at strategic points (based on tracks and scats, near waterholes) around the study site. Due to logistics, all available camera traps were not set on one single day in the field but on several consecutive days. Overall, between 5 and 14 camera traps were in use at the same time throughout the whole expedition (number of camera traps increasing with each additional day in the field during the first slot). Not all leopards photographed could be identified. From 42 events, 17% 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 39 useable leopard events were recorded throughout the whole expedition, where an event is a picture with as a certain individual identifiable leopard captured by a camera trap.

Capture success

A sampling period of 90 days was set and conducted from 07 August to 05 November 2014, yielding 34 events. Nine individual adult leopards were identified by their coat patterns. Four adult males were recorded; two of which had been captured and collared in 2013, one male was captured and equipped with a collar during the study period. In addition, two mature females were photographed on several occasions. Further, two more individuals were recorded whose sex could not be identified.

Table 2.5.4a. Camera-trapping effort and leopard captures 2013 and 2014.

Sampling period	Trap stations	Photos of leopards	Identified individuals
17 Aug – 15 Nov 2013	14	29	6
07 Aug – 05 Nov 2014	14	34	9

During the sampling period, 14 camera traps were active, nine of which recorded leopards. Six cameras recorded brown hyaena; pictures were not clear enough to identify individuals. Events of pictures taken of other predators within the study period are listed in Table 2.5.4b.

Table 2.5.4b. Number of camera trap pictures of different predators 2013 and 2014.

Sampling period	Brown hyaena	Spotted hyaena	Honey badger	Caracal	African wildcat	Jackal
17 Aug – 15 Nov 2013	4`	2	8	9	12	45
07 Aug – 05 Nov 2014	34	0	11	5	13	32

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 0.4271 was recorded (the probability that a leopard in the sampled area is photographed on a single sampling occasion) (Table 2.5.4d).The sample population was estimated to be eight leopards (SE ± 0.4827, 95% CI 6-6). 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 eight individual leopards (excluding subadults) were estimated to occupy an area of 104.93 km^2. The buffer width (half of the home range length of a female home range) was 4.4 km. The estimated effective area sampled was 318.52 km^2. A density of 1.8 individuals per 100 km^2 was calculated.

Table 2.5.4d. Results of population closure, capture probability, estimated abundance, standard error and 95% confidence interval of leopards sampled on Okambara game farm, Namibia, in 2014.

Test for closure	Null Model (M_0)		95% CI
	Capture probability	Abundance (SE)	
z = 0.592 P = 0.671	0.4271	8 ± 0.4827	7-7

2.5.5. GPS cluster analysis

The GPS cluster analysis based on the data of L051, L052, L055, L074, L075 showed no specialisation of individual leopards. Prey species varied among eight different species (see Figure 2.5.5). At 33% of the visited kill sites, remains of greater kudu were found. Thirty percent of the kill sites revealed remains of oryx, and at 14% of the kill sites remains of impala were detected. Remains of warthog were found at 7% of kill sites and at 4% of the kill sites, steenbock was found. Mountain zebra and cattle were each found 3% of the kill sites, respectively. Waterbuck, horse and porcupine were also found, each of which constituted of 2% of the kill sites.

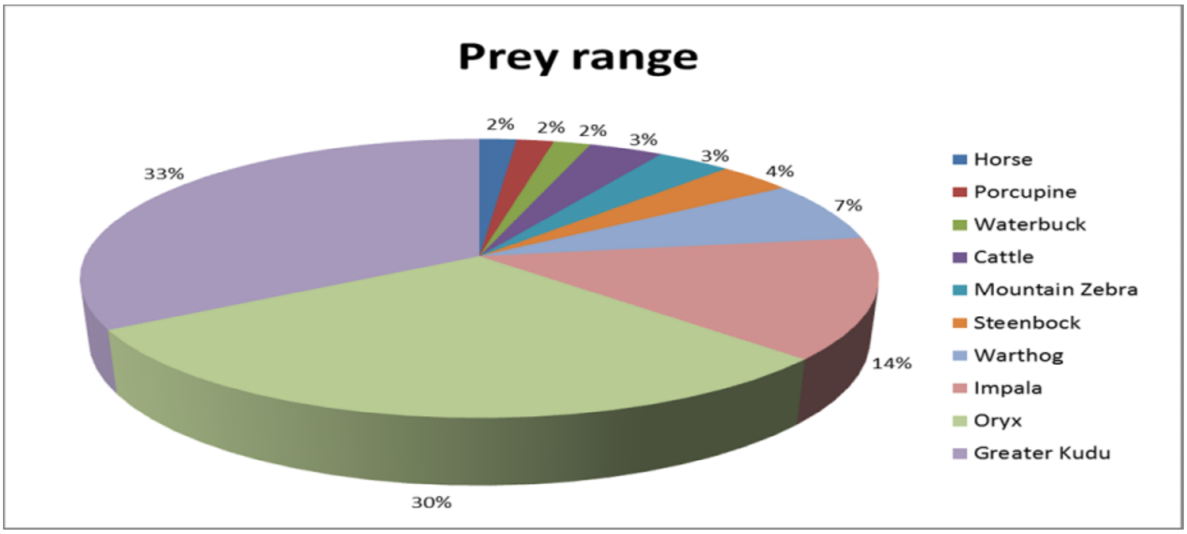

Figure 2.5.5. Prey range of leopards (% of kill sites) on Okambara and surrounding farms.

2.5.6. Game counts

Vehicle game counts were conducted during daylight hours between August and November 2014 using three line transects (see Figure 2.4.6a) 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 a scientist on each game count vehicle to provide some standardisation of observations and increase detection probability.

The three transects lengths were VGC 1 = 10.8 km, VGC 2 = 14.9 km and VGC 3 = 12.7 km. Twelve game counts were conducted, yielding 3,694 animals over 460.8 km driven. 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. Results are listed in Table 2.5.6b.

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

Results of the waterhole observations at seven different waterholes (Figure 2.3a; Bergposten, Frankposten, Gustavposten, Sandposten, Michael's Dam, Lodgeposten and Boma) produced 737 animals over 171 sightings. The percentage of juveniles was 8.55%. The study period was between August and November 2014. Some of the time animals noticed the observers in the hide, but more than 90% did not flee. The total numbers of observed game species are listed in Table 2.5.6a.

Table 2.5.6a. Total numbers of observed game species at waterholes on Okambara in 2014.

Species	**Total**
White-Tailed Gnu	21
Brindled Gnu	23
Eland	45
Giraffe	28
Impala	277
Greater Kudu	67
Oryx	24
Mountains Zebra	45
Sable Antelope	13
Springbuck	1
Warthog	113
Waterbuck	80
Total	737

Table 2.5.6b. Numbers of observed game species (total no. of individuals seen on vehicle game counts during expedition period, mean number of individuals observed on vehicle game count during expedition period (total number/number of game counts carried out), individuals/km^2 (mean/150km²)), Okambara 2014.

Species	No. Individuals	Mean	Individuals/km²
White-tailed Gnu (Black Wildebeest)	994	82.83	0.55
Brindled Gnu (Blue Wildebeest)	281	23.42	0.16
Common Duiker	7	0.58	0.00
Eland	149	12.42	0.08
Giraffe	215	17.92	0.12
Greater Kudu	169	14.08	0.09
Impala	523	43.58	0.29
Klipspringer	2	0.17	0.00
Mountain Zebra	216	18	0.12
Oryx	680	56.67	0.38
Plains Zebra	70	5.83	0.04
Red Hartebeest	51	4.25	0.03
Sable Antelope	14	1.17	0.01
Springbuck	128	16.64	0.07
Steenbuck	72	10.67	0.04
Warthog	92	7.67	0.05
Waterbuck	31	2.58	0.02
Total	3,694	307.83	2.05

2.6. Discussion and conclusions

2.6.1. Capture and collaring

Information on leopards is difficult to obtain by visual observations, so non-invasive methods were chosen to gain ecological and biological information. Also, these methods are cost-effective, objective and repeatable (Norton-Griffiths 1978). With the help of identifying leopard signs, such as tracks and scats, as well as using camera traps, potential locations for box traps were identified. In addition, box traps were placed near waterholes close to mountain ridges, as leopards prefer mountainous habitat but need to take in water regularly. Success of trapping the main target species, i.e. leopards, varied among box traps. Only in BT03A and BT04, set at the Bergposten waterhole and the lodge waterhole respectively, were leopards captured. Lack of trapping success at the other locations might be explained by various reasons (see below). Traps BT01, BT01A, BT05 and BT06 were set at locations where several signs of leopards (tracks or camera trap pictures) were detected.

GPS data gained via the three leopards collared on Okambara in 2013 showed that leopards seem to revisit waterholes every 7–14 days, depending on the availability of water sources within the home range and the time of the year, i.e. amount of rainfall. The bait in the traps was replaced every 3–5 days (depending on resources such as staff and meat) since Bailey (1993) showed in his study on leopards in South Africa that the trapping success decreased significantly with the time bait was left in the trap. Therefore, it is possible that on various occasions leopards visited waterholes when bait was older and less attractive. This was already known from the previous expedition in 2013. However, bait availability in this year was dependent again on the meat resources provided by the farm owner. The meat consumed on the farm is obtained via hunting on the premises. As this happens at irregular intervals and hunting success also varies, the supply of bait meat varied in amounts as well as in quality. Large pieces of meat, which are suitable to be attached inside or behind the trap are preferable. However, on several occasions only small pieces of meat or intestines were available. Although these pieces of bait are ideal for creating scent trails towards the traps (to increase the likelihood of a predator approaching the trap), they are only partly suitable for baiting traps. This might have affected the attractiveness of the baited box traps for carnivores.

BT06 was set late in the capture season; leopard tracks were found in front of the trap, but no animal was captured. The lack of trapping success might have been due to the short amount of time the trap was set at this location. Setting a box trap brings with it a lot of impact, e.g. cutting shrubs, driving to the locations, etc. The trap must have also had an intense human smell as it was handled by several people during relocation. So the amount of time between setting the trap and the end of the trapping season might have been too short for animals to get used to the new feature in their surrounding.

None of the leopards were recaptured in the box traps during the trapping season of this study. This suggests that leopards have an excellent memory of trap location and most likely 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 20 times during a study period. The trap shyness of leopards on farmland and the much lower trapping success compared to protected areas might be due to the persecution of leopards on farmland. Farmers use box traps to capture and eradicate carnivores. Therefore, selection pressure is in favour of trap shy animals as these are more likely to survive and produce more offspring. Hence, the local population of leopards consists of increasingly trap shy animals. Curious and less trap shy animals are less likely to survive.

No cheetahs were captured as the traps were set specifically 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.

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 2015 or early 2016.

2.6.2. Home range

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 (Moyer et al. 2005). Leopards, just as other large carnivores, cover home ranges that have to be of a size large enough to provide sufficient prey availability throughout the year. Where prey distribution is constant, these territories are often stable, however, 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). Data obtained via GPS collars from the three male leopards collared on Okambara showed no changes in home range sizes over a period up to nine months from the end of the dry season throughout the rainy season. Since on farmland prey movements are restricted by fences, especially on game farms with fences that keep the game confined with farm boundaries, prey availability is stable throughout the year. Therefore leopards are not required to migrate with prey or leave their home range to find prey.

Typically, adult male leopards require larger home ranges than females. Several studies revealed similar home range sizes within each sex, with males varying from 17 to 76 km² and females ranging from 6 to 18 km² (Bailey 1993, Hamilton 1976, Bertrum 1982, Mizutani & Jewell 1998, Stander et al. 1997, Norton & Lawson 1985, Norton & Henley 1987, Seidensticker 1976). However, in arid areas the home range sizes of leopards can be much larger (males 86 km², females 22–29 km²; Jenny 1996), and even for home ranges of individuals of the same sex there can be some degree of overlap, or sometimes even a complete overlap, e.g. if the whole home range of a female is within the home range of a male (Jenny 1996, Rabinowitz 1989, Grassman 1999). Most leopard home range data available are from studies that were conducted in protected areas (see Appendix I: Kruger National Park, Serengeti National Park). In Namibia the sizes of MCP (95%) varied from 108 to 229 km^2 for males and 53 to 179 km^2 for females (see Appendix I). A study conducted by Marker and Dickman (2005) on commercial farmland found 229 km² (MCP95) as home range size for male leopards and for females a range of up to 179 km^2. Stander et al. (1997) estimated home ranges of male leopards varying from 210 to 1,164 km², whilst female home ranges measured 183 to 194 km² in north-eastern Namibia.

In this study, the home range sizes found for the male leopards correlate mainly with the study of Marker and Dickman (2005), since home range sizes (MCP100) for L052 and L055 were 269 km² and 173 km² respectively, but they also correlate with the findings of Stander et al. (1997) showing that there can be a high variance between different individuals (L051, 414 km²). The home range of L075 was only 90 km², thus much smaller compared to other male leopards. However, the data only encompasses 37 days since the collar appears to have failed after this period. This is not unusual in studies using GPS collars as failures and production faults happen from time to time. It is interesting to note that all of the data obtained was within the home range of L052. This is highly unusual as male adult leopards defend their territory against other male leopards.

Since the end of the study period, L052 has not appeared on the camera traps again suggesting that L075 might have taken over his territory. However, since L052 has not been found again, this remains a theory only. L075, on the other hand, was shot in 2015 during a trophy hunt on a neighbouring farm. The collar was retrieved and checked by the manufacturer in Germany. It emerged that the collar was part of a faulty production line, which caused the failure of the collar after such a short time. Failing collars are always a setback in these types of studies. However, the report of this failure and the coincidental retrieval of the collar allowed the manufacturer to detect the fault in manufacturing and avoid it in future productions.

The fact that home range sizes on farmland are larger than in protected areas, despite the stable prey availability throughout the year, could be due to varying densities and abundance of leopards in protected areas and on farmland. Stein et al. (2011) determined a leopard population density of 3.6 leopards per 100 km² on farmland in central Namibia. Marker and Dickman (2005), on farmland in north-central Namibia, found that the average density of leopards on farmland is 2.1 leopards per 100 km^2. On the current Okambara study site, the estimated leopard density was 1.3 individuals per 100 km^2, 1.9 individuals per 100km² and 1.8 individuals per 100 km^2 in 2012, 2013 and 2014 respectively. There might be a high variance of leopard density even within an area, depending on the habitat and management of different farms. Some farmers shoot leopards regularly on their premises, thus often removing the territory holders and creating space for other, sometimes neighbouring leopards to move in. Therefore, leopard densities outside of Okambara, on which leopards are not persecuted, might be lower than expected and home ranges can be larger than in protected areas where there is fewer turnovers within the population. Game-proof fences, in general and in this study, were not a barrier and had no influence on the home range, as all individuals regularly crossed under the fence on Okambara. Furthermore, prey availability might be lower on farmland compared to protected areas. Although there is game farming in Namibia (including Okambara), the majority of farms are engaged in cattle breeding, thus only naturally abundant game species appear on those premises. Also, the game can move between cattle farms as the surrounding fences are purposely kept low in order to allow migration of game. Local prey availability is therefore subject to change and can affect the home range size of leopards.

It has been shown that overlap often occurs between individuals of different sex (Arthur et al. 1989). In leopards, males defend their territories against other sexually mature males, but tolerate females, cubs and even dispersing young males within their territories (Bailey 1993, Marker and Dickman 2005). This is supported by the data of L074, which show that her home range is completely within the home range of L055. Usually, several female home ranges are covered by the home range of only one male. As the home range of

L074 is only 38 km², it is assumed that additional females roam within the territory of L055 and most likely also the other male leopards. Camera trap pictures of female and juvenile leopards taken within the home ranges of the four males on Okambara support this finding.

2.6.3. Track counts and scat collection

The largest number of tracks and scats from leopards were found close to the edge of the small mountains in the northeast and southwest of the study site, where there is also water available (routes 3 & 6). Also, on routes 1 and 9 several signs of leopards where found; both routes include waterholes as well. Few signs of leopard occurrence were detected on routes 2, 4, 5, 10 and 12. No signs of leopards were found on routes 7, 8 and 11, all of which are situated in the plains. This correlates with the analysis of the GPS data, which showed mountainous areas to be the preferred habitat of leopards.

Results of these non-invasive methods also showed that other predators occur on Okambara. Cheetahs were detected more frequently in the open areas of the study site, where they probably avoid other predators such as leopard and brown hyaena and because their hunting technique is more suited to open areas (Caro 1994). Brown hyaenas occur throughout the study site as they are looking for carcasses from other predator kills everywhere and they patrol their large 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 or hide it properly, the probability that hyaenas will scavenge on it is high.

There were some restrictions to these methods. Route 1 and 4 included very hard, stony surfaces and some of the routes were in deep sand (2, 5, 6 and 8), both of which make the detection of tracks quite difficult. Also, weather conditions such as wind and rain influence the success of finding tracks; there was not much rainfall during the study period, but there were several days with strong winds. In addition, not all routes could be monitored at regular intervals, as the presence of elephants on the farm was a highly limiting factor, especially to the routes in the plains or some waterholes (especially Frankposten and Bergposten). Hence, not all routes were monitored at the same frequency and intensity.

2.6.4. Camera traps

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 three months of the study period, 187 pictures of most large and medium predator species present in the area (leopard, jackal, caracal, brown hyaena, African wild cat and honey badger) were recorded. Brown hyaena, honey badger, African wild cat and all of the caracal pictures were taken during or after sunset. All of these animals are mainly active during the night; therefore detecting those species during the day is unlikely. Jackals were recorded mostly during the night, when they are most active, but they can also be seen during the periods of dusk and dawn. Brown hyaenas and African wild cat were detected all over the study area, showing the varied habitat selection within these species. Caracal and honey badger were only detected near ridges either at waterholes or along fence lines; apparently this is their preferred type of habitat.

Several studies suggest that leopards are active between sunrise and sunset (Nowell and Jackson 1996, Hamilton 1976, Bailey 1993, Sunquist & Sunquist 2002). This is confirmed by pictures taken of leopards during this study period, with leopards active just before sunset as well as in the middle of the night, and with only a few records after sunrise, when temperatures are still low. 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), and leopards usually avoid the heat and prefer shady places to rest (Bothma and le Riche 1984, Walker 1996, Sunquist and Sunquist 2002). This applies to predators as well as herbivores. So, the locally abundant prey species are also less active during the heat of the day and it is self-explanatory that the activity patterns of leopard prey have an influence on leopard hunting behaviour. This leads to an increased activity of leopards between sunset and sunrise (Bothma and Bothma 2005, Sunquist & Sunquist 2002, Jenny and Zuberbühler 2005). Furthermore, in agricultural areas, where there is also intensive persecution of predators, these species tend to be more active during the night to avoid humans.

A high percentage (approx. 65%) of the predator pictures were of brown hyaenas and jackals, but no individuals could be identified. Due to their greater strength, size and stealth, leopards are the dominant predators in the study area. No persecution of predators occurs on Okambara, so predator ratios should be subject mostly to natural selection pressures. 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 hyaenas and leopards do coexist in space, but they tend to avoid each other in time (Killian et al. 2012). Generally, leopards and brown hyaenas are opportunists and better adapted to poorer habitat conditions (Estes 2012). Marker and Dickman (2005), on farmland in north-central Namibia, found that the average density of leopards in protected areas is 2.1 individuals per 100 km^2. On this Okambara study site, the estimated leopard density was 1.8 individuals per 100 km^2. In relation to the study of Marker and Dickman (2005) and of Stein et al. (2011), who determined a density of 3.6 leopards per 100 km^2 on farmland in a central Namibia leopard population, this study shows that leopard densities on farmland are highly variable. This is probably due to the various types of habitats and the different composition of these types on each farm. In addition, the rate of predator removal varies among areas/farms and can also lead to a higher range of leopard densities. In addition, the density of leopards found on Okambara is considerably lower than densities found in protected areas (see Appendix I) whilst their home range is larger compared to protected areas. This supports the assumption that home range size is related to density; thus lower densities of leopards lead to larger home ranges.

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 90 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 elusive carnivores appearing in low densities 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 based on just six 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 and brown hyaena. The area possesses abundant prey, good habitat features and minimal competition, and no persecution from humans within the premises. There were some constraints to the camera trap placement design, because traps could not be placed in the plains area where elephants and baboons were active and the likelihood of these animals damaging a camera was high.

2.6.5. GPS cluster analysis

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.

So far ten different prey species have been identified for four collared leopards in this study. The main prey species found at confirmed kill sites were greater kudu and oryx; both species are highly abundant in the mountainous parts of the farm. Since this is the preferred habitat of leopards, it is not surprising that they focus on the most available prey species. The third most consumed species was impala, which occurs in the mountains as well. On average, leopards prefer medium-sized prey (average 23 kg; Hayward et al. 2006); accordingly most prey animals found were juveniles or young adults.

The leopards of this study had a kill rate of once every five days on average. This correlates with Bailey (1993) who 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. The weights of the male leopards captured on Okambara ranged from 67.5 kg to 69.0 kg, thus they had to consume 4.9 kg per day and based on the average prey size of 23 kg this would result in a kill rate of four to five days. The female weighed less (40 kg), which is not surprising as sexual dimorphism is common in leopards. Her kill rate was between five to six days and prey was medium-sized. This is quite similar to the kill rates and prey size of the male leopards and therefore at first glance surprising considering her lower body weight. However, this female had been captured with a ten-month-old cub; as cubs at this age are still supported by their mother, it is very likely that her usual kill rate increased due to the increased demand for prey in order to feed herself and the cub.

No specialisation on certain prey species could be detected for any of the individuals.

2.6.6. Game counts

The study period for game counts was conducted in late winter and the beginning of spring, and finished in early summer. On vehicle game counts, the main species observed were oryx and white-tailed wildebeest; the third most detected species was impala. At waterholes, mostly warthogs and impala were detected, followed by greater kudu and waterbuck.

Hopcraft et al. (2005) postulated a prey abundance hypothesis, which states that leopards prefer to consume prey that is most common within the home range. Since oryx and impala were some of the most observed species and were detected via the GPS cluster analysis as two of the preferred prey species, the prey abundance hypothesis is supported by this study. Furthermore, results also 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 it. High numbers were also estimated for white-tailed wildebeest. However, white-tailed wildebeest exceed the preferred prey size of leopards, which is most likely why this species is not part of their diet. Also, wildebeest species occur in the plains, a habitat less used by leopards. Warthogs occur in high numbers on Okambara, but are apparently not an important part of the leopard diet. This may be due to the fact that warthogs are spending the night in burrows. Leopards are mainly nocturnal and hunt during the night or in the late evening or early morning hours, when the warthogs are hiding underground.

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 rest in undergrowth and do not need to go to waterholes during the first weeks of life.

Dense vegetation over large distances may have reduced the visibility of and therefore sample size for some species. To account for this, game counts should be repeated regularly throughout the year. Observers at waterholes rarely disturbed the animals visiting. Animals were alert, but not fleeing, thus providing possibilities 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. Data collected over different seasons could provide important information for farm management regarding population growth.

2.6.7. Conclusions

The expedition's research has shown that different carnivore species coexist on Okambara. Species included leopard, brown hyaena, cheetah, African wild cat, honey badger, caracal and black-backed jackal. The habitat types in relation to the prey abundance present seem to be suitable for populations of the different carnivore species and their reproduction, if no other threats such as persecution or trophy hunting of predators arise.

The Okambara study site is surrounded by livestock farms, primarily with cattle. Using camera trap pictures, several leopard individuals could be identified, and based on the GPS data gained so far it is very likely that most of the home ranges of these animals exceed the Okambara game fence line (see Figure 2.5.2a). Communication with neighbouring farmers should continue so that emerging problems such as leopard attacks on cattle can be recorded and discussed and non-lethal solutions can be found. Already, one kill of a cattle calf has occurred (predated by L051) on a neighbouring farm. As this project openly shares data, experiences and advice with farmers, the owner of this particular farm has pledged that there will be no persecution of leopards on his premises if losses of cattle stay low. This shows the importance of stakeholder involvement in this kind of project, as farm owners are increasingly interested in learning more about the ecology of predators and how to preserve them whilst also protecting their livelihoods.

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.

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.

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 animals, therefore creating easy prey for predators.

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, which have been included in the GPS cluster analysis. Game counts and camera trap surveys should also take place on neighbouring farms to gain more information about prey availability and density of leopards. Capturing and collaring of further predators, especially leopards, 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 to get more detailed information of the various occurring habitats.

2.6.8. Concluding remarks by Biosphere Expeditions (executive director M. Hammer)

This 2014 expedition concluded Biosphere Expeditions' work in Namibia, which stretched over more than a decade from 2002 – 2014, mainly working in central Namibia, but also in Caprivi in the north in 2008 and 2009. Yearly expedition reports are available via www.biosphere-expeditions.org/reports. Highlight achievements include:

1. Adding significantly to the knowledge about large cat ecology and behaviour, especially of cats living outside protected areas on farmland, a landscape crucial for large cat survival in Namibia and elsewhere in Africa, and indeed the world. One of our foci has always been to communicate research results to local people and from our science-based work, generate pragmatic advice on how to avoid human-wildlife conflict for local landowners. This has resulted in a

2. Significant reduction of large cat-landowner conflict and therefore in cats being killed in retaliation. Examples include kraal adaptations in Caprivi to make penetration by leopards and lions less likely, animal husbandry adaptations on central Namibian cattle and game farms, and the commitment by several landowners to refrain from killing large cats in return for our advice, sharing of research results and help with conflict avoidance. Because landowners control very large parts of land in central Namibia, this is a crucial step forward for cat conservation.

3. Biosphere Expeditions has also been involved in setting up what is now the largest leopard study in Namibia, generating new science-based answers to old conflicts that threaten large cat survival and in doing so winning the trust of an co-operation of many local landowners.

4. We have also engaged with local adults and children through educational activities, produced educational materials that were distributed nation-wide, created local employment and trained local people at the science/tourism interface. Some of them have gone onto careers in nature-based tourism.

Namibia was one of our earliest, and for many years our most successful and popular expedition. We would have liked to go on, but a number of circumstances prevented a continuation:

1. The increasingly hostile and nonsensical attitude of the Namibian government towards volunteer tourism. This includes a uniquely bureaucratic and wholly unnecessary visa procedure for volunteer travellers to Namibia, as well as wanton harassment of Biosphere Expeditions by government officials.

2. The very significant costs of running an expedition in Namibia with high, two-figure inflation rates year-on-year, paired with a significant, persistent and ultimately insurmountable disagreement with some of our partners on what are reasonable costs and charges that can and should be levied at a non-profit conservation charity such as Biosphere Expeditions, as opposed to a commercial tourism business.

3. Disputes with our science partners over the effectiveness and significance of some of the research conducted and whether it was meaningful in terms of conservation. We were also unable to overcome disagreements over the emphasis of pure research over conservation and the amount of funding required to run an effective and successful research and conservation project.

All this resulted in Biosphere Expeditions' shifting its big cat research work from Namibia to South Africa at the end of 2014.

Biosphere Expeditions sincerely thanks everyone who has helped us over the dozen years or so in Namibia. So many people were involved - too many to list them all - from our scientist, to local helpers, to our partners in Namibia and internationally, to - last but not least - the many participants who came and went, and appreciated Namibia as the remarkable country it is, as we did too over so many years. Thank you to all of you. You can rest assured that big cat conservation in Namibia is better off because of your commitment.

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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 at https://biosphereexpeditions.wordpress.com/category/expedition-blogs/namibia-2014/.

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