Reintroduction ecology: A behavioural analysis of cheetah (*Acinonyx jubatus)* at two separate orders of habitat selection.

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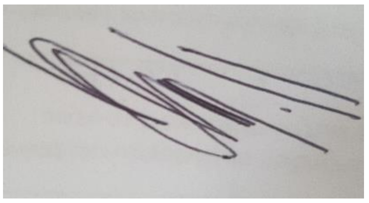
Declaration

I, Anthony Luke Madden, declare that this research report represents my own work, except where due acknowledgement is made, and that it has not been previously included in a thesis, dissertation or report submitted to this University or to any other institution for a degree, diploma or other qualifications. Signed on 24/05/2019.



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Abstract

Large carnivores are the first to be extirpated from an area due to human-associated conflicts. However, the presence of these animals serves as a significant draw card for ecotourism as well as being a major contribution to the ecological integrity of an environment. Today, the efforts to reintroduce these animals to their historic home ranges can be seen across South Africa, often in small game reserves. Essential to any successful reintroduction project is the monitoring of the animals' behaviour after their release, yet, research in this regard remains limited. In this study, I investigated the spatial behaviour of two reintroduced cheetahs, *Acinonyx jubatus,* into a small game reserve (180 km²) in South Africa, by assessing two orders of habitat selection. The first order was the home range establishment of the cheetah over time. This was achieved by creating both the 50% core and 95% total home range estimates as well as the cumulative home range estimates for every 30-day period post their release. The second order of habitat selection examined in this study was the feature selection within home ranges. This was conducted through the use of resource selection functions (RSF) that identified the preferences regarding aspects of topography, human disturbance and lion, *Pathera leo,* risk within the cheetahs' 95% cumulative home range. Both cheetahs initially exhibited a large increase in the rate of area expansion in home range establishment. This was then followed by a stabilisation in the rate of increase which was indicative of successful establishment. The success possibly depended upon the employment of temporal avoidance strategies towards lions including avoidance at a home range scale, selection for dense vegetation coverage, areas close to rivers which would offer refuge, and avoidance of areas in close proximity to dams which are used by lions. Human disturbance seemed to affect only the female cheetah as she avoided areas with high road densities. The study deduced that the home range establishment of the cheetahs was successful and identified the fidelity of the study site.

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Table of Contents

List of tables

List of figures

Chapter 1 - GENERAL INTRODUCTION

Research aim

The aim of this research is to identify the spatial behaviour of two cheetah individuals following reintroduction into a new area, at two separate scales, namely, home range establishment and habitat feature selection.

Motivation for study

Many of the iconic species of African wildlife are large mammalian carnivores that serve a significant role in ecotourism, which positively contributes to economic prosperity (Hunter, 1998). Predators such as cheetah *Acinonyx jubatus*, are important not only for their role in ecotourism, Lindsey et al, (2007), but for their crucial role in ecological processes such as the landscape of fear, trophic cascades and food web dynamics (Wiens, 1995). Unfortunately, such species are often the first to be extirpated from an area due to human interaction and the threat they impose on livestock. In an attempt to restore ecological integrity, in light of the importance of predators to conservation areas, many large mammalian carnivores are being reintroduced into their historical ranges.

In South Africa, the increasing demand for conservation areas has led to the emergence of many small game reserves within which large mammal carnivores are being reintroduced. However, there is an inadequate understanding of the ecological and spatial needs of these carnivores for the successful reestablishment of the species. Understanding of habitat feature selection as well as home range selection of cheetahs will allow management to preserve the correct habitat requirements for current and future cheetah populations within areas of great spatial limitations. Hayward et al. (2007) suggests that although translocation of carnivores is common, post-release monitoring is rarely executed, which often leads to the failure of the successful establishment of reintroduced populations. Aspects of post-release monitoring that are critical to reintroduction include territory establishment, resident prey migration and refuge habitat establishment. Thus, post-release monitoring also allows for the opportunity to locate stressed individuals and mediate habitat requirements. The ultimate goal of any reintroduction should be to establish self-sustaining populations that are subject to rigorous post-release monitoring (Hayward et al., 2007).

A critical aspect of post-release monitoring for reintroduced cheetah populations is the identification of their spatial behaviour. This behaviour comprises home range use and extent, and habitat selection. Both of these forms of behaviour are primarily influenced by an animal's ecological needs, which can be constrained by area or availability of habitat types, which includes food resource. Cheetahs, and other carnivores, will select for these areas and locations based on a culmination of different factors which include prey availability and distribution, relative body mass, and aspects of the environment. Environmental aspects which influence area selection are typically based on vegetation types and coverage percentages which provide for activities such as denning, hunting and predator avoidance. Habitat selection varies greatly between regions and sexes (Coro 1994; Voster, 2011). A lack of study in geographical and or regional variation, which includes studies undertaken in the Gauteng province, highlights a potential research gap that requires attention.

The next point of interest pertinent to small fenced game reserves that lacks research attention is the influence of inter-species competition on spatial behaviour and survival rates, specifically with reference to lion (*Panthera leo*) - cheetah competition. Inter-species encounters can have devastating consequences for the survival of reintroduced species, as processes such as interference competition, intra-guild predation and kleptoparasitism can all lead to the death of subordinate predator species such as cheetahs (Bisset et al., 2015). It is therefore crucial to understand the effects of dominant predator species, such as lion, on the spatial behaviour of cheetahs.

This study aims to advance the knowledge on the spatial behaviour and habitat preferences of reintroduced cheetahs in small reserves, thereby adding to a network of existing studies on cheetah movements. The crux of this study is the identification of areas utilised or avoided by cheetahs, and factors influencing their space and habitat utilization, all of which will be extensively addressed in chapter 2.

Literature review

Study animal

The cheetah is one of the large cat predators found in Africa, which currently has an IUCN status of vulnerable (Friedmann and Daly, 2004, Iucnredlist.org, Accessed 26 Jul. 2018). Habitat loss, poor management practice and human wildlife interactions are at the forefront of their vulnerability. There are approximately 6,700 cheetahs found globally, which are largely distributed over the African continent with 4,190 adults found in the Southern African region (Durant et al., 2015). The largest majority of cheetah are found outside of protected areas, occupying farmlands and wildlife ranges in South Africa (Friedman and Daly, 2004). Second to this region is Eastern Africa followed by Western, Central and Northern Africa respectively (Durant et al., 2015). Cheetahs only occupy 10 percent of their historic range in Africa, while in Southern Africa they are limited to 22 percent of their historic range (Durant et al., 2015). There are very few populations of cheetahs that are not spatially restricted. These populations, which are critical to the connectivity of cheetah populations and gene flow, are typically found as transboundary populations across Namibia, Botswana and Northern South Africa (Durant et al., 2017). Other attempts to conserve cheetah populations can be found in small fenced game reserves, where they are being reintroduced into their historic ranges.

The cheetah social structure is relatively unique when compared to other African large cats (Broomhall et al., 2003). Female cheetahs are usually solitary, unless accompanied by juvenile cubs, while male cheetahs form coalitions of two to three individuals which is important for their survival (Caro, 1994). Durant (2000) and Hunter (1998) found that the likelihood of a successful reintroduction of male cheetah individuals is heavily reliant on the ability of cheetahs to form such coalitions. Contributing to this point, Hunter (1998) adds that the size of the home range established by a male individual is testament to the necessity of these coalitions, as male cheetahs that had not yet joined a coalition, or where the accompanying male had died, would often develop home ranges equal to the size of the reserve in search of new coalitions. This often results in the death of the individual as it may be killed by inter-species interactions or even by other territorial cheetahs (Bisset, 2004). In contrast to this, males that have formed well-defined coalitions establish small concentrated territories (Bisset, 2004).

Cheetahs are typically found in open plains habitats such as grassland savannas, although in recent studies they have also been found to occupy woodland savannas habitats (Broomhall et al., 2003). In these habitats the preferred cheetah prey are medium sized ungulates, such as impala (*Aepyceros melampus*), and Thomsons gazelle (*Eudorcas thomsonii*) (Owen-Smith and Mills, 2008). There seems to be no distinct difference in prey preference between solitary female and solitary male cheetah individuals (Clements et al., 2016). The movement of prey contributes to the home-range behaviour of cheetahs. It is expected that if prey are migratory, in large areas such as the Serengeti, female cheetah home ranges will be vast, thus covering these migratory patterns (Broomhall et al, 2003). In areas where prey species do not migrate, the opposite will be true and female cheetah home ranges will be small and concentrated (Broomhall et al, 2003). In the same paper, it is shown that male coalitions are less affected by prey migration but rather establish concentrated territories that overlap with potential female breeding partners.

Compared with other large mammalian carnivores, the cheetah home ranges are large. Home range size in addition to their social dynamics also produces much lower density populations. A further contribution to their low densities and ranging behaviours, as suggested by many researchers (Caro, 1994; Cozzi et al., 2012; Bisset et al., 2015), is their spatial avoidance to inter-species competition such as between cheetah and lion.

<u>The influence of lion on cheetah spatial behaviour</u>

Lions are one of Africa's dominant predators, usually found in prides of several individuals. They use several strategies to procure food, which include ambush hunting, stalking and scavenging (Loarie et al., 2013; Makacha and Schaller, 1969). Due to their versatile food gathering techniques, lions can peruse food resources in both dense woodland savannas as well as open grassland savanna systems (Loarie et al., 2013). The presence of lions often has a negative impact on subordinate predators such as cheetah. Bisset et al. (2015) highlights that in the Serengeti 73% of cheetah cub mortality is a direct result of lion interactions, while 12.9% of cheetah kills were lost to lions (kleptoparatism) (Scantlebury et al., 2014). In a recent study by Buk et al. (2018), it is indicted that the largest single cause of metapopulation cheetah mortality, which includes spatially restricted reserves, is lion interactions which results in a 31% mortality rate. In light of this, contribution towards the effects of cheetah individuals in the presence of lions requires added research.

When faced with inter-species competition within a spatially limited area, behavioural strategies to enhance the likelihood of survivorship must be employed by cheetah individuals. These strategies can be both spatial and/or temporal avoidances. However, Durant (2000), suggests that such tactics are usually on a very fine scale and that cheetahs will almost definitely have spatial and temporal overlaps with dominant predators such as lions. This highlights a gap in scientific knowledge as to how cheetahs avoid dominant predators in spatially restricted areas such as small fenced game reserves.

Spatial scales of behavioural post- release monitoring

Home range extent

Assessing home range establishment of reintroduced animals is a critical tool in measuring the amount of available resources within a conservation area. Home range is defined as the area an animal covers in order to fulfil its ecological and biological requirements such as caring for young, food gathering and avoiding competition (Burt, 1943). In other words, it is the spatial extent a species or animal occupies while procuring resources, selecting mating partners and rearing young. It does not consider isolated, infrequent exploratory excursions outside this boundary as that would not constitute its realised niche. The home range established by an animal can also be viewed as its utilisation distribution, within which a core area of 50% represents the most frequently visited and thus significant area related to the animal’s usage (Powell, 2000). The process of home range establishment is influenced by both biotic and abiotic factors. Abiotic factors include climate and topography while biotic factors include resource procurement as well as inter and intra specific competition (Broomhall et al., 2003).

Understanding factors that influence the establishment of an animal or species home range serves as an important tool for the reintroduction and long-term conservation of a species. An animal being introduced to an area has no prior knowledge of the resource and landscape features within the area (Panzacchi et al., 2015). This highlights an important trade-off between resource procurement and energy expenditure, whereby the animal must search for suitable habitat while still conserving energy. It is thus expected that a newly introduced animal would first establish suboptimal home ranges and with time, develop more preferable, smaller, concentrated home ranges. This holds particularly true for animals situated in small fenced game reserves, where prey species are not migratory.

Although many researchers have looked at the home range establishment of reintroduced cheetahs (Hunter, 1998; Hayward et al., 2007; Broomhall et al., 2003; Cozzi et al., 2012), there is a gap in the research on the effects of seasonal variation on cheetah home range establishment specific to each sex. As seasonal variation brings with it change in resource availability, it is expected that home range establishment will differ significantly. Another factor influencing home range establishment that is not well researched is that of dominant predators such as lions. Most research has shown where cheetahs prefer to establish home ranges, however, the question remains as to whether there is active avoidance of these preferable home range sites in the face of competition. This question can be further examined in light of the scale of habitat feature selection.

Habitat feature selection

The understanding of habitat requirements is central to the reintroduction and translocation of animals, and especially important where the designated area has been subjected to previous landscape altering practices such as agriculture which degrade historic home ranges. Due to inadequate research on carnivore habitat feature selection, many studies have used home range evaluations as an estimate of habitat preference (Katajisto and Moilanen, 2006). This can often be misleading as home ranges can vary owing to a variety of different characteristics such as the age of individuals, sex, and whether the animal has an established territory (Katajisto and Moilanen, 2006). Although this variation results in a seasonal increase or decrease in home range size, the features used by individuals may stay constant (Reynolds-Hogland and Mitchell, 2007). For this reason, home ranges and habitat feature selection must be evaluated independently.

Pettorelli et al. (2008) has shown that habitat features such as prey availability, water resources, vegetation cover and the presence of competing predators, influence the distribution of cheetahs. Cheetahs will either avoid or be attracted by these features based on their ecological needs. An example of a favoured habitat feature is that of dense vegetation cover such as woodland savanna which cheetahs use for cub rearing and predator avoidance (Durant, 1998). A habitat feature that is avoided by cheetahs is roads, as they convey vehicles and attract dominant predators such as lions (Reynolds-Hogland and Mitchell, 2007). The cheetah's preference for some habitat features remains uncertain, such as artificial or natural water points (Pettorelli et al., 2008). Water points serve as gathering points for many cheetah prey species, however, they also attract dominant predators such as lions. Therefore, my research seeks to identify key influential habitat features while deriving hypotheses as to why these features are selected or avoided. This is of particular interest to the study as the spatial limitation imposed by fencing does not allow for cheetahs to travel large distances in search of preferred habitat features.

Available cheetah data

One female and one male cheetah were fitted with Geographic Position System (GPS) collars by the Dinokeng Game Reserve (DGR) association and released into the reserve on the 28th October 2012. The female cheetah was translocated from Karongwe Game Reserve, while the male individual originated from a region in Darlington and had notoriously escaped from several reserves before being introduced to DGR. Because of collar failure the female data only spans one wet season (28/10/2012 - 30/04/2013), while data for the male is available until end January 2014 (28/10/2012 – 29/01/2014). Besides the GPS location of the animals, the collars recorded animal ID, local date, local time, location co-ordinates, temperature (degrees Celsius), altitude (metres), and distance covered. GPS coordinates were recorded at 4 hourly intervals.

Thesis outline

Chapter 1 serves as an introduction into cheetah reintroduction and provides the reader with a context. The study focus will be explored in detail in chapter 2.

Chapter 2 aims to identify the spatial behavioural response of two reintroduced cheetahs through the analysis of second and third order habitat selection. These orders are, namely, home range establishment and habitat resource selection respectively. The three overarching objectives that guide the research are:

- To determine where the reintroduced cheetahs' home ranges are established and their response over time in Dinokeng Game Reserve (DRG).
- To determine what the preferred habitat features are for both the male and female cheetahs and identify where these are situated in Dinokeng Game Reserve.
- To determine whether lion habitat selection influences the habitat selection of the male and female cheetahs respectively.

Chapter 2 is written in article format consisting of its own introduction, methods, results and discussion. Tables and figures relevant to the chapter are presented at the end of the report, while references relevant to each chapter are at the end of each chapter.

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Chapter 2

Second and third order habitat selection of reintroduced cheetahs: home range establishment and within home range resource selection.

Introduction

Key to the success of any reintroduction project are aspects of post-release monitoring (Hunter, 1998). It has been shown that the practice of post-release monitoring ensures the survival of species by assessing whether adequate resources are present as well as in assisting in adaptive management strategies, thereby aiding the success of the individual's or species' establishment (Hunter, 1998). The need for such measures is amplified by the spatial limitations brought about by the fencing boundaries around small game reserves which further limit an animal's ability to procure its required resources. In South Africa, in an effort to boost ecotourism and species conservation, many previously degraded landscapes have been rehabilitated in an effort to restore the areas to their historic pristine state (Di Minin et al., 2013). One of the most successful and iconic examples of this is Phinda Private Game Reserve – the restoration of this previously overgrazed land began during 1991 to become a well-established game reserve. Phinda Private Game Reserve is one of many examples in South Africa to achieve numerous successful reintroduction projects in which previously extirpated species have been reintroduced to their historic ranges (Di Minin et al., 2013).

Translocation and the reintroduction of animals into small fenced game reserves require the understanding of habitat requirements. There are three fundamental criteria that facilitate the successful introduction of a species into an area, namely, the correct methodological considerations and funding, communication with and involvement of local communities, and lastly, the identification of ecological requirements for the introduced species (Hunter, 1998). For the purpose of this research, the final point will be examined in detail. The identification of the ecological requirements of a species is critical in the context of game reserves previously used for agricultural activities such as cattle and produce farming. The correct quality and quantity of adequate resources must be present in order to host a population or animal. Therefore, an understanding of habitat preference is key to the practice of reintroduction

Reintroduction success is further dependent upon the correct method and scale of post-release monitoring. Analysis of an animal's behavioural and spatial movements as well as habitat preferences must also be explored. However, as stated by Johnson, (1980), in an attempt to avoid bias, and/or misleading results, a 'hierarchal nature of selection' through selection order must be used to demonstrate the movement and behaviour of an animal. The use of selection orders is appropriate where the selection of one order determines the selection of another. For example, if an animal is found within its selected home range, its habitat preference is determined by the home range it has selected. As the reverse could also be true, it is import to identify these orders. The orders of habitat selection are: the 'first-order selection' which is the geographical region selected; the 'second-order selection' which is the home range selected by the animal; the 'third order of selection' which is the preferred usage of features contained within the animal's selected home range; and finally, the 'fourth order of selection' which identifies the food acquired by the animal within the feature it has selected (Johnson, 1980).The second and third orders are pertinent to this study on the reintroduction of two cheetah, *Acynonyx jubatus,* individuals to a small fenced game reserve in Gauteng, South Africa.

Home range establishment, as previously stated, the second order habitat selection, is typically described as the boundary surrounding the realised niche of an animal (Burt, 1943). Habitat feature selection provides insight into the preferred features and resources used by the animal. Habitat feature selection coupled with home range estimates serves as a pivotal conservation tool for wildlife management as it highlights movement and distribution patterns of an animal, ultimately providing management with reliable results that can be used to facilitate relevant animal resource portioning as well as continued resource quality assessments (Marker et al., 2008).

Cheetahs, like most free-roaming, big cats are included in many reintroduction projects as they provide a significant contribution towards ecotourism efforts (Smith and Wilson, 2002). Apart from their economic significance, their presence as predators contributes to ecological processes such as trophic cascades and landscapes of fear, which are considered essential elements in maintaining heterogeneity within landscapes (Wiens, 1995). It is important to mention that the due to the economic benefit large predators bring to a reserve, the population density is often to high resulting in the need to facilitate feeding and potentially unbalancing the ecology of the system (Clements et al., 2016). Cheetahs, however, are subordinate predators, thus the presence of dominant predators such as lions *Panthera leo* (Bissett et al., 2015), coupled with confrontational interactions with humans, pose a threat to the survival of the species. Factors such as topography, human disturbance, resource selection and the influence of dominant predators, all contribute to typical home range sizes and resources selected by cheetahs, evidentially resulting in large variability. It has been documented that home range sizes vary between gender, with males occupying a home range between 121.5 km² and 607 km², and females between 14.7 km² to 703.3 km² (Marnewick and Somers, 2015). While there are still several theories as to what influences male home range establishment, it is largely acknowledged that females respond to prey distributions (Caro, 1994). Females that encounter migratory herds occupy large home ranges, while the presence of sedentary prey herds result in more concentrated home ranges (Marnewick and Somers, 2015).

This study centred on the reintroduction of a male and female cheetah into Dinokeng Game Reserve (DRG). The study periods differed for each cheetah individual. The male study period spanned a period of two wet seasons and one dry season (21/04/2013 – 29/01/2014), while, due to collar failure, the female study period only constituted one wet season (28/10/2012 - 30/04/2013).

The objectives of the study were to: 1) analyse the ranging behaviour of two reintroduced cheetah individuals from the time of reintroduction, 2) establish seasonal environmental determinants of cheetah habitat selection, 3) compare ranging behaviour and selection patterns between the male and female cheetah, and 4) assess the influence of lions on cheetah habitat selection and home range establishment. I expected the home range size to increase over time, and in the case of the male trend towards stabilisation. For the male, I expected the dry season home range to be smaller than that of the two wet seasons as resources such as prey and water would be more concentrated. I expected cheetahs to select for environmental features that would serve for both hunting and refuge, thus a mixture of dense vegetation cover and open savanna situated in close proximity to one another. Adding to these expectations were features likely to host suitable prey abundance such as water points and low human disturbance areas. I expected little seasonal and between female and male differences in feature selection. Finally, I anticipated that the male individual would not avoid nor select for areas of high lion probability, while the female cheetah would select for areas devoid of high lion occurrence.

Methods and materials

Study area

The study was done in Dinokeng Game Reserve (DGR), situated in the Limpopo and Gauteng provinces, South Africa (latitudes, 25°15’28” S and 25°28’12” S and longitudes 28°17’55” E and 28°28’25” E) (Figure 1). DRG is approximately 185 km² in extent and has a perennial water flow provided by the Pienaars River which consists of both the Kaalaagte Spruit and the Boekenhout Spruit (Yiu, 2017).

Before DGR's establishment in 2011, the land was mainly used for farming and agriculture. Being situated in the South Temperate Zone, DRG is located in an area characterised by a wet season spanning from October to April and a dry season from May to September. The average annual rainfall of the area is 626 mm (New et al., 2002). The low temperatures fall between 5° C and 18℃, from June to July in the dry season, and high temperatures rise to between 21℃ and 30℃, from December to February in the wet season.

There are diverse vegetation types in DGR, of which open grasslands *Combretum apiculatum* veld, dense woody vegetation *Burkea africanan* bushveld, and an open tree layer with a dense shrub layer *Boscia albitunca* bushveld are just some examples (Yiu, 2017). The vegetative diversity found in DGR is an ecological requirement for cheetahs as it can provide refuge to facilitate spatial behaviours such as hunting and the avoidance of dominant predators. Thus it will be of interest to the study to identify cheetah vegetation type preferences in this heterogeneous landscape. Within the reserve, there are many road networks, the main road being the Rust de Winter Road (D48), which divides the reserve into two sections (Fig 2.1). The presence of these road networks would most probably affect cheetah spatial behaviour and thus is worth documenting.

The reserve is home to over twenty different mammal species. One of the most abundant species, and an important prey for cheetah, is impala *Aepyceros melampus,* Owen-Smith and Mills, (2008) and Clements et al., (2016), which are found in numbers in excess of one thousand individuals in DRG. Other mammals found in DRG include African elephant *Loxodonta*, African buffalo *Syncerus caffer,* white rhinoceros *Ceratotherium simum*, blue wildebeest *Connochaetes taurinus,* greater kudu *Tragelaphus strepsiceros*, brown hyena *Hyaena brunnea* and lion *Panthera leo.*

<u>Data collection</u>

Location data (Global Positioning Systems (GPS) coordinates, day and time) for two individual cheetahs were provided to us by DRG association. The two cheetahs had been collared with Geographic Positioning System (GPS) collars (African Wildlife Tracking, Pretoria) and were released from the same holding boma on 28/10/2012. Locations were recorded at 4 hourly intervals and spanned the duration of a year and a half for the male

(28/10/2012 – 29/01/2014), and one wet season for the female (28/10/2012 -30/04/2013) due to collar failure.

Environmental features that may have influenced the habitat selection of cheetahs included Vegetation Continuous Fields (VCF), slope, distance to rivers and dams, distance to buildings, road density, and lion probability of occurrence (Table 1). Lion probability of occurrence was calculated as the predicted probability of lion occurrence, calculate by Yiu, (2017) for the same time period, associated with each cheetah location point (Yiu, 2017). To document the percentage tree cover for the area (VFC), I used the 250 m Terra MODIS VCF Imagery (DiMiceli et al, 2011). The imagery was then resampled to the same spatial resolution as the Global Digital Elevation Model (GDEM) of the area Yiu, (2017) which was 30 meters. Road density, adopted from Yiu, (2017) was created at a 30 m resolution starting from a road layer provided by the Dinokeng Game Reserve Association, density was calculated using the kernel density tool in ArcGIS 10.2 and radius defined by distance between roads. The the major road (Rust De Winter) was counted twice due to the high rate of traffic flow (Figure A-1). Maps regarding buildings, rivers and dams were obtained from previous research conducted by Yiu (2017). All maps, shapefiles and raster files were projected as UTM WGS 1984 35s in ArcGIS 10.3 (ESRI).

Data analysis

Home range establishment was modelled using GPS location points collected as previously described. All home ranges were estimated using the Time Local Convex Hull (T-Locoh), by employing the package (tlocoh) in R 3.1.3. T-Locoh follows traditional home range methods such as minimum convex polygons (MCP) as it includes aspects of temporal behaviour (Lyons et al., 2013). The Locoh model, which precedes the T-Locoh model, neglects temporal behavioural responses solely relying on an animal’s spatial response (Lyons et al., 2013). Both spatial distribution and time differences are included in the T-Locoh method for constructing home range establishment. I selected for a time-space selecting factor (s) where the diffusion distance (difference in time spent at location) and spatial parameters equalled 50% of the location points of the cheetah. Time intervals of 24 hours were selected for the entire study period and were based on the cheetahs’ relative movement patterns, derived from the distance of location points to the centroid of the data set, for a specific interval and cheetah. I employed the adaptive method (a-method) for the nearest neighbour analysis by using a cumulative time-scale distance equal to or less than the a-value. The a-value (a) is defined as the cumulative distance of the parent points to their relative neighbours (Lyons, 2014). Values of (a) were chosen so that 95% of locations had a minimum number of three nearest neighbours, which serves as a minimum requirement for the construction of a hull. During the construction of the home ranges many different a-values were chosen to create isopleths. Isopleths were then plotted to reveal their area to edge ratios. Values of (a) were then selected for the final construction of a 50% core and 95% home range where a low edge to area ratio was present (Lyons et al., 2013).

In order to represent how home ranges expanded after the cheetahs were released into DGR, I modelled their cumulative 50% and 95% home ranges. A 50% core area is viewed as the most important area within the animal's home range, and the 95% considered the large extent of the animal's home range (Powell, 2000). Plotting the home range expansion was achieved by cumulatively adding location points for each consecutive 30-day interval for both cheetahs, and then plotting the expansion in area over each 30-day period, as well as plotting the rate of change (slope) against time to illustrate any progression. This was done with the aim to identify stabilisation in cheetah behaviour, indicating whether or not a cheetah had settled into its new environment. In addition, for the male I calculated seasonal home ranges, which comprised of two wet seasons (28/10/2012 -31/03/2013and 01/10/2013 – 29/01/2014), and one dry season (01/04/2013 -30/09/2013) and a total home range spanning the entire study period; for the female, due to insufficient data, only one wet season (29/10/2012 – 30/03/2013) was calculated. Therefore, seasonal home ranges were compared for the male individual and were the comparison of two wet seasons to one dry season. Home ranges of lions for the same period where taken from Yiu (2017) and compared with the cheetah home ranges in this study to assess the degree of overlap. The degree of overlap, for both the 50% core home ranges and 95% home ranges, was measured as a percentage overlap using the following equation (Miller, 2012):

$$\frac{2(OZ) \times 100}{(HRa + HRb)}$$

Where OZ represents the area of overlap between the two home ranges, HRa represents the total home range of one animal or species and HRb represents the total home range of the species or animal with which that of HRa is being compared.

To analyse within home range habitat feature selection of both cheetah individuals, resource selection functions (RSF) were built using logistic regressions (generalised linear model, GLM). These RSFs were built using the package 'glm' in R3.1.3. Models were built using the use-availability design, where used points were defined by the animal's location within its specific cumulative home range (Manly et al., 2002). Each variables distribution was test and is represented by Q-Q plots (Figure B 1-18). Multicollinearity between models for both categorical and numeric variable, Wißmann and Toutenburg, (2007), was tested using the package 'vcov'. A cut off level of 0.07 was used to determine multicollinearity between models (Yoo et al., 2014). Available points were generated as random points within the same home range for the pooled wet season (2012-2013 & 2013-2014) and dry season (2013) for the male cheetah as well as the wet season of the female. These available points were created for every 30-day interval within the seasons so as to represent what was available at the time to the animal. As the RSFs were conducted for changes in season and not changes in extent over time, the two wet seasons were pooled as one to observe possible seasonal feature changes. Random points were generated at a ratio 1:1 to used locations, to represent resources available to the animal at that specific spatial and temporal period (Recio et al., 2014). Values associated with environmental variables (Table 1) influencing cheetah movement patterns, were extracted in ArcGIS 10.3 (ESRI) for both used and available locations. Resource selection functions were constructed for the general 95% home range estimates, as the research interest was aimed at how cheetahs select resources, and not necessarily differences in selection strategies between the 50% core and 95% home range.

Six priori models were built (Table 1) based on a combination of three environmental categories (topographic roughness, human disturbance and lion risk), and including a global model. Models were constructed for the pooled wet season of the male (28/10/2012 - 31/03/2013and 01/10/2013 – 29/01/2014), the male dry season (01/04/2013 -30/09/2013) and the female wet season (28/10/2012 – 30/03/2013), and at a spatial scale determined by the 95% home range.

Models were compared using Akaike's Information Criterion modified for small sample sizes (AICc) (Burnham and Anderson, 2004). Models were further compared using the model's relative likelihood based on their Akaike weights (w_i). The model with the highest probability was then selected as it was deemed the best representation of the data collected (Burnham and Anderson, 2004).

Results

Home range extent

The cumulative home ranges of both the female and male cheetahs, which included the 50% core and 95% home ranges, increased in size with time from reintroduction. This is typical for newly reintroduced animals as they identify and procure resources (Figure 2, 3). The largest increase in area was seen during the first 30-day interval after the release of the animals. A trend towards stabilisation in area can be seen in the male individual with a decrease in the rate of area increase (-12%) in the 15th (450-day) period. This decrease was seen after a spike in rate increase (45%) from the 13th (390-day) period (Figure 3). A trend towards stabilisation was discovered for the female individual and identified as a levelling off around 40 km^2 in the last 30-day period for the 95% home range and 14 km^2 for the last 60-day period for the 50% core (Figure 2).

The total home range extent for the male cheetah was recorded as 86.16 km^2 and 18.80 km^2 for the 95% and 50% core home ranges respectively (Figure 4). The 95% home range was established in the north and south of the reserve, while the 50% core range was concentrated in the northern section of the reserve (Figure 4). Central DGR was utilised by the female cheetah, which occupied a 50% core home range of 14.72 km^2 and a 95% home range of 40.64 km^2 in the wet season (2012-2013) (Figure 5). Seasonal home ranges of the male cheetah were similar in size between the second wet season (2013-2014) and the dry season (41.70 km^2 vs. 41.47 km^2 respectively). The first wet season (2012-2013) home range covered the largest area, which was 49.58 km^2 and was comparatively bigger than the female home range for the same period (40.64 km^2). Core areas were established solely in Northern DGR in the second wet season and in the dry season, while the core area occupied by the male in the first wet season after release was established in both Northern and Southern DGR (Figure 6).

The cheetahs appeared to show differing levels of lion avoidance behaviour at the home range scale. The 95% home ranges of male cheetah in both wet seasons only had a 35% and 33%, overlap with the lions home ranges, respectively, while the highest overlap (38.46%) occurred in the dry season (Table 2). The female cheetah had a small home range overlap of 18.41% with lions (Table 2). In terms of the 50% core home ranges, the female cheetah showed high levels of lion avoidance, which were testament to a 7.74% overlap (Table 2). The male cheetah's core area overlap displayed contrasting levels of avoidance compared to the 95% overlap. The overlap in the first wet season was 41.84% and in the second wet season 30.83% (Table 2). A complete lack of avoidance was recorded in the male cheetah's dry season which constituted a 71.50% overlap (Table 2).

Environmental feature selection

There existed no multicollinearity between model variables. All variables were normally distributed (Figure B1-18). In selecting models for habitat feature selection (GLM), model 6 (global model) proved the most viable, in terms of its AIC weighting, for both seasons for the male and for the female ($w_i \geq 0.99$) (Table 3). This model includes all attributes pertaining to environmental roughness: topographical roughness (slope, vegetation Continuous fields (VCF), distance to river and distance to dam), human disturbance (road density and distance to buildings) and lion risk (lion occurrence probability). Thus, due to this model having the lowest AICc value and highest AIC weight it was chosen for further analysis.

Aspects of topological roughness influencing the within home range selection of cheetahs saw a strong selection for slope by the female and male during the wet season, while no slope selection was observed in the dry season by the male (Figure 7). Both individuals used areas close to rivers for the entire study period (Figure 8), while also selecting areas further away from the dams and waterholes (Figure 9). The female selected for areas with dense vegetation cover (high VCF), while the male preferred open areas (low VCF) in both seasons (Figure 10). Variables contributing to human disturbance included road density and distance to buildings. Buildings, as suggested by the weak slope, did not have a large effect on within home range habitat selection for both cheetah individuals (Figure 11), however, the male cheetah did select areas further from buildings in the dry season (Figure 11). A strong selection for areas of low road density was observed for the female cheetah as well as the wet season of the male, while areas of high road density seemed to be selected by the male during the dry season (Figure 12). Contrary to what was predicted in this study, both the female and male cheetah were more likely to occur in areas of high lion occurrence probability in all seasons (Figure 13). However, as previously described the cheetahs did showcase some avoidance at a home ranging scale (Table 2).

Discussion

Both cheetah individuals showed an initial expansion of their home ranges post-release, indicating a large rate of increase (slope) for the first 30 days. This was to be expected as animals must first assess their new surroundings, identifying optimal and suboptimal habitats (Hunter 1998). The female cheetah's area increase slowed down after the initial expansion and indicated a trend towards a plateau. It is largely understood that a decrease in the rate of home range expansion of a reintroduced animal is a potential indication that the animal has settled into its new environment (Hunter 1998). The same trend towards stabilisation can be seen in the male cheetah's rate of area increase, however, there is an evident spike during the 12th (360-day) and 13th (390-day) period for the male. A possible explanation for such a spike is the introduction of three female lions (Yiu, 2017). The introduction took place on 02/11/2013, which is 370 days after the release of the male cheetah and also falls within the spiked period. It is further assumed that the lion pride would have been held in a boma located at the release site that may coincide with the start of the spike in the male cheetah's area increase. This is the only introduction of lion during the cheetah study period and therefore such activity would be novel to the cheetah. With the release site of lions falling within the male's home range (Yiu, 2017), such a dramatic increase in area expansion could be an act of avoidance. After a peak home range size of 108 km², the male cheetah slowed down its range expansion and settled at a size of around 90 km². This contrasts with a previous study by Mills et al .(2004), which took place in the Kruger National Park, in which solitary males occupy home ranges of up to 216 km². Although the 216 km² is indeed larger than that of the DGR, the contrast between the two home ranges is noteworthy. Male cheetahs are very dependent on coalitions and therefore solitary animals usually go in search of them, resulting in large home ranges and increases in the rate of area extent over time. However, this was not the case in my study. The influence of hard boundary lines (predator proof fencing) that surround DGR, may possibly account for the limitation in home range expansion as observed in my study. In this case, the limitation would not be indicative of stabilisation, as earlier suggested. This account is further supported by the fact that more than 50% of the reserve constitutes the male's 95% home range.

When comparing home range size differences between the female and male cheetahs, this study's results are in agreement with Broomhall et al., *(*2003), regarding the male cheetah establishing comparatively larger areas than the female's home range to increase his mating probabilities and potentially overlapping areas of the female home range. As suggested by

Broomhall et al., (2003), the largest influence on male cheetah movement is female cheetah movement and, as seen in this research, females occupy smaller concentrated home ranges. There was, however, little overlap between the female and male individual which may be a factor of time. It is possible that due to the short female study period such an overlap could not yet be identified. In a similar study conducted by Bisset. (2004), which spanned a duration of 19 months, the home ranges of cheetahs reintroduced into Kwandwa Private Game Reserve (200 km²) showed a solitary female occupy a relatively small home range of 65.6 km², which is similar to the size of the female home range in my study. A possible explanation for this difference in size is the fact that the study area varied between both studies by 20 km² and thus could be a correlation between reserve size and home range establishment. Another alternative explanations of the differences in home ranges between the two studies could be explained by the duration of the study, where Bisset. (2004) spanned 13 months longer than my study for the female cheetah.

My study results indicated little seasonal variability in home range extent and location between the second wet season (2013-2014) and the dry season for the male cheetah. The first wet season (2012-2013) differed from the previously described seasons as it was around 9 km² larger and occupied a core area in both Northern and Southern DGR. The reasoning for this difference, as with the cumulative area increase, is that this season directly follows the release of the animal and thus exploratory behaviour is to be expected at the far ends of the reserve. There were, however, significant differences between seasons when describing the cheetah's home range overlap with lions. The two wet seasons were similar in overlap only differing by roughly 10% and, as their percentage overlaps were both less than 50%, showcased lion avoidance. A 71.5% overlap was identified in the dry season of the male study, which could be a result of more restricted resource concentrations as water availability decreases. This result is in agreement with Durant, (2000), whose study shows that male cheetahs are not influenced by the presence of lions. In contrast, the female took up residence in the central and western sides of the reserve for both her 50% core and 95% home range, which could be explained by her low home range percentage overlap with the lions' home ranges. The female cheetah home range only overlapped with the lions' ranges by 18.41% and 7.74% for the 95% and 50% core home ranges respectively. This highlights a clear avoidance of lions at the home range scale, which holds particularly true for her most important area, the 50% core area.

The male individual selected for areas of low vegetative coverage percentages for both the wet and the dry season as well no slope selection in the dry season. Both the male and female did however select for areas of steeper slope in the wet seasons. This is accordance with studies by Bisset et al., (2015) and Broomhall et al., (2003). Open vegetation types such as grassland have been typically identified as preferred habitat types, however, as suggested by Bisset et al., (2015), this may be a result of study site location and not specifically preferability. It has now been shown that while male coalitions seem to still favour open savanna areas, female individuals show increased favourability for dense woodland to facilitate behavioural necessities such as refuge and cub rearing (Broomhall et al., 2003). The reasoning for this vegetative selection by males could be two-fold. Firstly, such areas could facilitate high speed chases, for which cheetahs are renowned, and secondly, open habitats may be selected for in an attempt to find and join a coalition (Caro, 1994). Regarding the female cheetah, whose home range and therefore habitat selection consisted of dense vegetation, these findings are in agreement with Broomhall et al., (2003) and Hunter (1998), and are likely the result of refuge and forms of ambush hunting, where slopes would not play a vital role.

Both cheetahs occupied areas of high lion probabilities of occurrence, with the female cheetah having the highest selection probability. These findings, coupled with the percentage home range overlaps, are in contrast to research conducted by Caro (1994) as well Bisset et al., (2015) as female cheetahs were found to occupy home ranges as far as possible from the home ranges of lions. In the case of DGR, the constraint posed by the fence around the reserve might prevent spatial separation between the two species. In the absence of spatial avoidance on account of space constraints, temporal avoidance (i.e. using the same areas but at different times) might be a better strategy. In fact, Bisset et al. (2015) suggested that in areas spatially limited by predator proof fencing, temporal avoidance strategies are key to the survival of subordinate predators. The results of my study show a scale dependant avoidance where cheetahs typically avoid lions at a home ranging scale, but may show signs of temporal avoidance by temporally shifting their selection of habitat features when they occur in areas of high lion probability. When high resource availability occurs in areas of high lion densities, competitor avoidance costs may be too great for cheetah to spatially avoid lions.

This point is further explained when one looks at cheetah preference for water sources. According to Yiu (2017) lions had a preference towards areas in close proximity to dams, however, did not select for areas close to rivers unless in search of refuge in dense riparian

vegetation. Cheetahs, during the same study period, negatively selected areas close to dams, and positively selected for areas in close proximity to rivers. This highlights potential avoidance behaviour. Although cheetahs selected for areas with high lion probability, they employed scale specific avoidance strategies such as selecting for resources devoid of lion.
The female cheetah occupied a home range that had the highest amount of human activity (central and western DGR), shown by a high road density as well as number of buildings per area, but on a fine scale avoided human disturbance by selecting areas with low road densities. Building proximity instead, did not have an effect on female behaviour. This suggests a feature-dependant avoidance to human disturbance. Similar results were found in a study by Houser et al. (2009), where human disturbance and perturbation resulted in cheetahs occupying dense habitat types that buffered the influence of human activity. The male individual in DGR showed seasonal differences to the influence of human disturbance specifically regarding road density. The male showed a strong selection for areas with high road density in the dry season and a negative selection for such areas in the wet season. This may be a result of vehicle traffic differences between seasons, however, it is difficult to identify the exact reason for these two contrasting results.

The results of this study show that adequate dense vegetative coverage must be preserved in order for cheetah to effectively avoid lions within spatially limited areas and also highlights the importance of riverine vegetation that facilitates refuge. While human disturbance does not seem to be influential on the spatial behaviour of cheetahs, there does seem to be some selection with respect to road density that could be further investigated.

In summary, reintroduced cheetah into DGR appear to express complex spatial behaviour specific to both broad and fine scale habitat selection. While an obvious limitation to the study is the small sample size as well as a very limited female study period which did not allow for the identification of movement trends over long periods, relevant, site specific management applications can be drawn from the research as well as providing a baseline for further research. The research highlights the study site's fidelity and indicates the successful establishment of both cheetah individuals into the reserve by showcasing a stabilisation in home range establishment, successful dominant predator avoidance techniques, habituation to human disturbance and the absence of homing behaviour.

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Table 1. Environmental categories as well as six defined priori models, used to select resource selection functions for the entire study period, (28/10/2012 -29/01/2014) of two reintroduced cheetah into Dinokeng Game Reserve (DGR), South Africa.

Environmental category	Variables include
Topographical roughness	Slope, Vegetation Continuous fields (VCF), distance to river, distance to dam
Human disturbance	Road density, distance to building
Lion risk	Lion occurrence, VCF
Model number	Reasoned model set
1	Slope +distance to dam + distance to river + VFC
2	Road density +distance to building
3	Lion occurrence + VFC
4	VFC+ lion occurrence + slope
5	Distance to river + distance to dam
6 (global model)	Slope + VCF + road density + lion occurrence + distance to river + distance to dam + distance to building

Table 2. 95% and 50% core home range (HR) percentage overlaps with lions home ranges (from Yiu, 2017) of two reintroduced cheetah into Dinokeng Game Reserve, South Africa.

Male cheetah	Wet season (2012-2013)	Dry season (2013)	Wet season (2013 – 2014)
95% HR overlap	35.22%	38.46%	33.06%
50% HR overlap	41.84%	71.50%	30.83%
Female cheetah			
95% HR overlap	18.41%	-	-
50% HR overlap	7.74%	-	-

Table 3. Resource selection function models and their accompanying AICc, Delta AICc and AIC weightings (w_i) for female and male individual in Dinokeng Game Reserve, South Africa

Male dry season				
Model number	K value	AICc value	Delta AICc	(w_i)
M6	8	2076.84	0.00	1
M5	3	2141.71	64.87	0
M1	5	2145.36	68.52	0
M2	3	2147.61	70.77	0
M3	3	2216.08	139.24	0
M4	4	2217.01	140.17	0
Male wet season				
M6	8	4501.45	0.0	1
M1	5	4535.04	33.59	0
M5	3	4562.80	61.35	0
M4	4	4727.18	225.73	0
M2	3	4759.12	257.67	0
M3	3	4772.71	271.26	0
Female wet season				
M6	8	3250.60	0.00	1
M4	4	3288.91	38.30	0
M3	3	3290.10	39.50	0
M1	5	3296.02	45.42	0
M5	3	3298.65	48.05	0
M2	3	3308.04	57.44	0

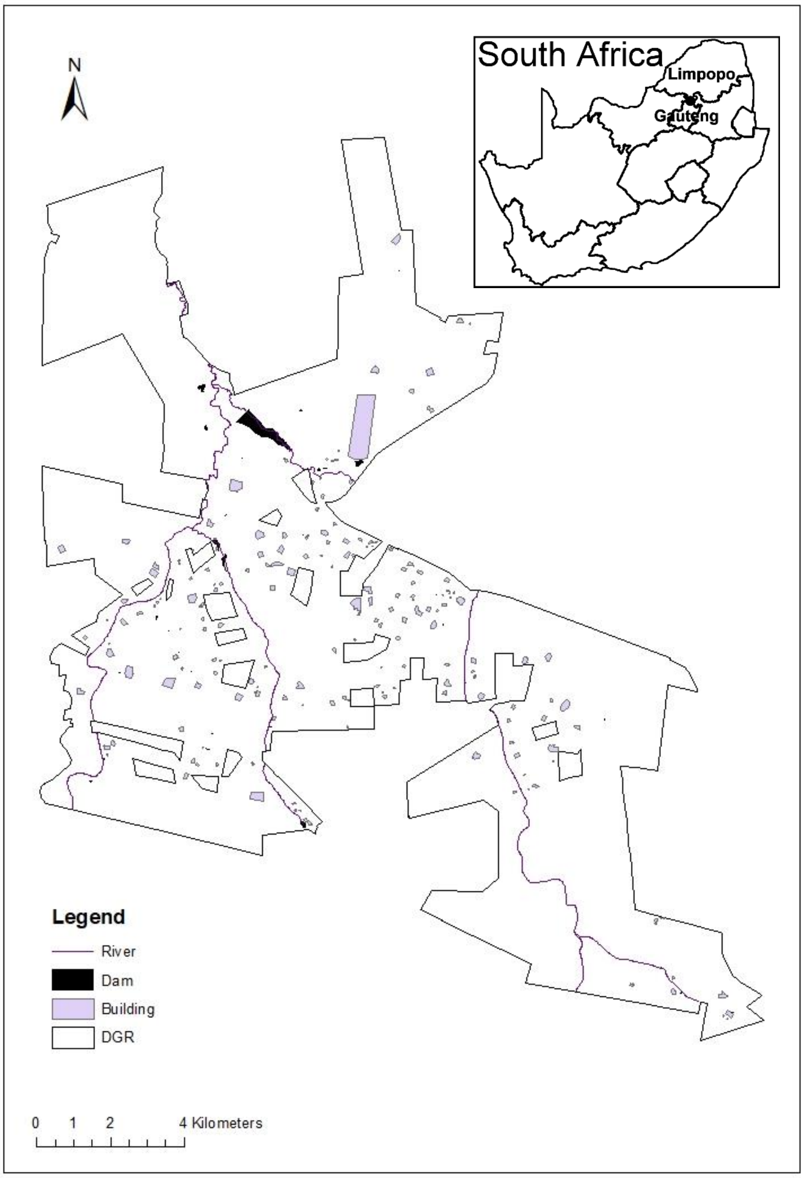
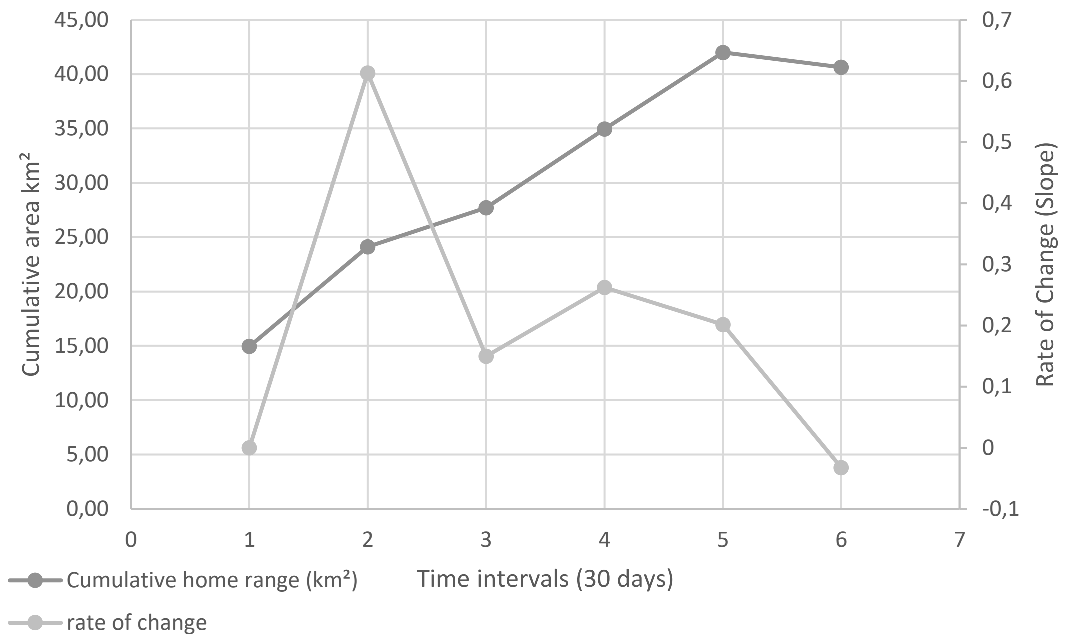


Figure 1. Map of Dinokeng Game Reserve (DGR). Inset map: location of DGR in South Africa.

(a)



(b)

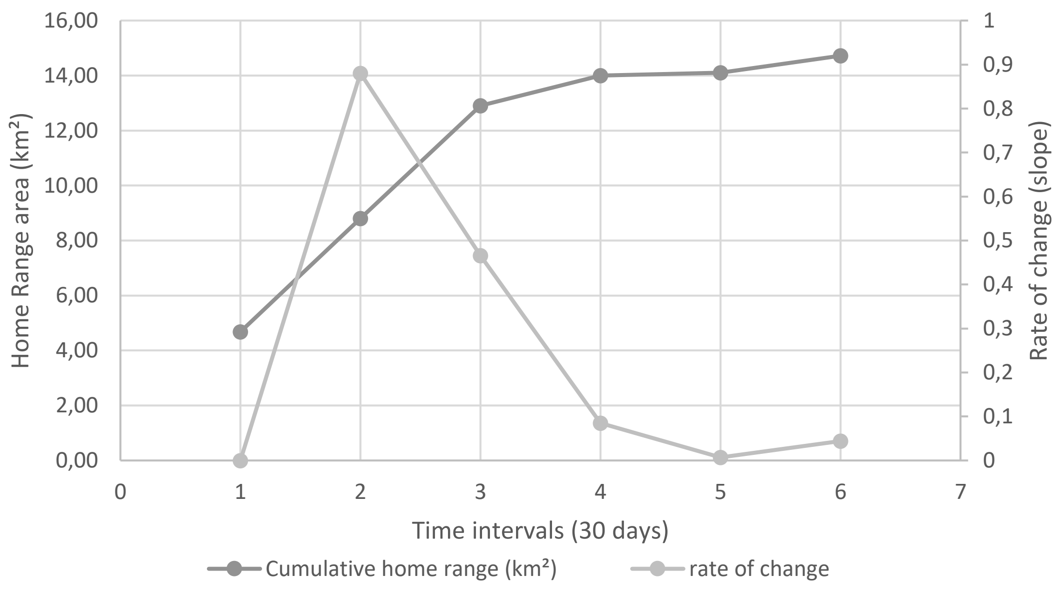
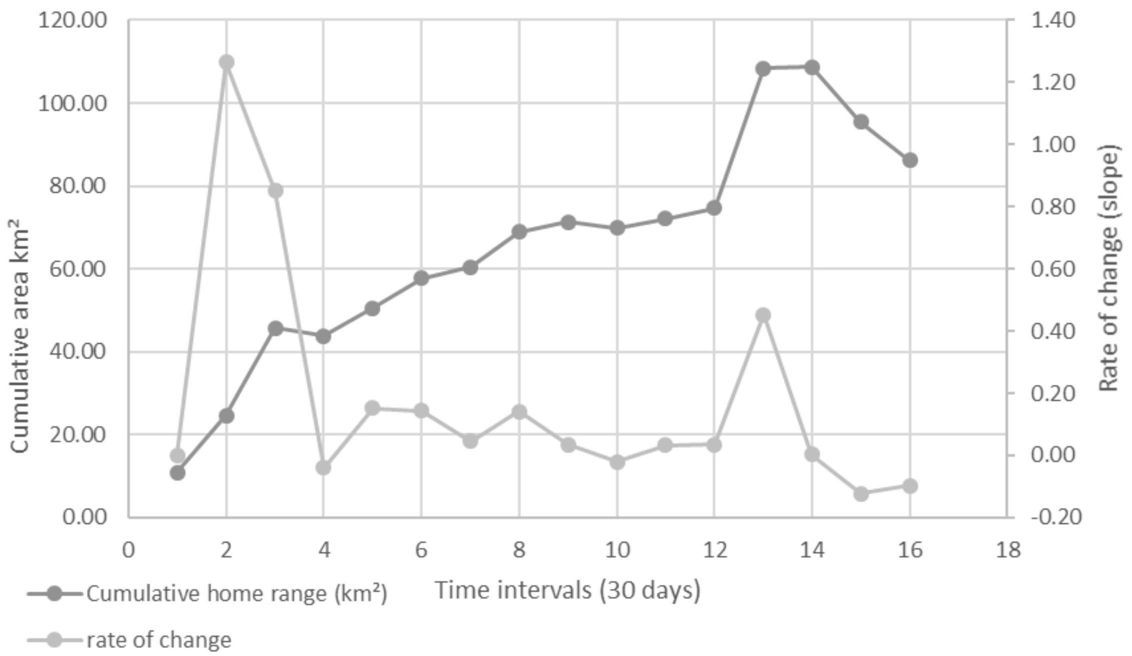


Figure 2. Cumulative increase in home range area for the female cheetah after reintroduction, as well as relative rate of change in area (slope), in Dinokeng Game Reserve. (a) 95% home range and (b) 50% core home range.

(a)



(b)

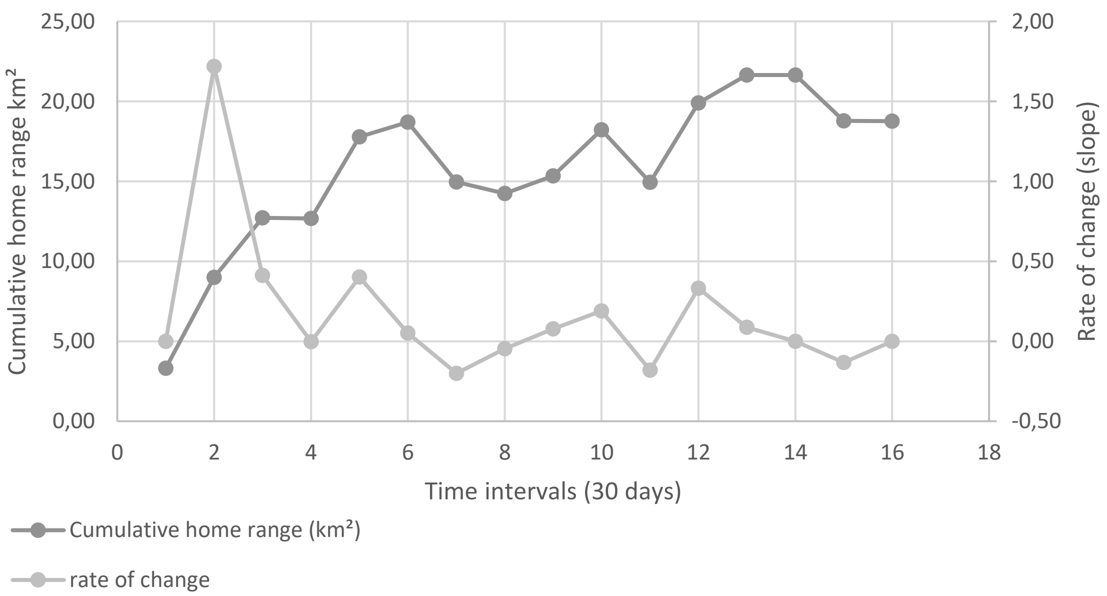


Figure 3. Cumulative increase in home range area for the male cheetah after reintroduction, as well as relative rate of change in area (slope) in Dinokeng Game Reserve. (a) 95% home range and (b) 50% core home range.

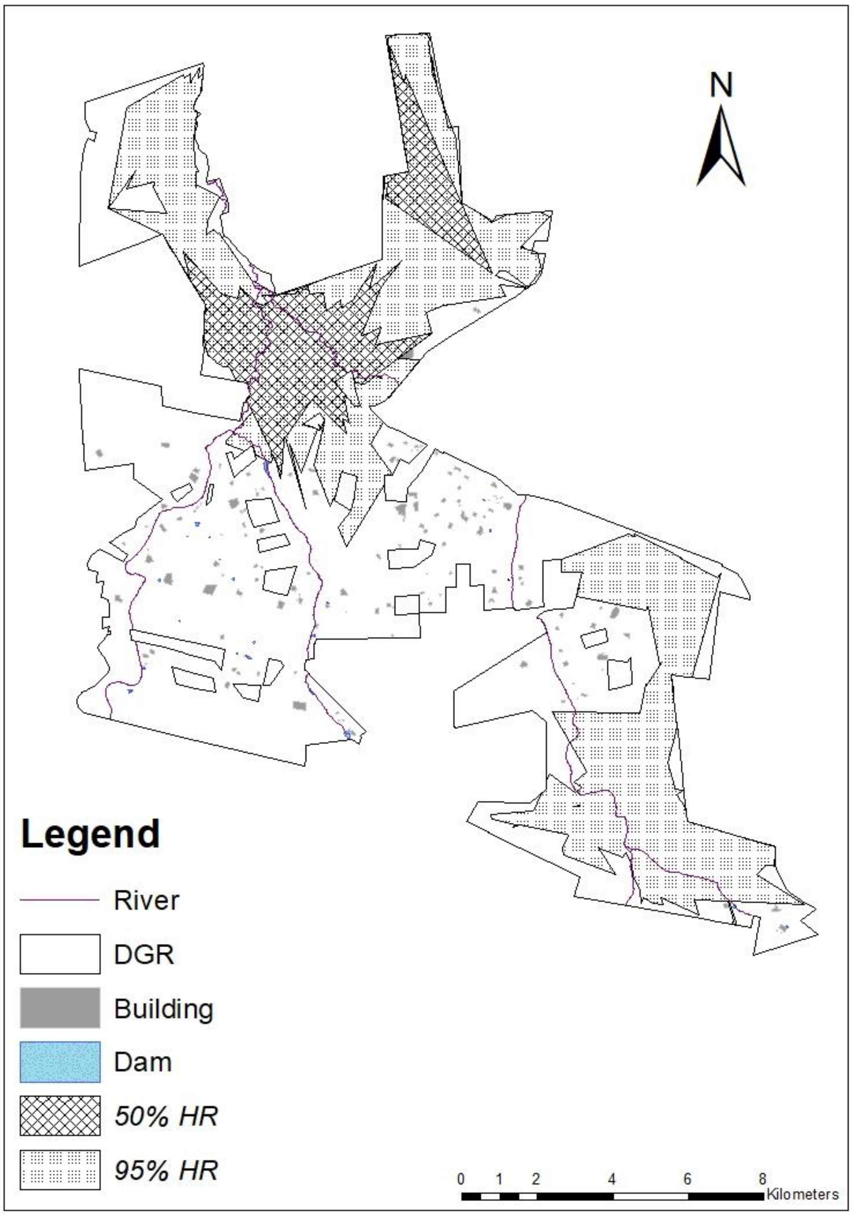


Figure 4. Total home range of the male cheetah for the entire study period *(28/10/2012 – 29/01/2014)* at Dinokeng Game Reserve. Both the 95% home range and 50% core are represented.

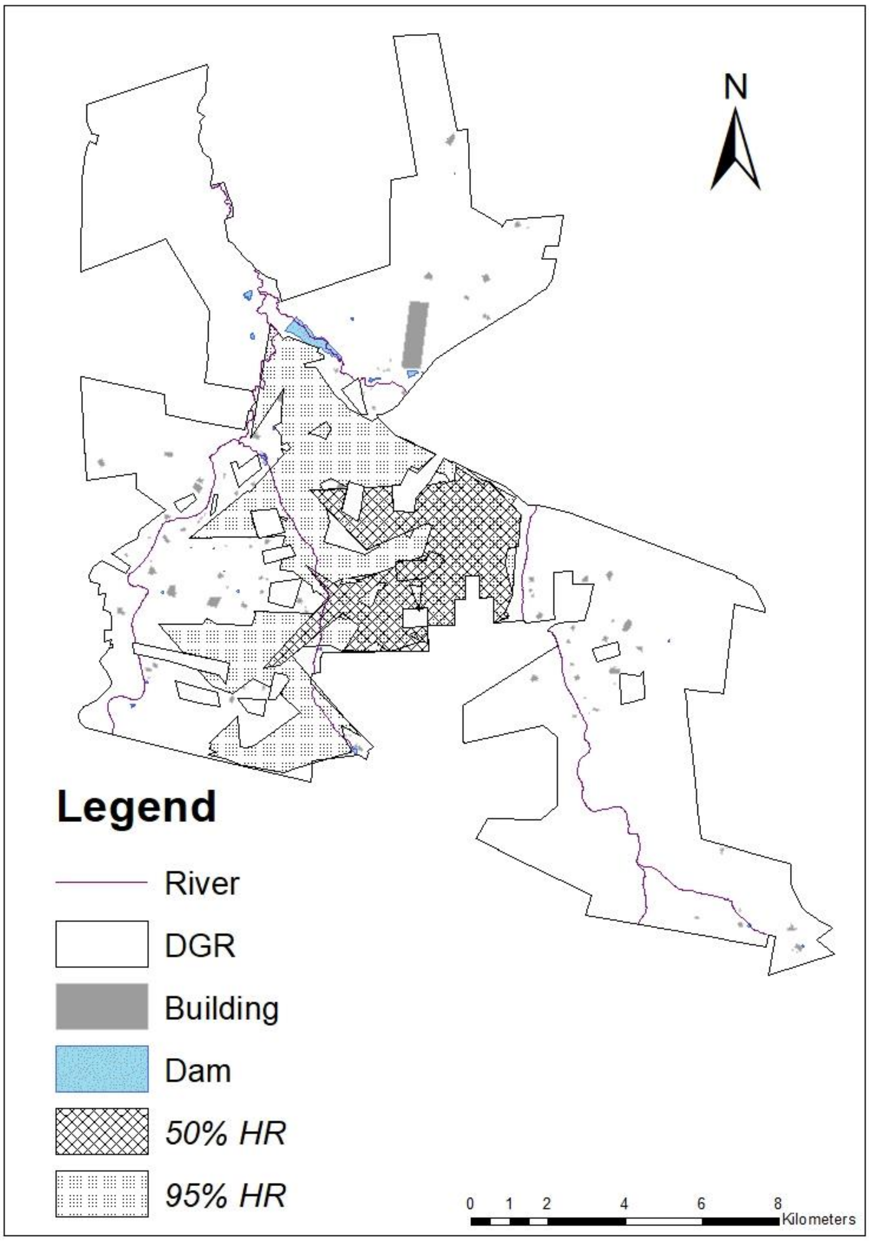


Figure 5. Total home range of the female cheetah for the entire study *(28/10/2012 - 30/04/2013)* period at Dinokeng Game Reserve. Both 95% home range and 50% core are represented.

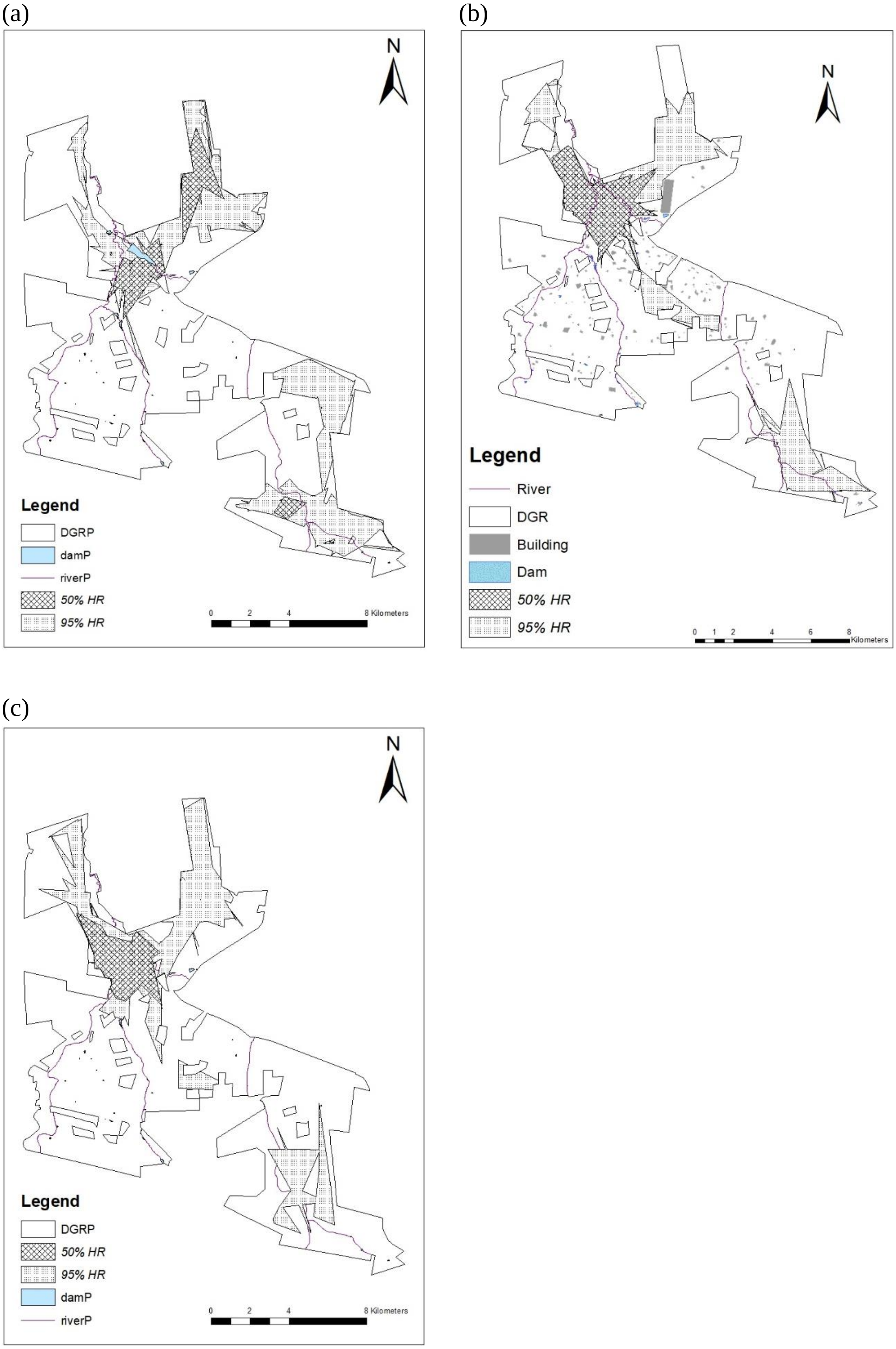


Figure 6. Seasonal home ranges established by the male cheetah in Dinokeng Game Resreve. (a) wet season (2012-2013), (b) dry season (2013) and (c) wet season (2013-2014).

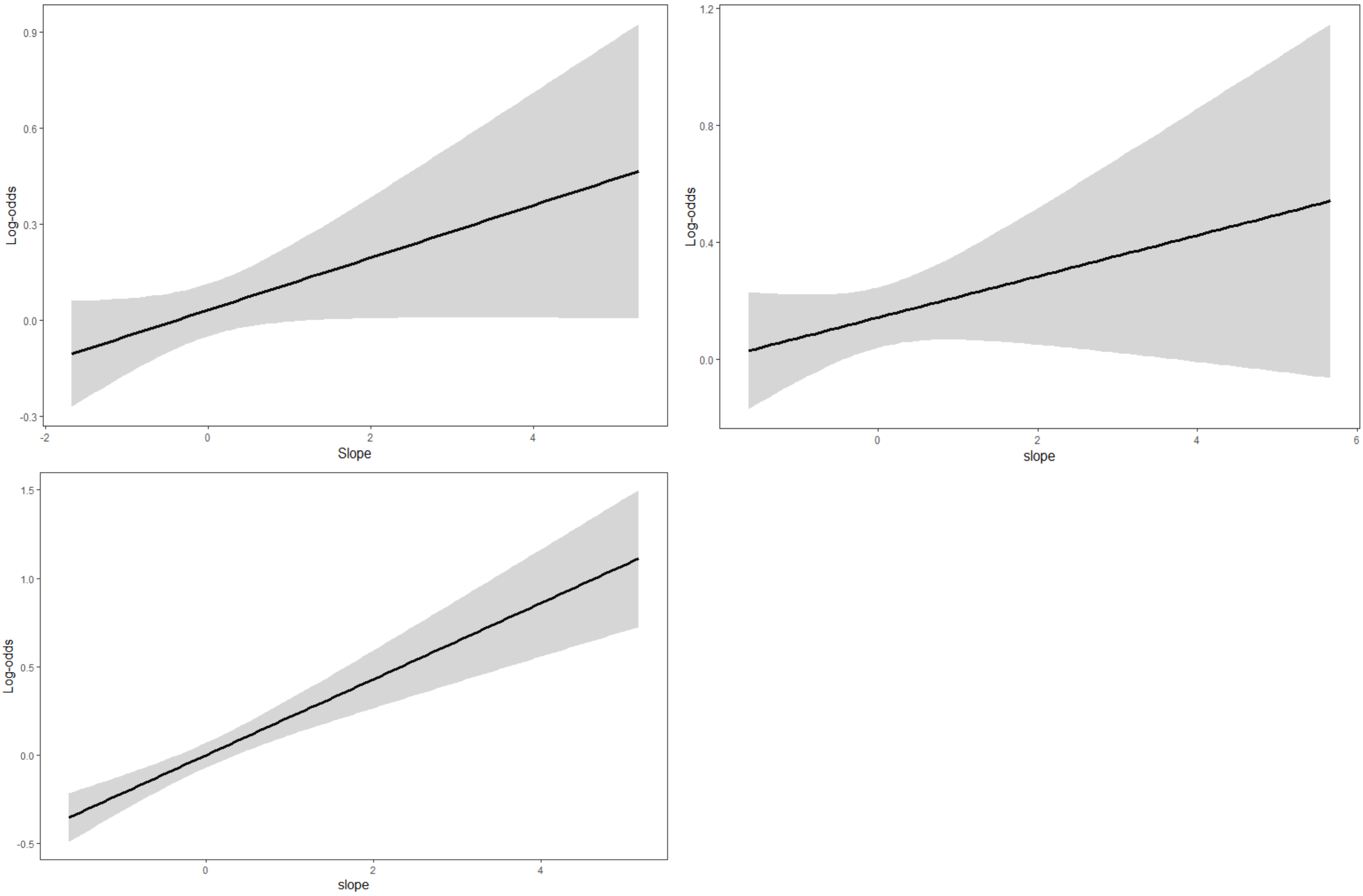


Figure 7. Regression estimates and 95% confidence intervals for resource selection functions of slope for a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season; Top right: male dry season; Bottom left: pooled male wet season.

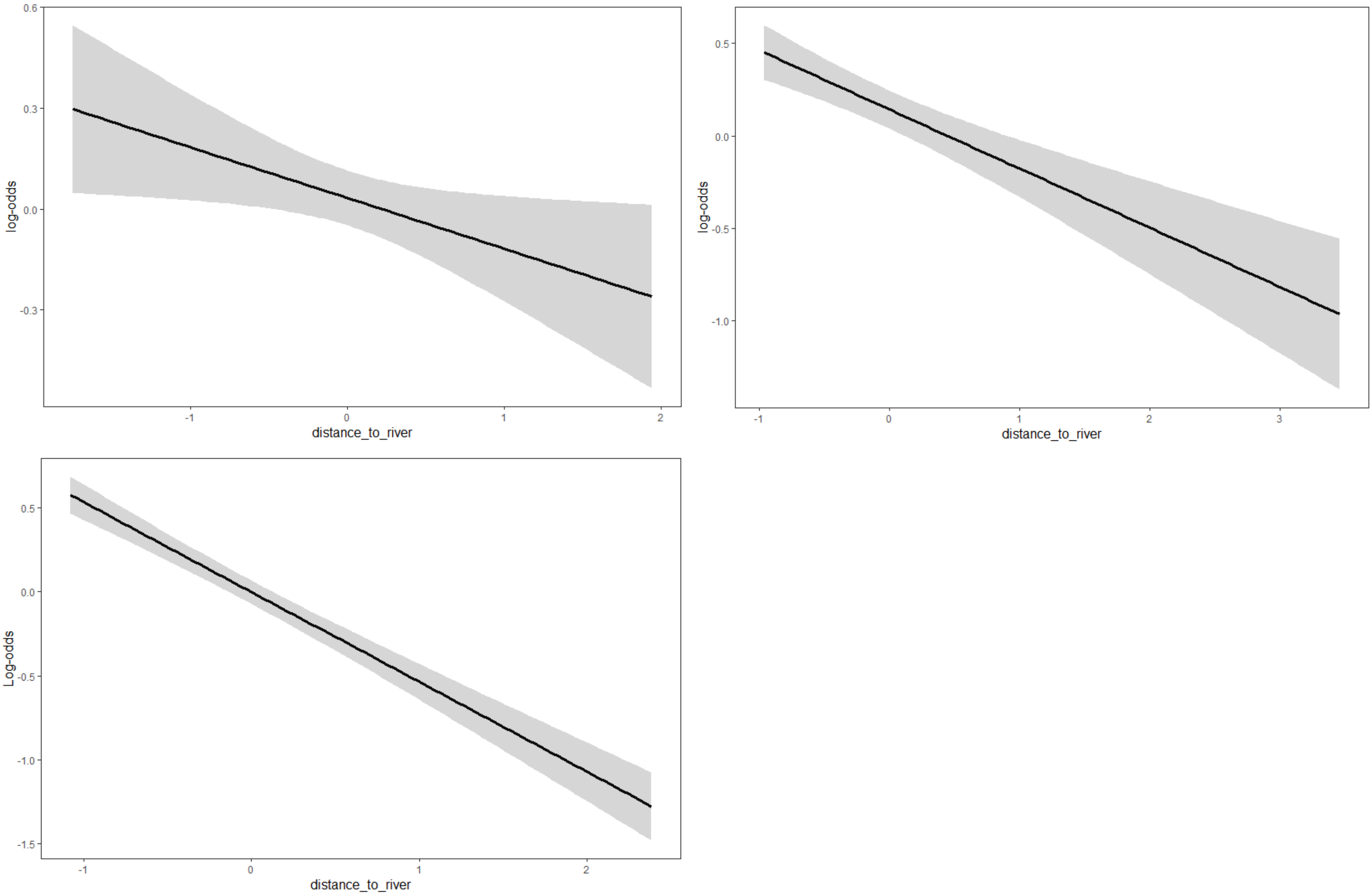


Figure 8. Regression estimates and 95% confidence intervals for resource selection functions of distance to rivers for a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season, Top right: male dry season and Bottom left: pooled male wet season.

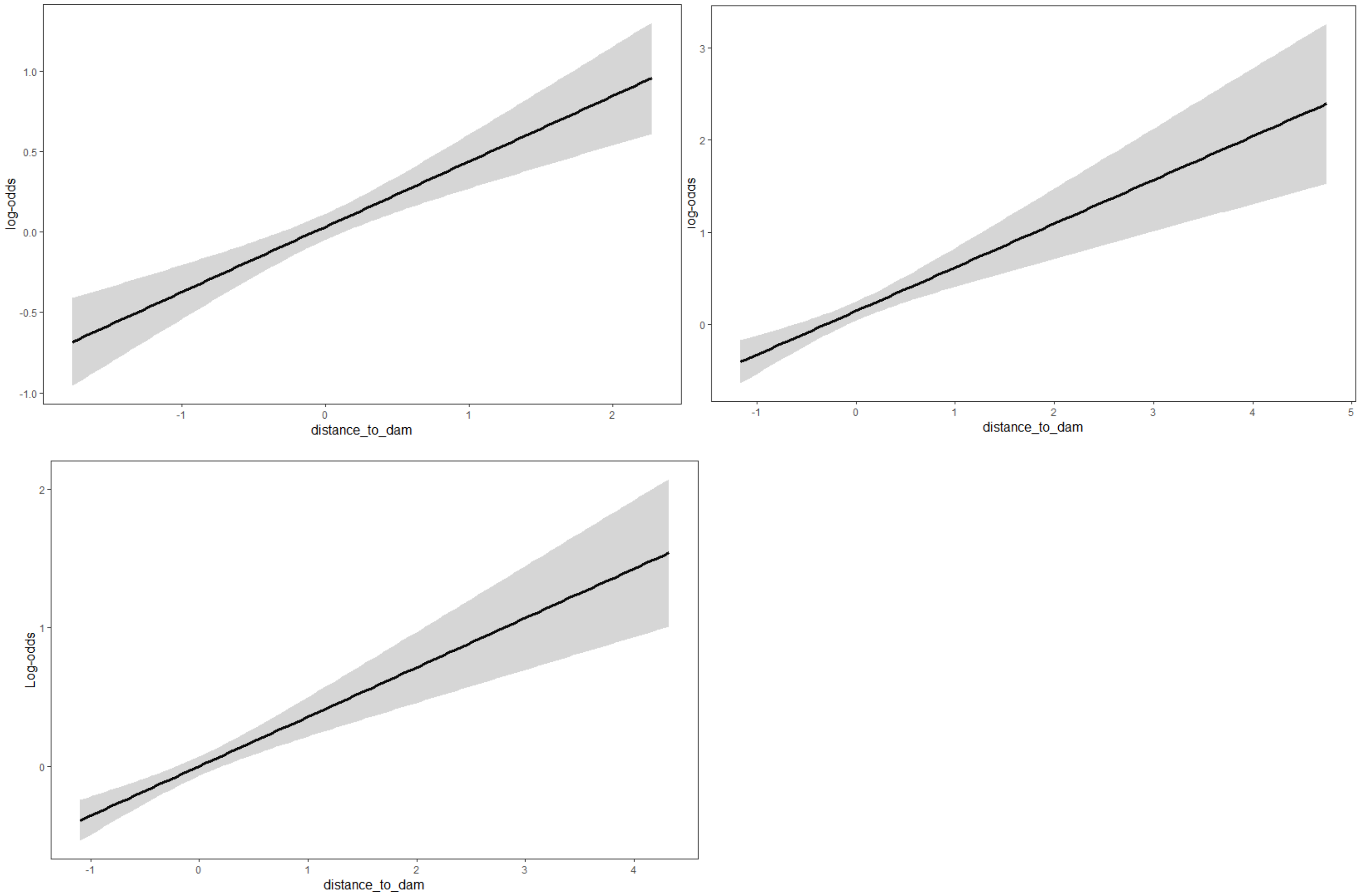


Figure 9. Regression estimates and 95% confidence intervals for resource selection functions of distance to dams for a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season, Top right: male dry season and Bottom left: pooled male wet season.

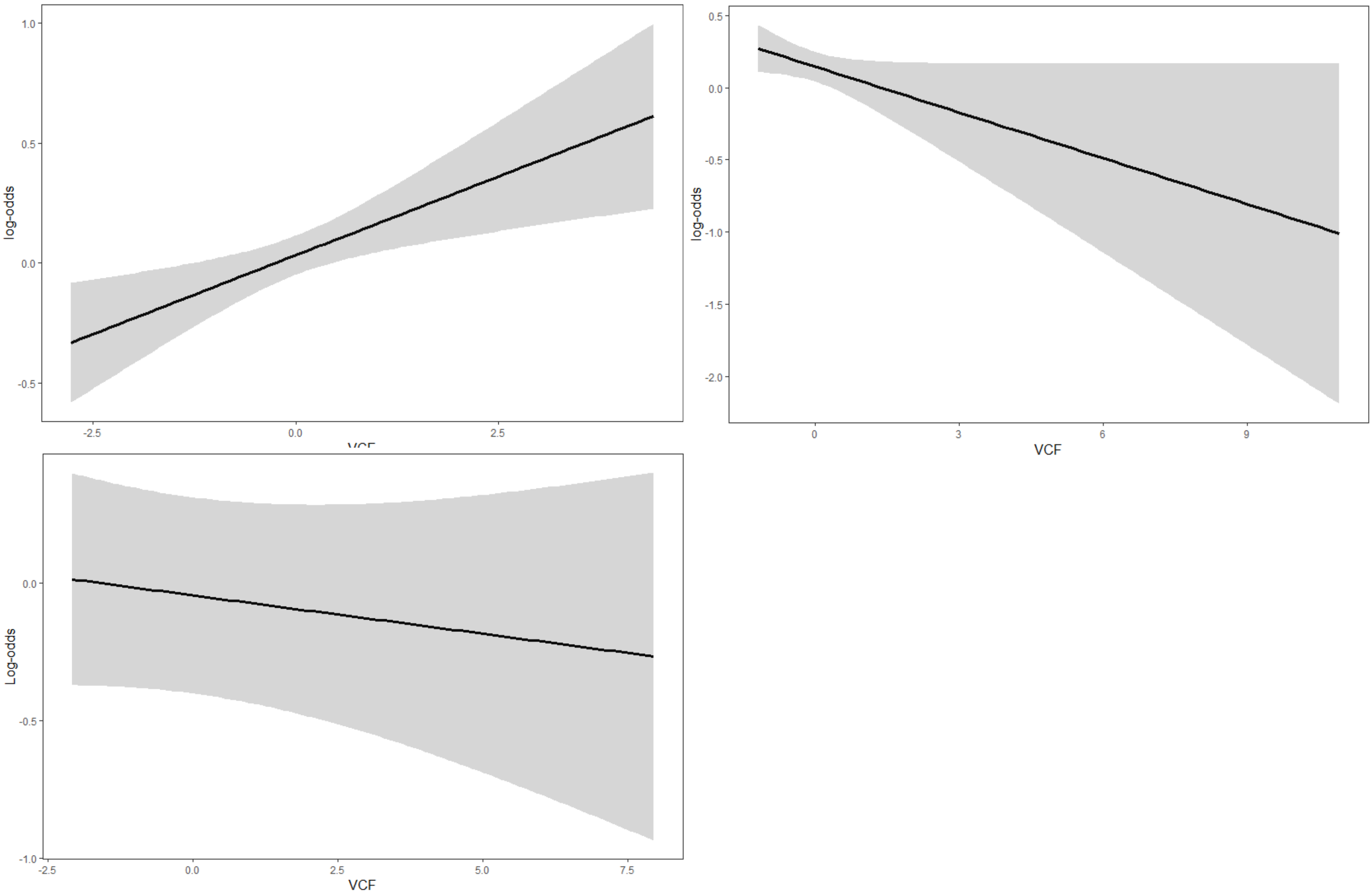


Figure 10. Regression estimates and 95% confidence intervals for resource selection functions of vegetation coverage percentages (VCF) for a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season, Top right: male dry season and Bottom left: pooled male wet season.

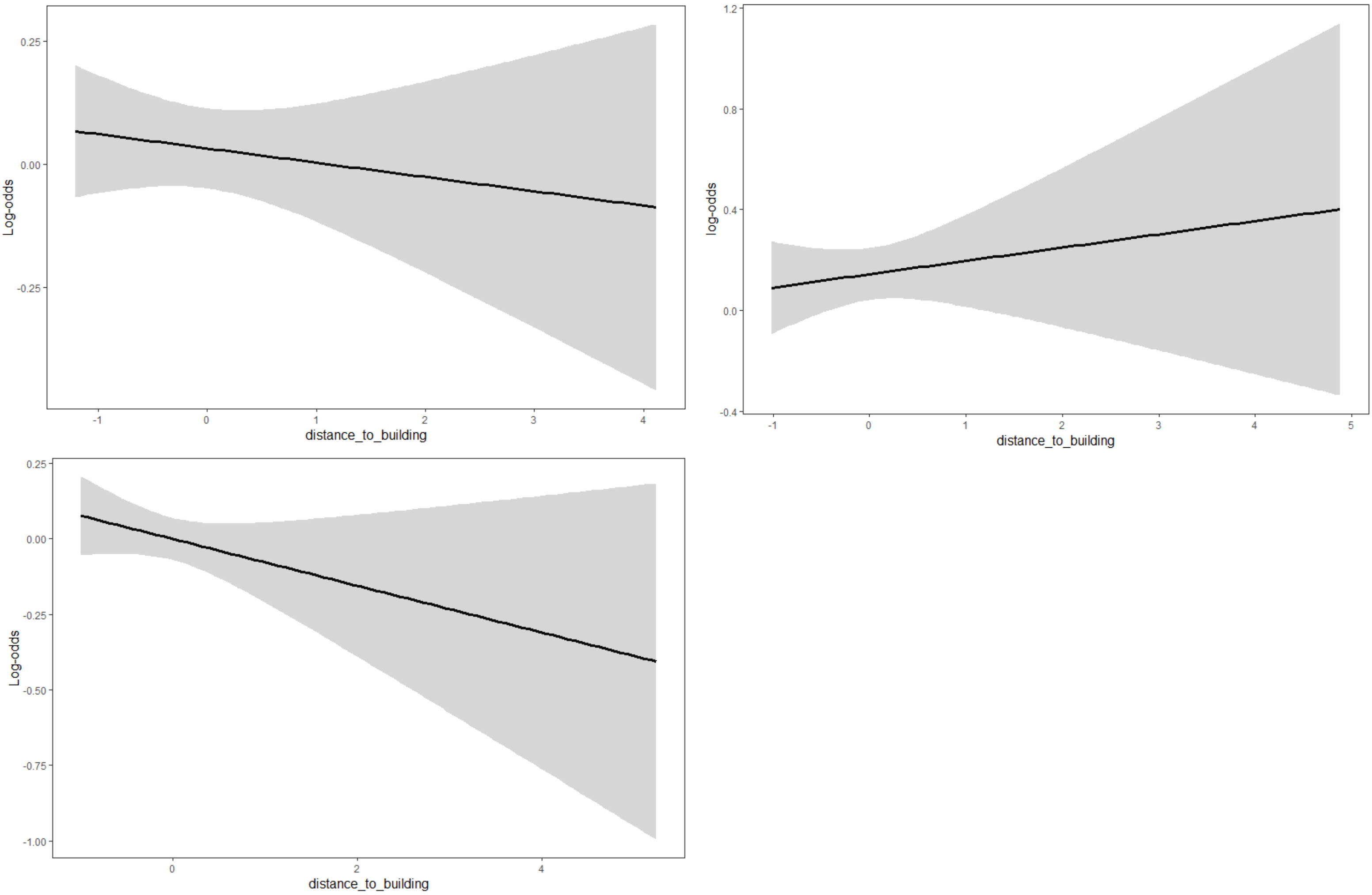


Figure 11. Regression estimates and 95% confidence intervals for resource selection functions for distance to building of a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season, Top right: male dry season and Bottom left: pooled male wet season.

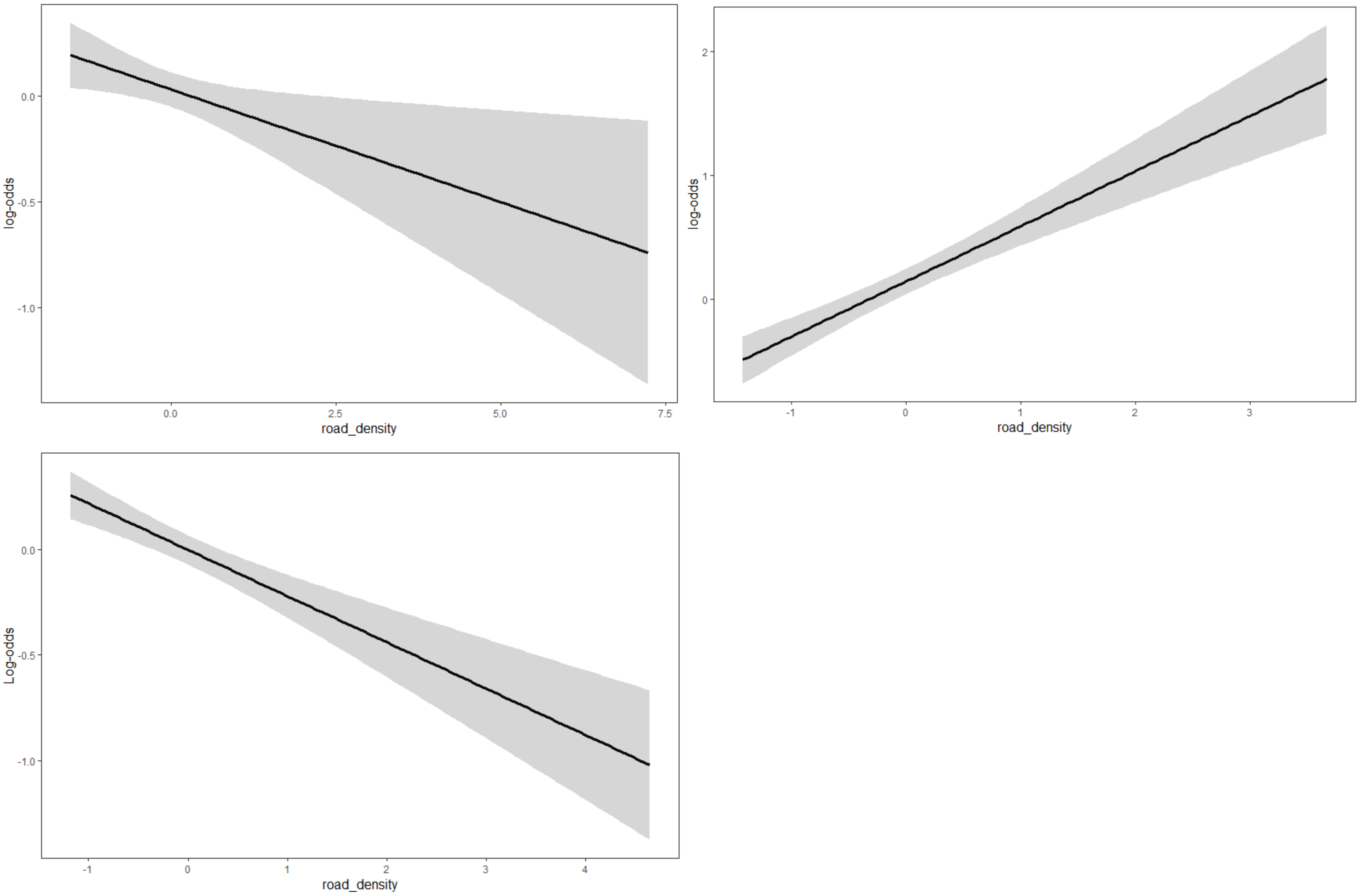


Figure 12. regression estimates and 95% confidence intervals for resource selection functions for road density of a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season, Top right: male dry season and Bottom left: pooled male wet season.

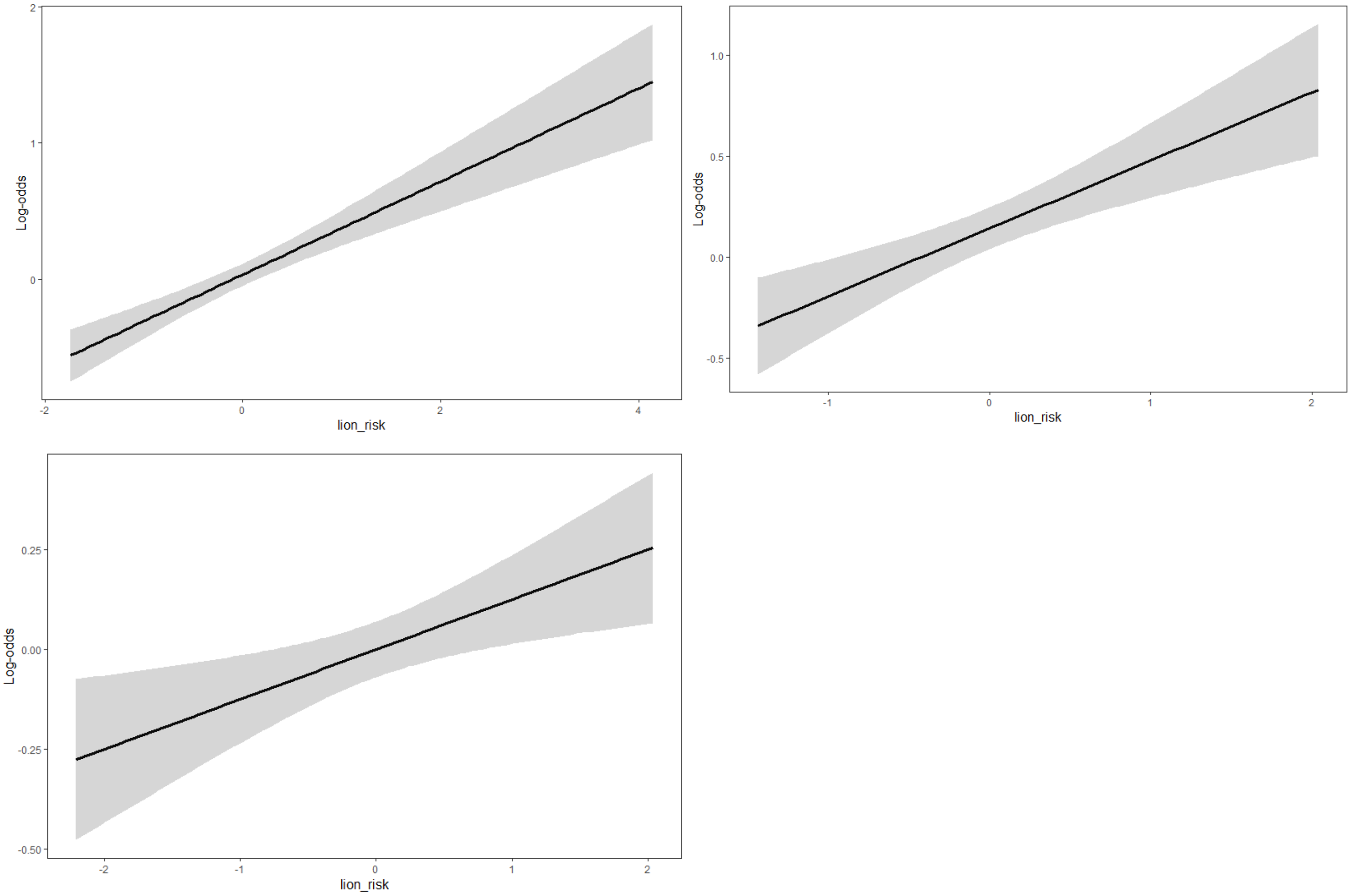


Figure 13. Regression estimates and 95% confidence intervals for resource selection functions for lion occupation probability of a male and female cheetah reintroduced into Dinokeng Game Reserve. Top left: female wet season, Top right: male dry season and Bottom left: pooled male wet season.

Appendix A

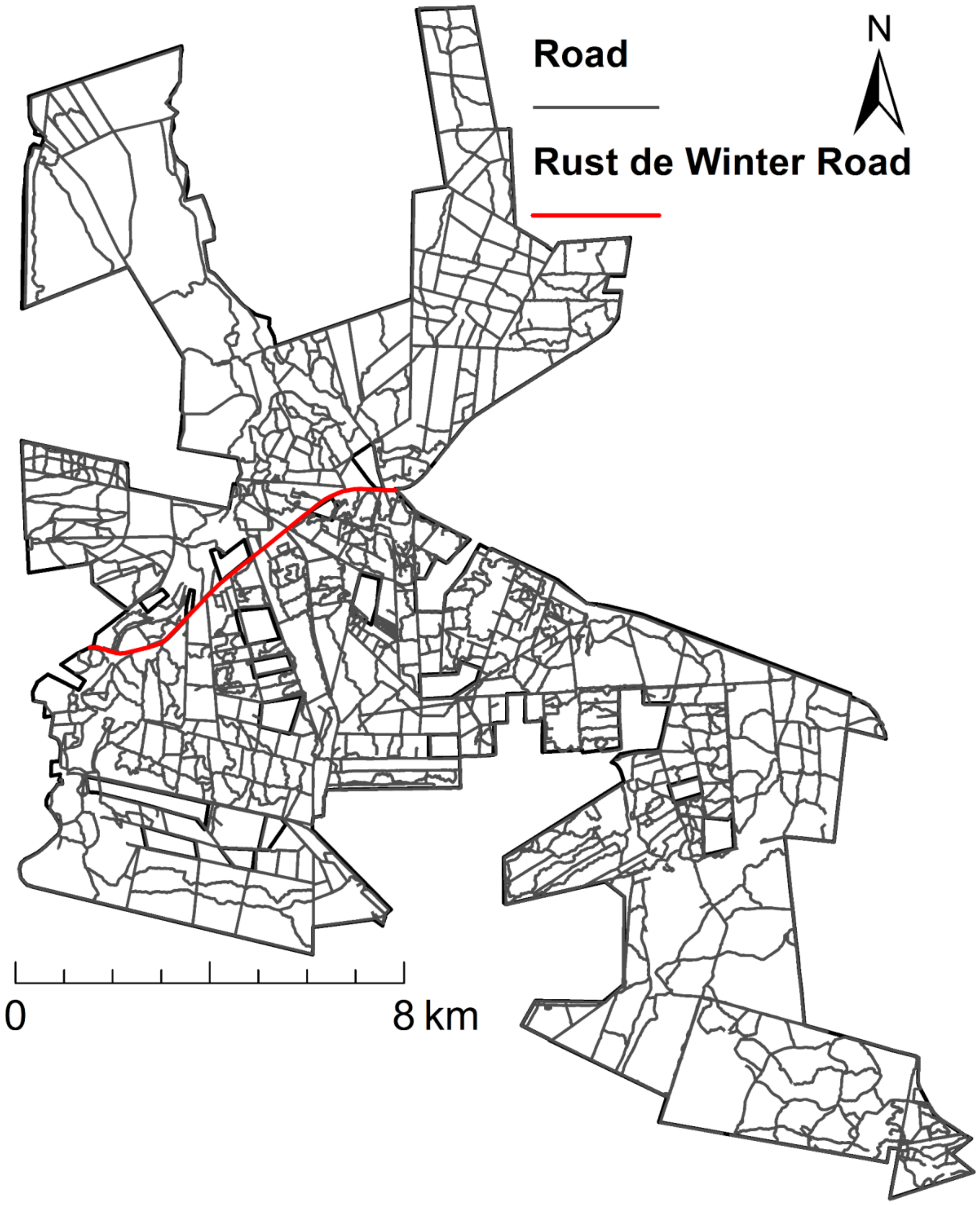


Figure A-1 Map of Road network found in Dinokeng Game Reserve. Figure adopted from Yiu, 2017.

Appendix B

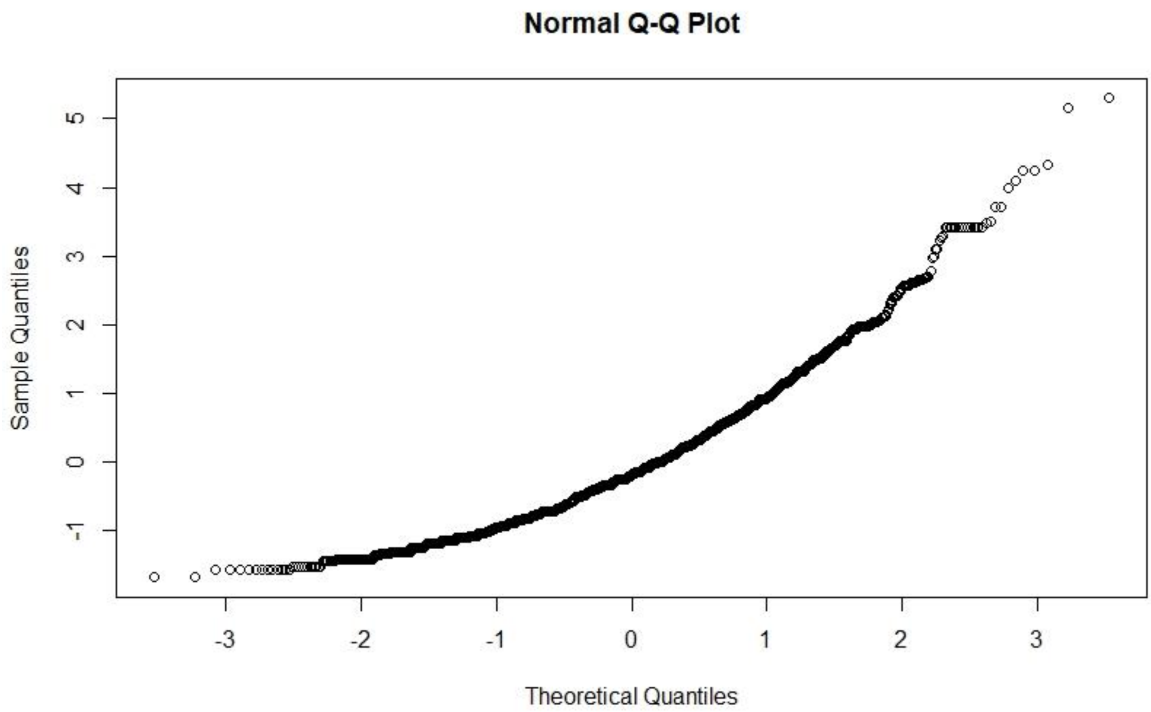


Figure B-1. Graph representing Q-Q plot for the predictive variable slope for the female cheetah. Illustrating the variables distribution.

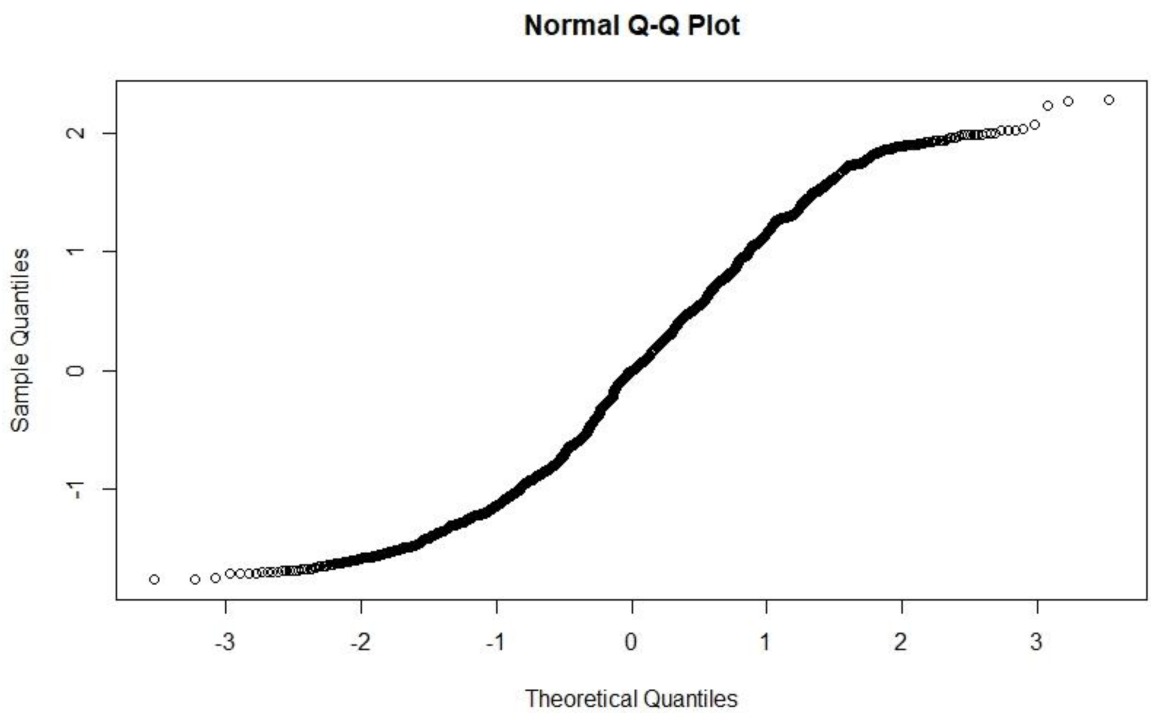


Figure B-2. Graph representing Q-Q plot for the predictive variable distance to dam for the female cheetah. Illustrating the variables distribution.

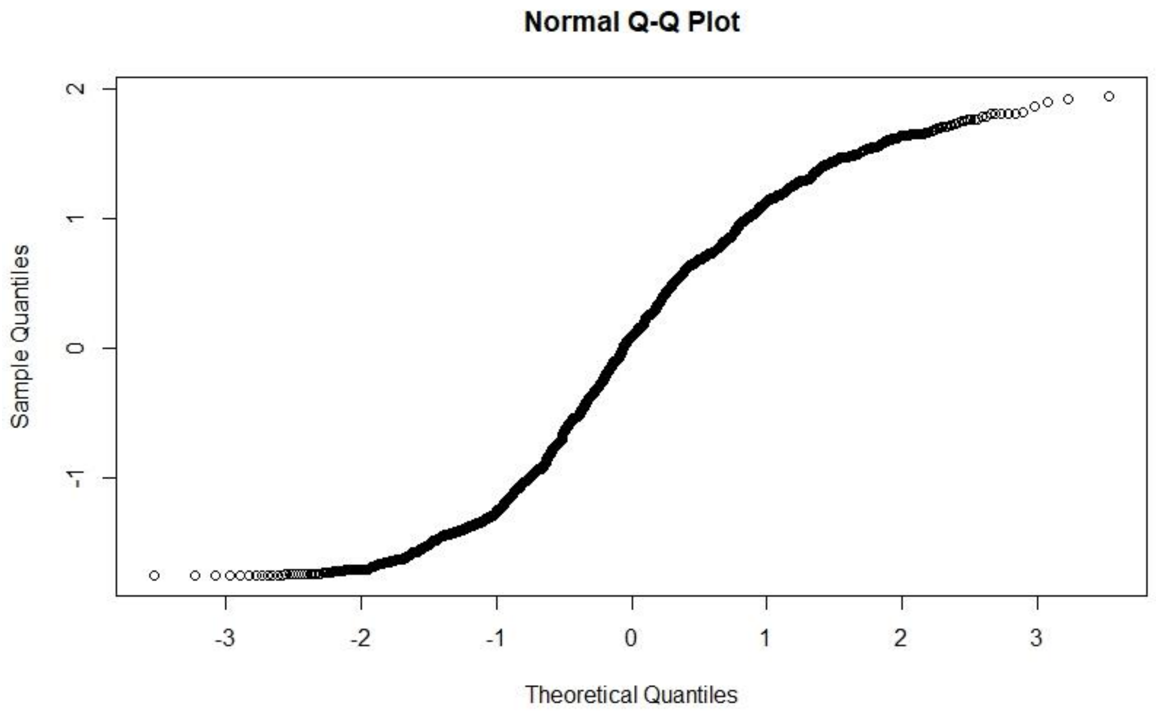


Figure B-3. Graph representing Q-Q plot for the predictive variable distance to rivers for the female cheetah. Illustrating the variables distribution.

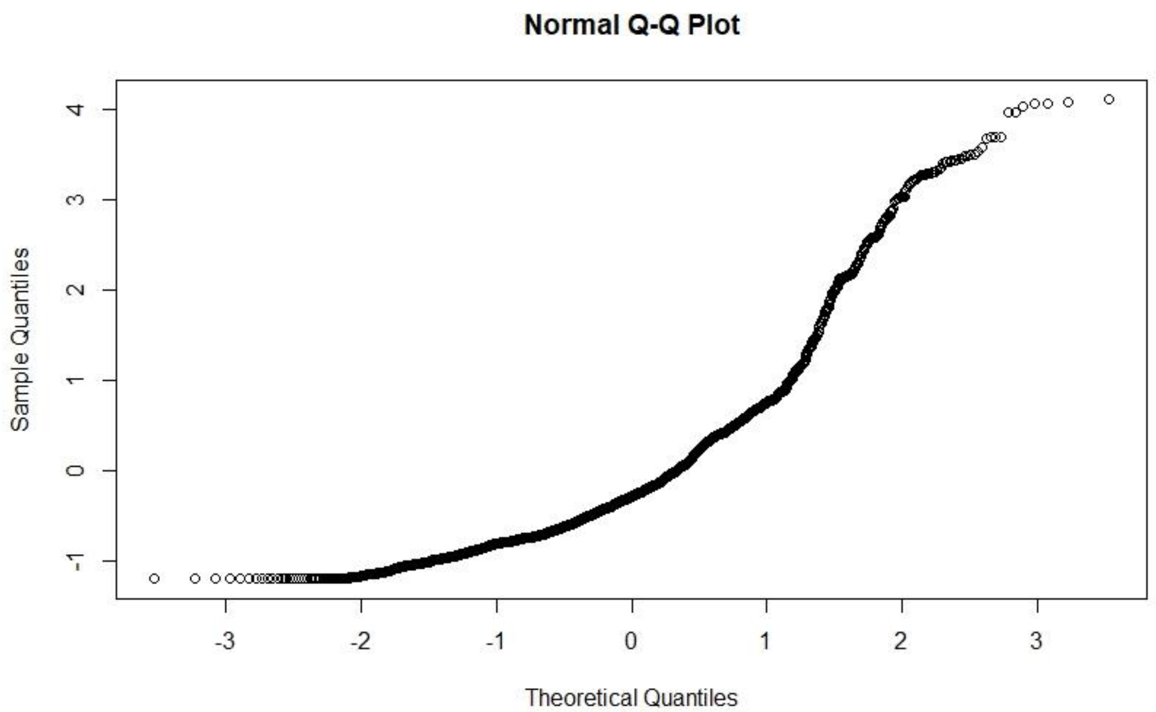


Figure B-4 Graph representing Q-Q plot for the predictive variable distance to buildings for the female cheetah. Illustrating the variables distribution.

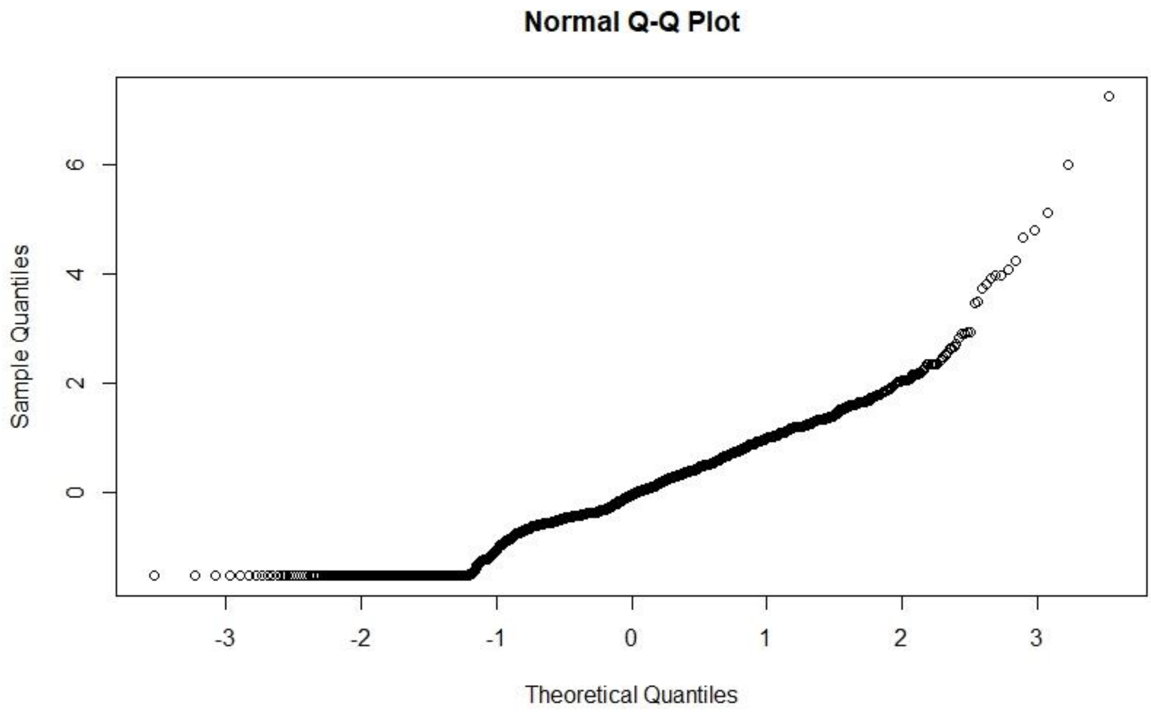


Figure B-5. Graph representing Q-Q plot for the predictive variable road density for the female cheetah. Illustrating the variables distribution.

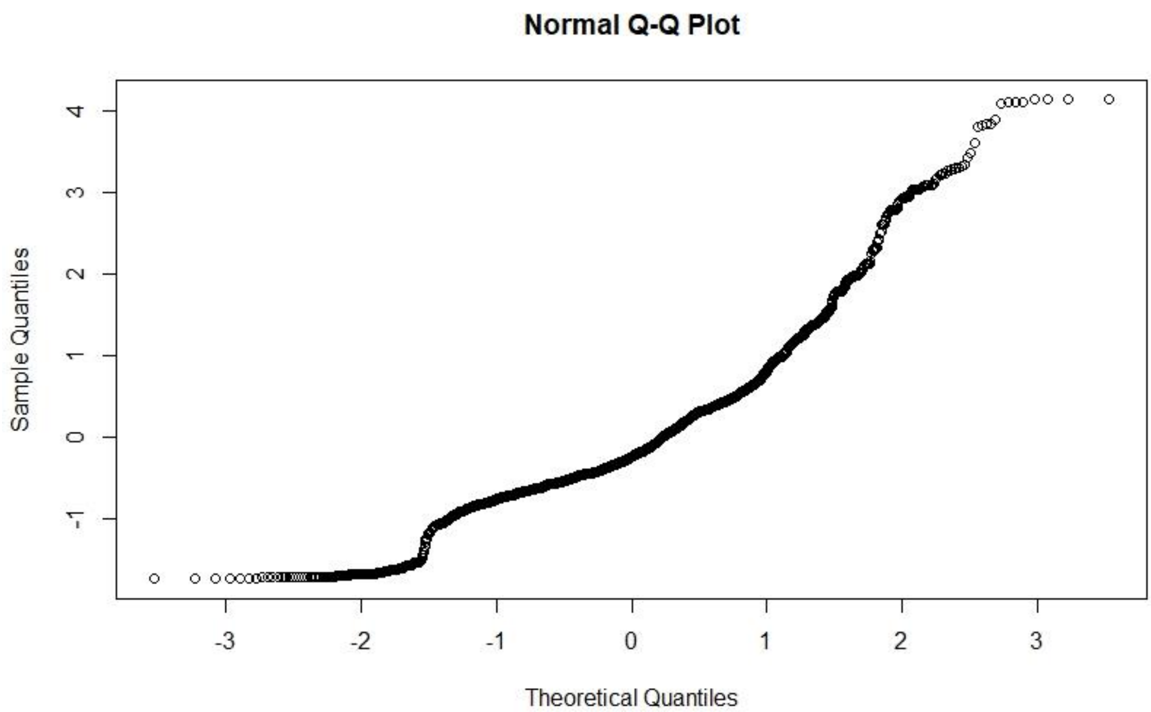


Figure B-6. Graph representing Q-Q plot for the predictive variable lion risk for the female cheetah. Illustrating the variables distribution.

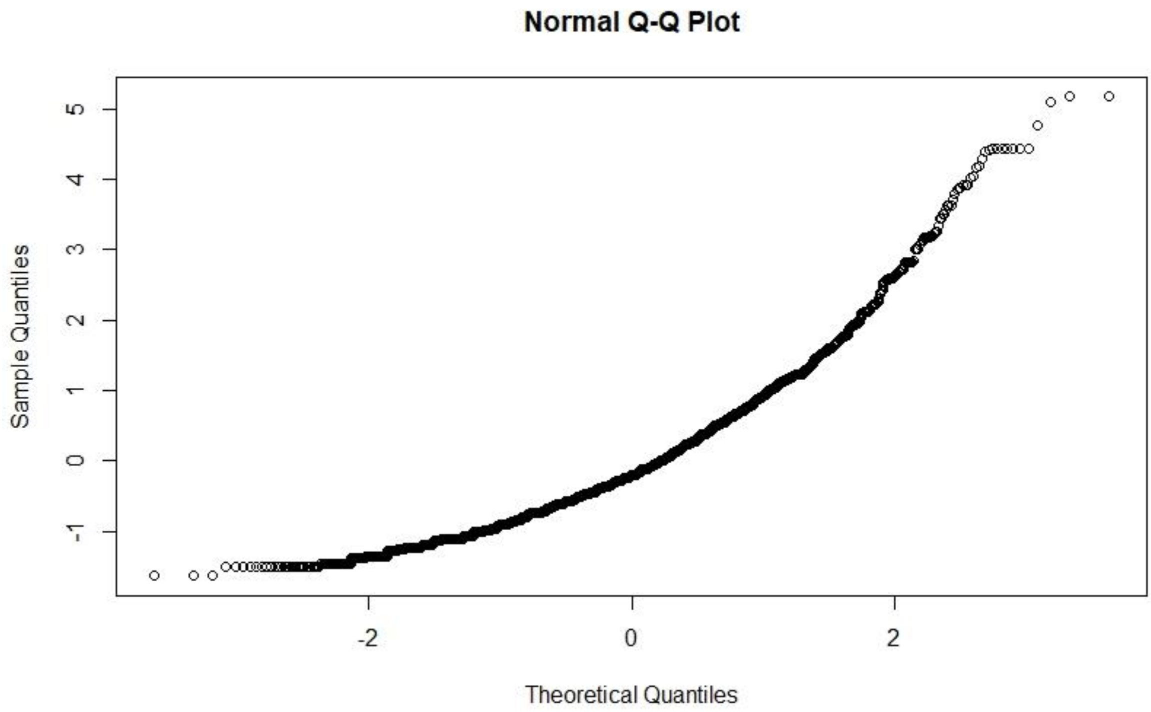


Figure B-7. Graph representing Q-Q plot for the predictive variable slope for the male cheetah in the wet season. Illustrating the variables distribution.

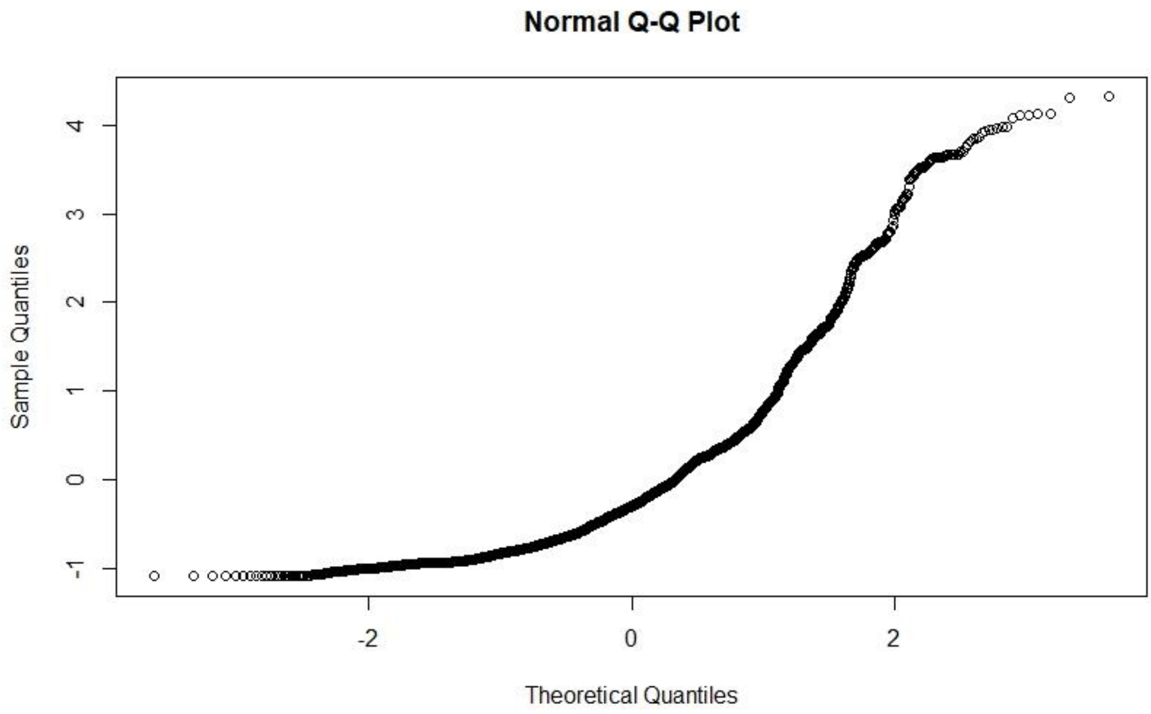


Figure B-8 Graph representing Q-Q plot for the predictive variable distance to dam for the male cheetah in the wet season. Illustrating the variables distribution.

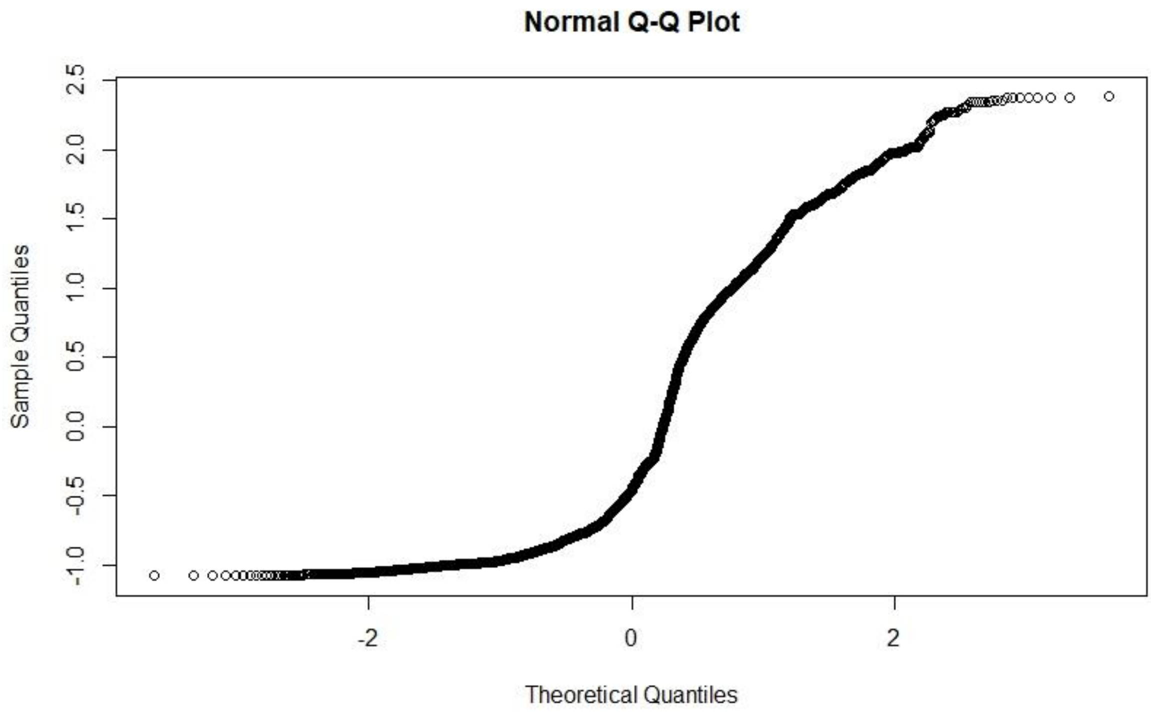


Figure B-9. Graph representing Q-Q plot for the predictive variable distance to river for the male cheetah in the wet season. Illustrating the variables distribution.

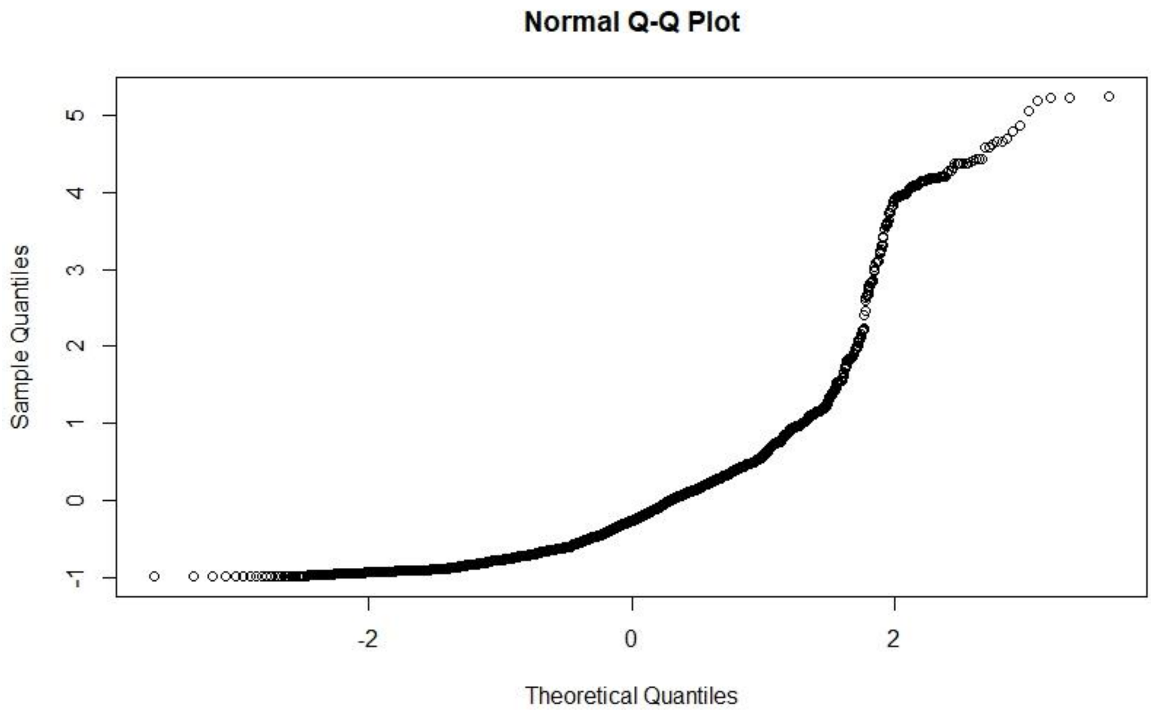


Figure B-10 Graph representing Q-Q plot for the predictive variable distance to building for the male cheetah in the wet season. Illustrating the variables distribution.

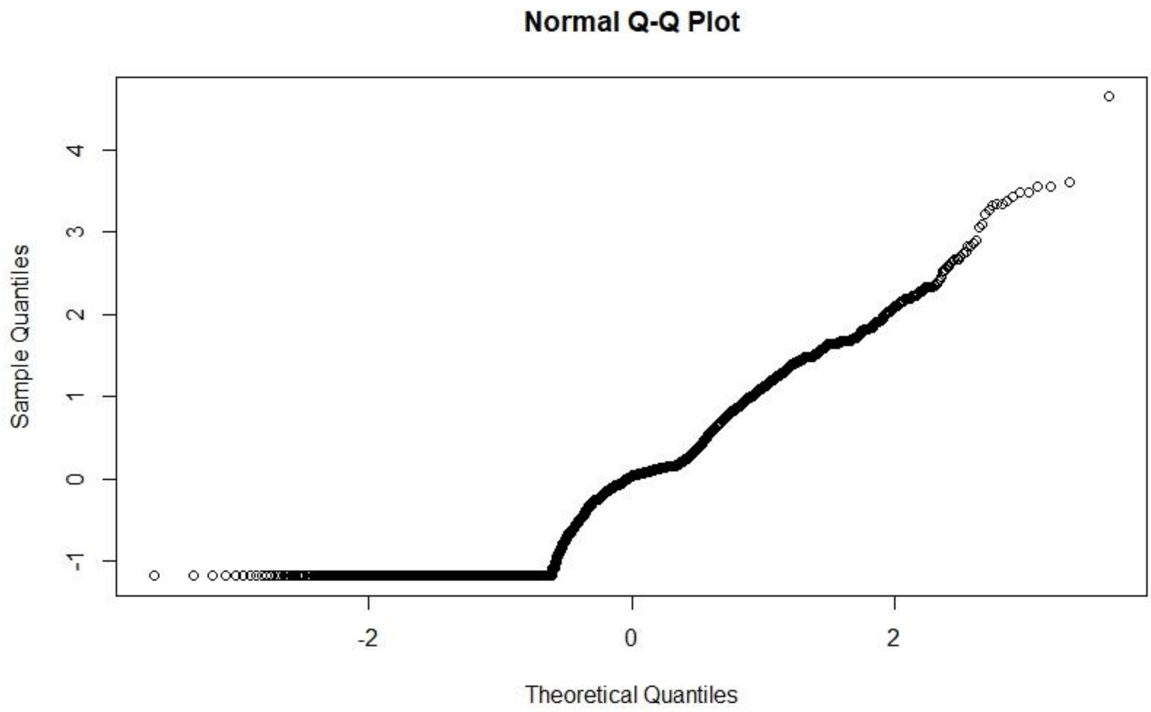


Figure B-11 Graph representing Q-Q plot for the predictive variable road density for the male cheetah in the wet season. Illustrating the variables distribution.

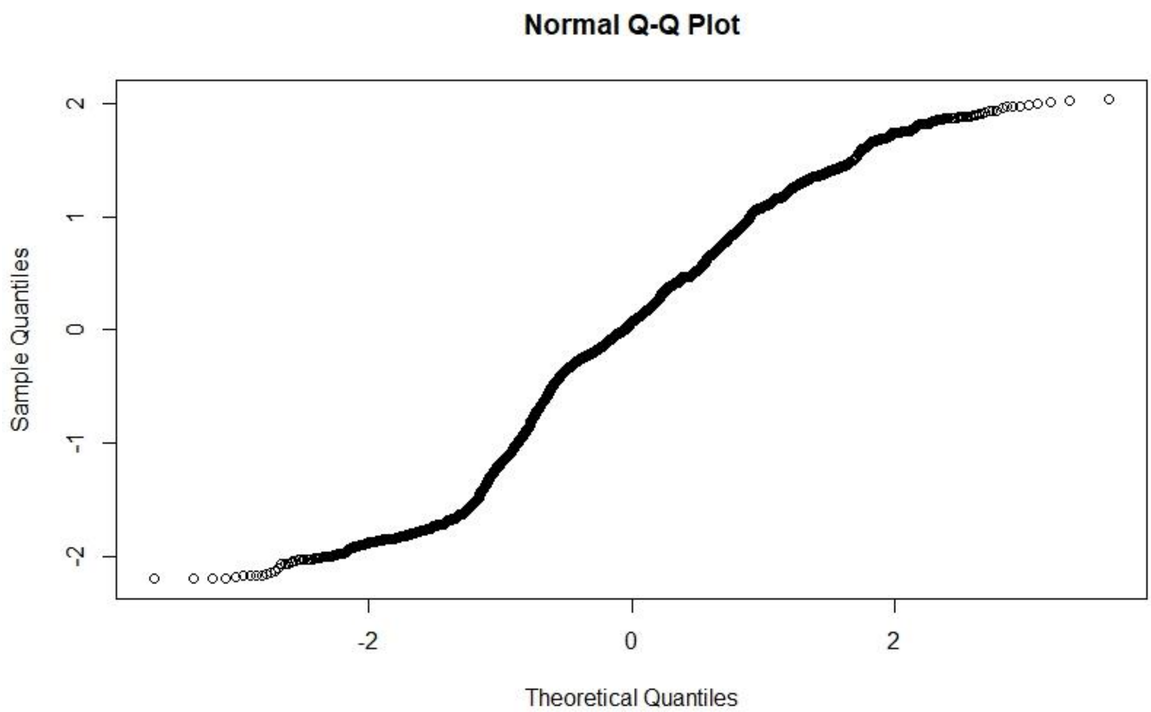


Figure B-12 Graph representing Q-Q plot for the predictive variable lion risk for the male cheetah in the wet season. Illustrating the variables distribution.

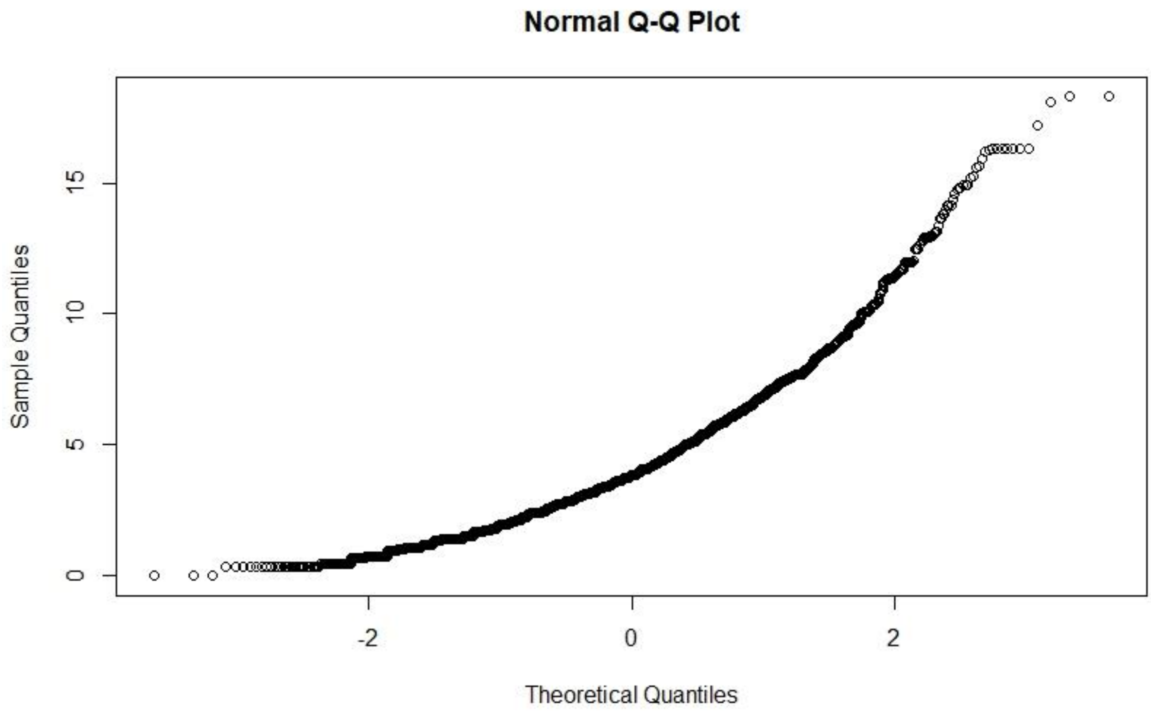


Figure B-13 Graph representing Q-Q plot for the predictive variable slope for the male cheetah in the dry season. Illustrating the variables distribution.

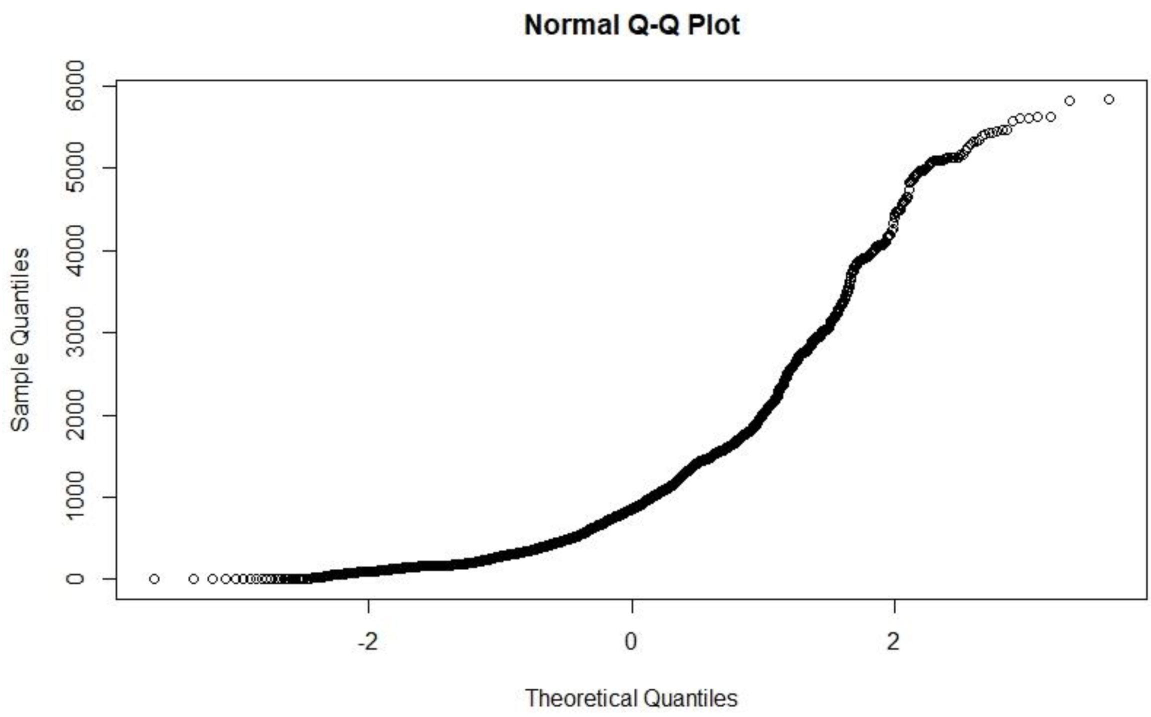


Figure B-14 Graph representing Q-Q plot for the predictive variable distance to dam for the male cheetah in the dry season. Illustrating the variables distribution.

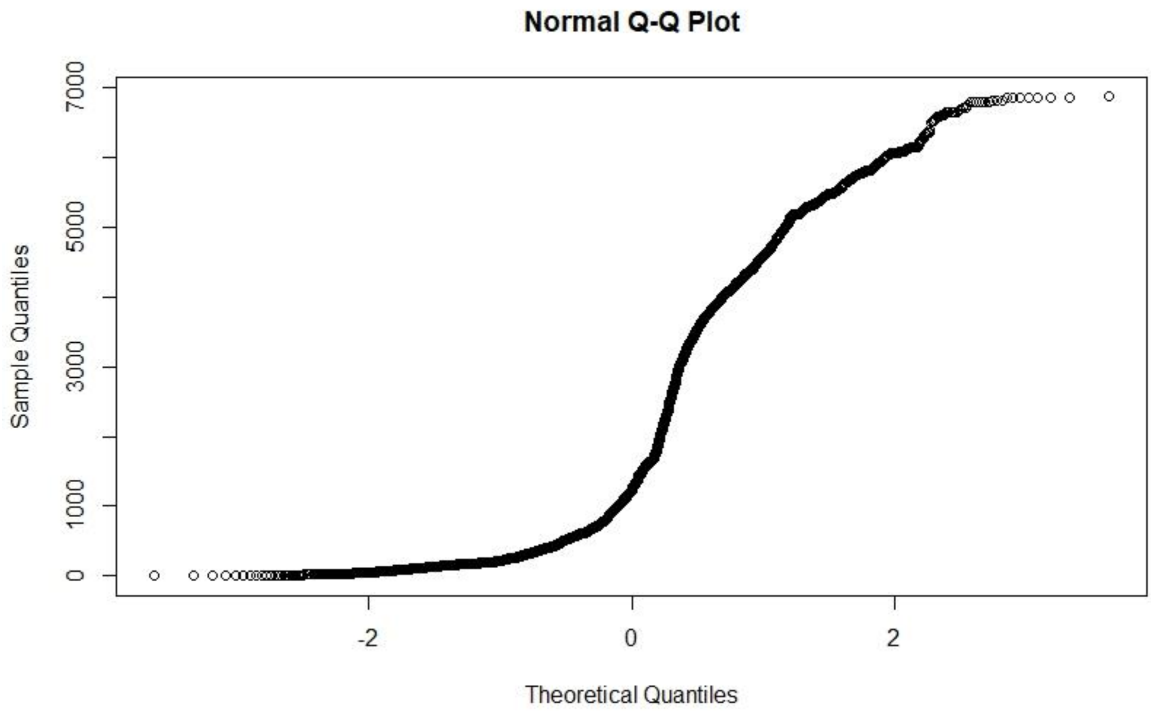


Figure B-15 Graph representing Q-Q plot for the predictive variable distance to river for the male cheetah in the dry season. Illustrating the variables distribution.

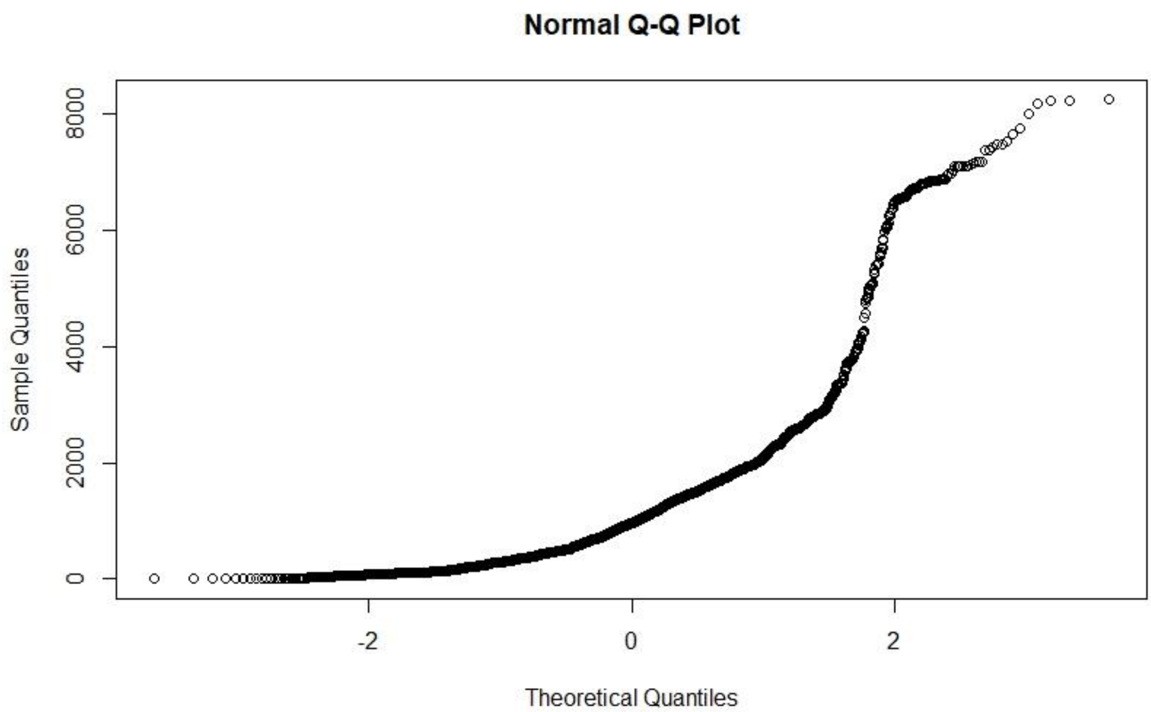


Figure B-16 Graph representing Q-Q plot for the predictive variable distance to building for the male cheetah in the dry season. Illustrating the variables distribution.

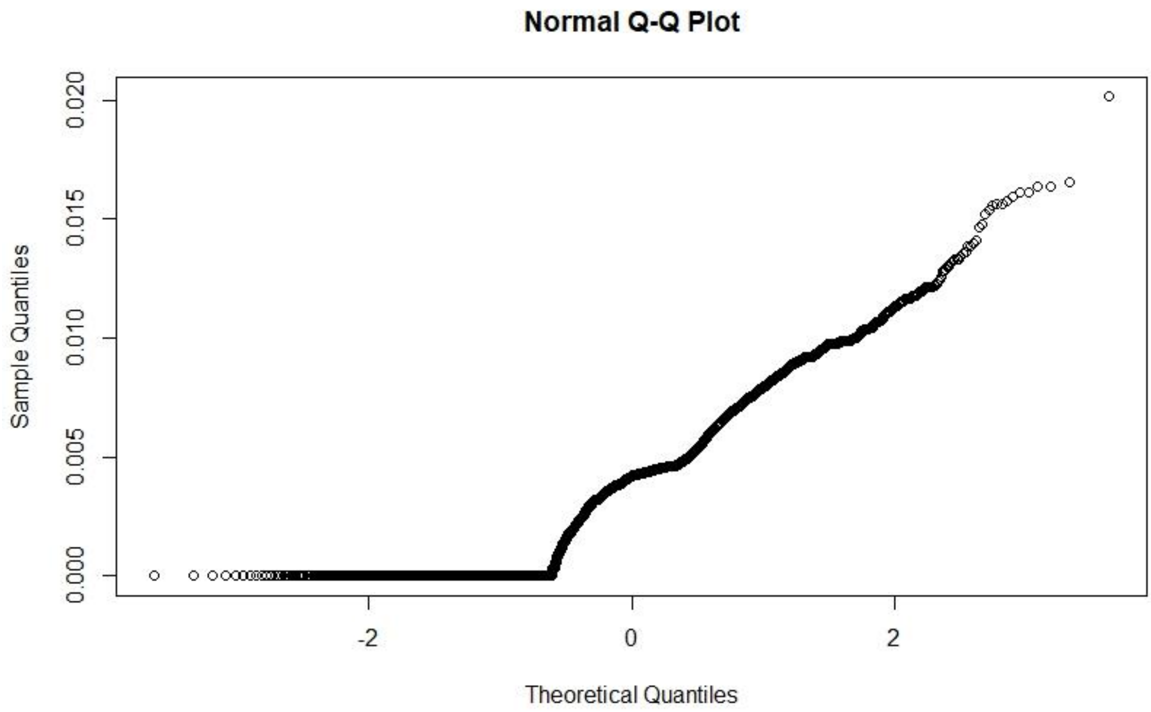


Figure B-17 Graph representing Q-Q plot for the predictive variable road density for the male cheetah in the dry season. Illustrating the variables distribution.

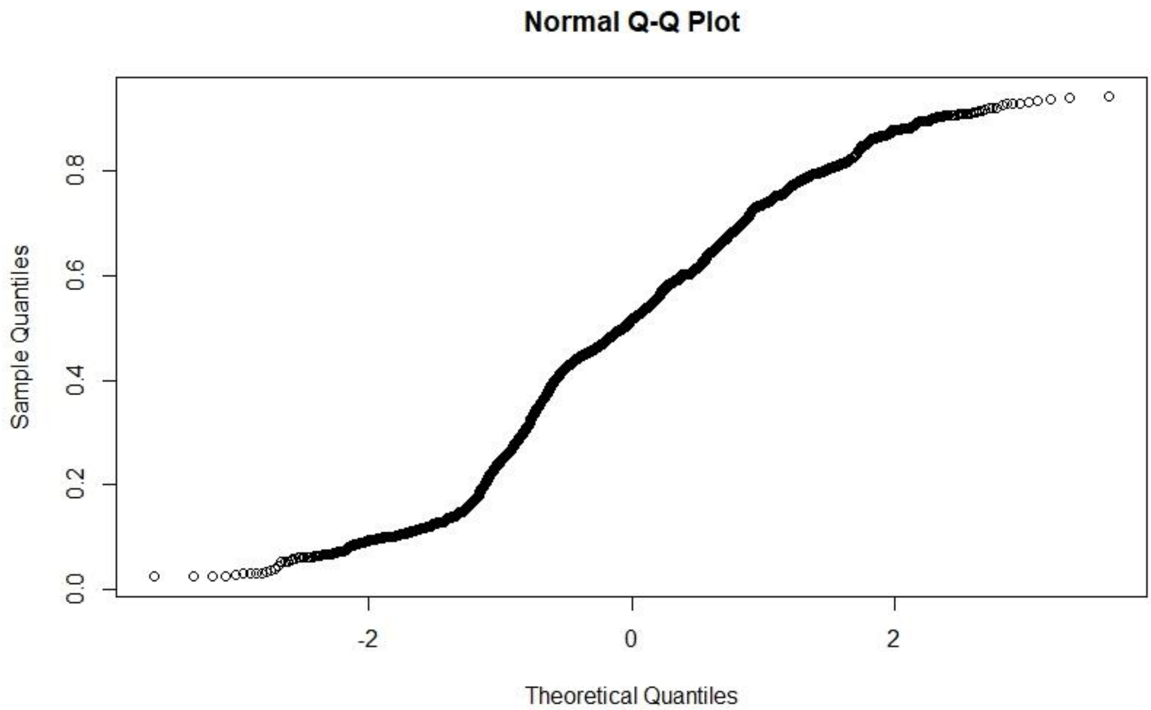


Figure B-18 Graph representing Q-Q plot for the predictive variable lion risk for the male cheetah in the dry season. Illustrating the variables distribution.