HABITAT SELECTION OF AFRICAN ELEPHANTS *(LOXODONTA AFRICANA)* AFTER REINTRODUCTION IN DINOKENG GAME RESERVE

Jeanette de Hoog

A Research Report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science

Johannesburg, May 2014

DECLARATION

I declare that this Research Report is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

(Signature of candidate)

15th day of May 2014 in Johannesburg

ABSTRACT

Conservation has led to African elephants (*Loxodonta africana)* being reintroduced to small game reserves. However, only a few studies have been done on how elephants react to their new environment after a translocation. Dinokeng Game Reserve introduced a herd of 10 elephants *(Loxodonta Africana)* in October 2011. Using Global Positioning System collar locations of one female elephant, I aimed to determine whether an elephant's exploration resulted in an expansion of its home range as the elephant settled in its new environment. Secondly, I aimed to determine how the use of resources and conditions in an elephant's environment changed from release to the end of the study period. To achieve my first objective, I calculated the elephant's daily distance movement distances and home ranges over 16-day and seasonal periods. I used logistic regression to assess the habitat selection of the elephant over the study period. The results of the research demonstrated that the elephant slowly explored its new environment, which resulted in an expansion of its home range over time. However, it took almost two years before the elephant displayed signs of settling in its home range. The elephant used habitats further away from buildings, closer to fence boundaries and water sources, with low elevation and high greenness at the start of the study. Over time, the elephant's habitat selection was no longer constrained by buildings and it demonstrated stronger evidence of using habitats with lower elevation towards the end of the study period. The findings suggest that elephants do not necessarily explore extensively before finding an area to remain in, and it may take longer than a year for them to settle. Furthermore, human settlements seem to limit elephant's habitat selection a translocation, but this influence decreases as the elephant settles in its new environment.

Keywords: elephant, translocation, exploration, movement, habitat selection, habitat use

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1 INTRODUCTION

Human activities have resulted in animals being translocated to new environments for conservation purposes (Stamps & Swaisgood 2007), with many translocations and reintroductions taking place in small, isolated and fenced game reserves in South Africa (Slotow & van Dyk 2004). Dinokeng Game Reserve (DGR) introduced a herd of 10 elephants *(Loxodonta africana)* into the reserve on the 26th October 2011 (Dinokeng 2013). The elephants were translocated from Makalali Game Reserve, which is near Hoedspruit in the Limpopo Province (Dinokeng 2013). After release, the elephants did not explore the reserve as expected, based on previously published research; rather they moved to a small area in the northern part of the reserve, where they have remained for the past 18 months. This raises the question of how reintroduced elephants react to their new environment, as well as which resources and conditions are preferred by elephants in selecting a habitat that will ensure the establishment of a sustainable population. Understanding how animals react to a new environment and why, is important in ensuring the translocated animals' welfare, as well as in improving management actions of translocation programmes (Pinter-Wollman 2009; Scillitani *et al.* 2013; Slotow & van Dyk 2004).

Post-release monitoring is used to determine whether the animals are adjusting to their new environment (Grobler *et al.* 2008; Pinter-Wollman, Isbell & Hart 2009; Scillitani *et al.* 2013; Stamps & Swaisgood 2007). Globally, the results of post-release monitoring of translocated elephants have only been published for five studies (Fernando *et al.* 2012). These studies have mainly focused on the spatial behaviour after release of the elephants (Fernando *et al.* 2012; Pinter-Wollman 2009; Roy *et al.* 2010; Slotow & van Dyk 2004; Stüwe *et al.* 1998).

Translocated African elephants *(Loxodonta africana)* in Pilansberg National Park (PNP) in South Africa all displayed exploratory behaviour after release, but the extent of exploration and the size of their initial home range differed according to each elephant (Slotow & van Dyk 2004). Exploration was indicated by the elephant's movement paths and their home ranges (Slotow & van Dyk 2004). The core home range sizes varied from 3-23 km^2, whilst the total home ranges varied from 24-139 km^2 (Slotow & van Dyk 2004). African elephants *(Loxodonta africana)* translocated to Tsavo East National Park in Kenya had minimum convex polygon (MCP) home ranges varying from 322.9-2492.1 km^2 (Pinter-Wollman 2009). Some of these elephants homed to their natal habitats (Pinter-Wollman 2009). The elephants that did not home were found to explore less when near human activities (Pinter-Wollman 2009). In Malaysia, a translocated female Asian elephant *(Elephas maximus)* had moved within a range of 7000 km^2 within a year post-release, whilst six months post-release, the translocated male elephant moved within a 350 km^2 range (Stüwe *et al.* 1998). An Asian elephant *(Elephas maximus)* was translocated due to human-elephant conflict in India (Roy *et al.* 2010). Five months after release, the elephant had established a MCP home range of 95.75 km^2 (Roy *et al.* 2010). Asian elephants *(Elephas maximus)* were translocated to national parks in Sri Lanka as part of human-elephant conflict resolution (Fernando *et al.* 2012). After release, these elephants showed increased ranging, and either returned to their original site, wandered around or settled in a new site (Fernando *et al.* 2012). These elephants had MCP home ranges that varied between 60.4-4380.4 km^2 (Fernando *et al.* 2012).

A common finding in elephant translocation studies is that these elephants either remain in the new environment or try to return to their source site (Fernando *et al.* 2012; Pinter-Wollman 2009). If the elephants settle in the new environment, learned behaviours and feeding strategies from the elephants' previous environment may not be transferrable (Stamps & Swaisgood 2007). Therefore, to gain knowledge of a new environment with no local population, exploration is necessary (Pinter-Wollman 2009; Ryckman *et al.* 2009; Stamps 2001). Exploratory movements are considered as movements out of an animal's range that allow the animal to gain knowledge of their new environment (Hutto 1985; Pinter-Wollman 2009; Scillitani *et al.* 2013).

Habitat selection provides insight into the behaviour of translocated animals, which may assist in improving translocation success (Scillitani *et al.* 2013; Stamps & Swaisgood 2007). Hutto (1985) defines habitat selection as a result of the following processes: cues from their geographical area, innate instructions genetically passed on of which habitats to use or avoid, previous experience, or settling based on ranking of habitats through exploration. The elephant in this study had been translocated from its original geographic range; therefore, it had no previous knowledge of the area.

To understand habitat selection after translocation, ecosystem components must be assessed (Boettiger *et al.* 2011; Roever, van Aarde & Leggett 2012). Abiotic ecosystem components that are suspected or known to affect elephant habitat selection include vegetation structure and greenness, water, slope and human associated factors, such as roads, fences and settlements (Boettiger *et al.* 2011; Roever, van Aarde & Leggett 2012). As a general rule, elephants use habitats near to water, with high vegetation cover, away from human settlements (Harris *et al.* 2008) and with low slopes (Roever, van Aarde & Leggett 2012; Wall, Douglas-Hamilton & Vollrath 2006).

The availability of foraging resources is thought to influence habitat selection in new environments (Anderson *et al.* 2005; Ryckman *et al.* 2009; Scillitani *et al.* 2013). The influence of foraging resources on elephant habitat use and movement patterns is increasingly being investigated with the use of remote sensing imagery, such as the Normalized Difference Vegetation Index (NDVI) (Boettiger *et al.* 2011; Marshal *et al.* 2011; Young, Ferriera & van Aarde 2009). Although areas with high NDVI values most likely have high forage abundance and quality, previous research suggests that elephant movements are not always specifically directed to high NDVI areas (Boettiger *et al.* 2011; Marshal *et al.* 2011; Young, Ferriera & van Aarde 2009).

Human associated factors have been used as predictors for the habitat selection of elephants (Harris *et al.* 2008; Roever, van Aarde & Leggett 2012). Various elephant populations have been found to avoid human settlements (Harris *et al.* 2008), whilst translocated elephants in Kenya explored less when there were more human disturbances in an area (Pinter-Wollman 2009). Elephants in the PNP displayed a negative response to fences by increasing their daily travel distances when moving in areas near fences, which may have been further escalated by electrified fences and human activities increasing outside fences (Vanak, Thaker & Slotow 2010). Elephants' responses to roads vary, especially in areas where roads are near water sources (Pinter-Wollman 2009; Roever, van Aarde & Leggett 2012). Considering the effect that human disturbances can have on elephants, it is important to consider the effect of human disturbances after a translocation (Pinter-Wollman 2009).

The studies that have been done on elephant translocations focus on spatial behaviour after release. Only one study (Slotow & van Dyk 2004) has focused on how the home ranges have changed during various times in the study period. Habitat selection of translocated elephants from release to settlement still requires more research. Therefore, this study provides more information on the exploration, home ranges and habitat selection of a translocated elephant as it settled into its new environment. This research will contribute towards better understanding elephant translocations, and improving management actions after the release of translocated elephants.

My first objective was to determine whether an elephant's exploration resulted in an expansion of its home range as the elephant settled in its new environment. I expect that after release from the boma, the elephant explores until it finds an area with sufficient resources. I then expect the elephant to remain in this localised area until it has to start exploring again to find more resources. As the elephant explores, it becomes more familiar with its new environment. Over time, the elephant's exploration and ranging limits increase until it has settled in its new environment.

My second objective was to determine how the use of resources and conditions in an elephant's environment changed from release to the end of the study period. I expect that after release from the boma, the elephant avoids humans; therefore factors associated with human disturbances constrain the selection of preferred resources and conditions in the initial habitat selection. Over time, I expect the effect of human disturbances on the elephant to decrease, shifting the influence of factors in habitat selection. Therefore, the effect of constraining factors in limiting the use of preferred resources and conditions decreases. These preferred resources and conditions would include water, high vegetation cover and low slopes.

2 MATERIALS AND METHODS

2.1 Study area

This study occurred in DGR from October 2011, when the elephants were released from the boma, to July 2013. DGR, situated in north-east Gauteng and southern Limpopo, is 185 km^2 (Dinokeng 2013). The elephants were translocated from Makalali Game Reserve, which is approximately 350km away (AfriGIS 2013). DGR is fenced; therefore, the movements of the elephants were limited to the reserve.

The area is part of the Savanna Biome (Mucina & Rutherford 2006) and contains three vegetation units: Springbokvlakte Thornveld in the northern part, Central Sandy Bushveld in the southern part and Loskop Mountain Bushveld in the south-east (Contour Project Managers 2009). Springbokvlakte Thornveld occurs on plains and is predominantly made up of *Acacia* species in low thorn savanna or shrubby grasslands (Mucina & Rutherford 2006). Central Sandy Bushveld occurs in low areas and is made up woodlands of *Terminalia sericea* and *Burkea Africana* on deep sandy soils, and *Combretum* on shallow rocky or gravelly soils (Mucina & Rutherford 2006). Loskop Mountain Bushveld occurs on low mountains and is made up of open tree savanna, broad-leaved tree savanna and grasses (Mucina & Rutherford 2006). These vegetation units have summer rainfall (Mucina & Rutherford 2006).

The study period included two wet seasons (November-March) and two dry seasons (April-October). I classified these seasons after assessing the mean monthly precipitation distributions of the three vegetation units, and found that there was a sharp decrease in precipitation in April, and a sharp increase in precipitation in November (Mucina & Rutherford 2006).

2.2 Data collection

I used data from a female elephant in the herd that was fitted with a satellite collar for elephant (ELS201), manufactured by Africa Wildlife Tracking, by DGR in 2011. This collar captured the Global Positioning System (GPS) coordinates (longitude, latitude) of the elephant on an hourly basis. There were some days where no data were captured or that had a few hours missing as a result of the GPS not being able to send data. The specific dates are listed in the appendix.

I did an exploration analysis and developed a habitat model using ArcMap 10.1 (ESRI 2012). The geographic coordinate system that used was the World Geodetic System 1984 (WGS84). The projected coordinate system used was the Universal Transverse Mercator (UTM) zone 35S. Vegetation greenness was represented by Moderate Resolution Image Spectrometer (MODIS) NDVI imagery, which had a temporal resolution of 16 days and a spatial resolution of 250 m. To represent elevation, a Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) was used, which had a spatial resolution of 90 m. Shapefiles, compiled for the environmental management plan at DGR by Contour Project Managers, of rivers, dams, fence boundaries, roads and buildings used for the habitat model. Rivers and dams included all permanent water sources in DGR. Fence boundaries included the fences of the boundaries of DGR and the fences of any enclosed areas within DGR. Roads included any roads within DGR Buildings included any tourism facility or residence within DGR.

2.3 Data analysis

To investigate how elephants explored and used habitats, two scales of analysis were used: 16-day periods (fine scale) and seasonal periods (broad scale). The time period of 16 days was selected because this coincided with the temporal resolution of the NDVI imagery. There were 36 16-day study periods, referred to as P1 through to P36. The dates of these periods can be seen in the appendix. The four seasonal periods, which were defined as described in section 2.1, are referred to as the first wet season (W1), the first dry season (D1), the second wet season (W2) and the second dry season (D2).

The testing of autocorrelation is becoming an increasingly important aspect of telemetry studies, because it increases the occurrence of type I errors (Aarts *et al.* 2008; Dormann *et al.* 2007; Hawkins 2011). However, in home range analyses with a constant sampling interval, the elimination of autocorrelation through subsampling can result in the underestimation of home ranges (de Solla, Bonduriansky & Brooks

1999; Rooney, Wolfe & Hayden 1998). In regression modeling, spatial autocorrelation of residuals may result in underestimated standard errors and overestimated significance (Aarts *et al.* 2008; Dormann *et al.* 2007; Hawkins 2011). Spatial autocorrelation was not eliminated for the exploration analysis, which had a constant sampling interval, to avoid underestimation of the home ranges. For the habitat model, the effect of spatial autocorrelation was tested, which is discussed in more detail with the habitat model calculations.

To determine the extent of the elephant's exploration over time, I calculated the daily movement distances. An increased daily movement distance was taken as an indication of increased exploration. Conversely, a decrease was taken as an indication that the elephants were remaining in a localised area. To ensure that exploration was taking place and not just large movements in the same area or movements towards water sources, I plotted movement paths. These were generated in ArcMap 10.1 (ESRI 2012), and used to judge whether the elephant's movements towards new areas were only in response to water sources. The daily movement distance was calculated by determining the step length between coordinates, and then summing the distance moved per day. The "adehabitatLT" package (Calenge 2006) was used in R (R Development Core Team 2013) to calculate the step lengths. The daily movement distance was then averaged over the 16-day and seasonal periods. Summary statistics (mean, median, standard deviation, maximum and minimum) of the daily movement distance per 16-day and seasonal period were calculated and graphed as boxplots using the "boxplot" function in R (R Development Core Team 2013).

Home ranges were generated to determine whether the movements that were assessed using the daily movement distance, were resulting in an increase in the elephant's home range. A home range was generated for each 16-day period and seasonal period. The home ranges were generated using the "T-LoCoh" package (Lyons, Getz & R Development Core Team 2013) in R (R Development Core Team 2013). T-LoCoH is based on LoCoH, which constructs a home range by aggregating the MCP hulls around each point (Getz & Wilmers 2004). T-LoCoH allows for timestamps to be incorporated in location points (Lyons, Turner & Getz 2013). The timestamp of each location was not required for the analysis of the home range; therefore, the scaling parameter for time was set to zero in the T-LoCoh home range calculation. To construct local hulls, a set of nearest neighbours for each point needs to be identified (Lyons, Turner & Getz 2013). I used the adaptive method (a-method), which selects neighbours with a cumulative distance from the root point less than or equal to the value of "a" (Getz *et al.* 2007). A range of "a" values were tested, from 1000 to 8000. "a" was set at 6500, which best filled the holes in the home range areas . The home range was separated into core home range (50%) and total home range (95%), and mapped in ArcMap 10.1 (ESRI 2012). I compared home ranges to determine whether the area of the home range was increasing, which was taken as evidence of increased exploration.

I used a cumulative average home range approach to determine whether the elephants were settling in their new environment by testing whether the home range size was increasing over time or if it became constant. For the first cumulative average home range, a home range was generated for the first period. The second cumulative average home range included the coordinates from the first study period and the second study period. Therefore, for each home range generated, the coordinates from that study period and the previous study periods were added. I calculated the percentage change to determine whether the cumulative average home range was increasing, or reaching a constant size. Settling was indicated by a decrease in the percentage change.

I used logistic regression to calculate the probability of the elephants selecting a habitat characterized by various resources and conditions (Manly *et al.* 2002). The response variable was whether available resource units were used. The explanatory variables included nearest distance to water sources, nearest distance to fence boundaries, nearest distance to roads, nearest distance to buildings, elevation and NDVI (Table 1). The correlation between the explanatory variables was tested using the "cor" function in R (R Development Core Team 2013), to ensure that multicollinearity did not affect the variances of the parameter estimates to a degree that would affect the biological interpretation of the results (Aarts *et al.* 2008).

Table 1. The range of the explanatory variables used in the habitat model for an African elephant (*Loxodonta africana)* in Dinokeng Game Reserve.

Variable	**Range**
Distance to water sources	0.000-3903.167 m
Distance to fence boundaries	0.000-1718.973 m
Distance to roads	0.013-1644.266 m
Distance to buildings	0.000-3742.067 m
Elevation	1048.000-1327.000 m
NDVI	349.000-8881.000

The spatial resolution of the study was set at 90 m for analysis, which coincided with the smallest resolution of the DEM raster cell size. This was done using the "Fishnet" function in ArcMap 10.1 (ESRI 2012). The 250 m NDVI imagery was resampled to a spatial resolution of 90 m. To determine the NDVI for each seasonal period, the resampled 16-day NDVI values were averaged over each season.

I calculated logistic regression models in R (R Development Core Team 2013) using the "glm" function from the "DAAG" package. A separate analysis was conducted for each 16-day and seasonal period. Six models were generated with various hypotheses of the habitat selection of the elephant (Table 2). These models were based on a study of the habitat selection of seven different elephant populations in southern Africa (Roever, van Aarde & Leggett 2012). They include a combination of the factors that are known or suspected to affect elephant habitat selection. These models gave an indication of whether there was a shift in the influence of factors in habitat selection, from human disturbances constraining the selection of preferred resources and conditions in the initial habitat selection, to the use of preferred resources and conditions having the largest influence as the elephant settled in its new environment. These preferred resources and conditions would include water, high NDVI and low elevation.

If spatial autocorrelation is present in regression modeling, the independence of residuals is reduced (Hawkins 2011) and the models may be overfitted (Burnham & Anderson 2002). This can be overcome with the use of methods such as cross-validation to select models that are not overfitted (Aarts *et al.* 2008). I used cross-validation to test the fit of the habitat selection models that were generated using logistic regression. The "cv.glm" function from the "boot" package (Canty & Ripley 2013; Davison &

Hinkley 1997) was used to do this calculation in R (R Development Core Team 2013). I ran a 10-fold cross-validation to determine the cross-validation estimate of prediction error; thereby, assessing the inaccuracies of the model that may have resulted due to spatial autocorrelation.

Table 2. Model category and the associated variables used in the logistic regression models for the habitat selection of an African elephant (*Loxodonta africana)* in Dinokeng Game Reserve.

Category	**Variables**
1) Landscape features	DEM, distance to water
2) Water and food	Distance to water, NDVI
3) Elevation, water and food	DEM, distance to water, NDVI
4) Human factors	Distance to roads, distance to fences, distance to buildings
5) Limiting factors	DEM, distance to water, distance to roads, distance to fences, distance to buildings
6) All	DEM, distance to water, distance to roads, distance to fences, distance to buildings, NDVI

Multimodel inference in the form of model averaging was used to improve prediction. Thereby, inferences could be made from the six models, increasing the information that could be used for the interpretation of the results (Anderson 2008). The “model.avg” function in the “MuMIn” package was used in R (R Development Core Team 2013). The coefficients in the averaged model were compared to determine the most important predictors of habitat selection for the study period. This was done in the form of a confidence interval plot, using the coefficient estimate and the 95% confidence intervals (CI), which were the 2.5% and 97.5% quantiles. I compared the change of the continuous variables over time to determine how the influence on selection changed from release to the end of the study period. When the parameters were negative, it was taken as an indication that the elephant was demonstrating evidence of selecting habitats with a decreased value of that variable. Positive parameters were taken as an indication that the elephant was demonstrating evidence of selecting habitats with an increased value of that variable. When the parameters included zero, it was taken as inconclusive evidence of the effect of that variable on the elephant’s habitat selection.

3 RESULTS

I analysed location data for one female elephant. There were 11 740 GPS locations that were used for the analysis.

3.1 Exploration

For the 16-day periods, the pattern of the elephant's daily movement distance was such that there were periods of increased and decreased daily movement distance (Figure 1). Overall, the average daily movement distance and the range of distance moved per day was increasing for the 16-day and seasonal periods (Figure 1, Figure 2).

Increased daily movement distances were found to often coincide with major movements (Figure 1, Figure 3). The first major movement was observed in P1 (16/10/2011-31/10-2011) after release from the boma, which was in the center of the reserve, when the elephant moved to a localised area in the north-eastern corner of the reserve (Figure 3). Other major movements towards new areas can be seen in P6 (17/01/2012-01/02/2012), P9 (06/04/2012-21/04/2012), P26 (02/02/2013-17/02/2013) and P34 (10/06/2013-25/06/2013). In between these periods, the elephant would move between these areas and areas previously encountered, as seen in P16 (27/07/2012-11/08/2012) and P30 (07/04/2013-22/04/2013). P34 (10/06/2013-25/06/2013) was an exception because the elephant moved in this direction once and did not return there during the study period. Although the elephant would move to new areas, it would always return to the north-eastern corner. In P31 (23/04/2013-08/05/2013) the elephant retracted its movement back into the original corner of the reserve. However, the movement range increased again, demonstrated in P34 (10/06/2013-25/06/2013) and P36 (12/07/2013-27/07/2013). Movements were not presented for the seasonal period because the lines became undistinguishable with the number of location points in a season.

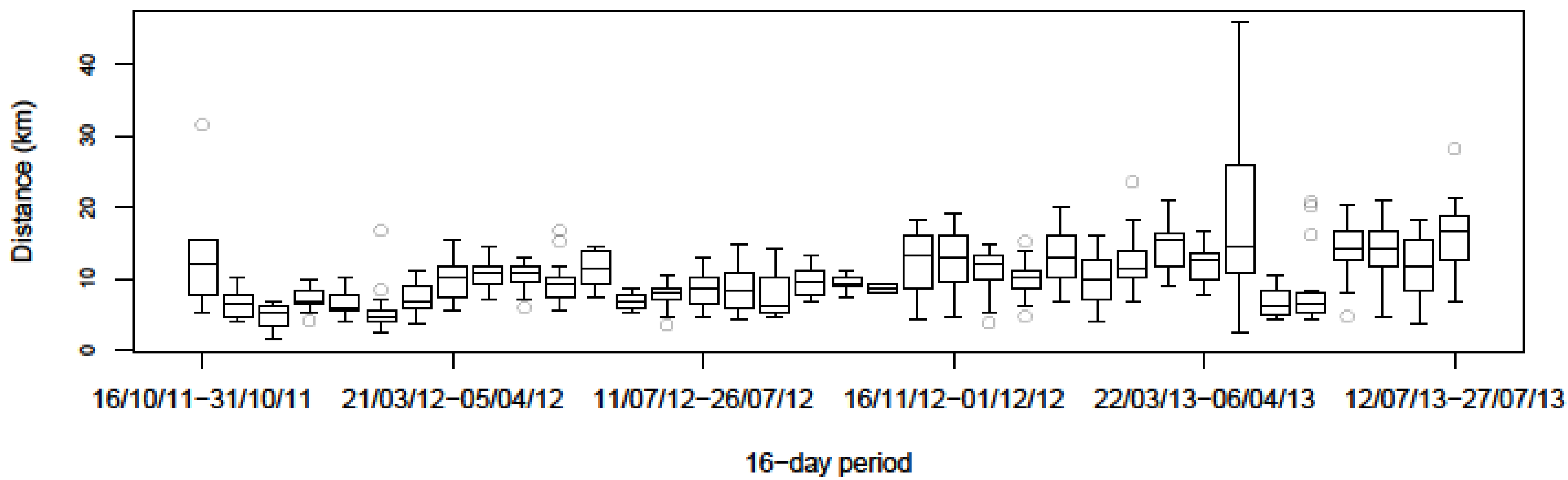


Figure 1. Daily movement distance for 16-day periods (fine scale) for an African elephant *(Loxodonta africana*) in Dinokeng Game Reserve. Cirles represent outliers.

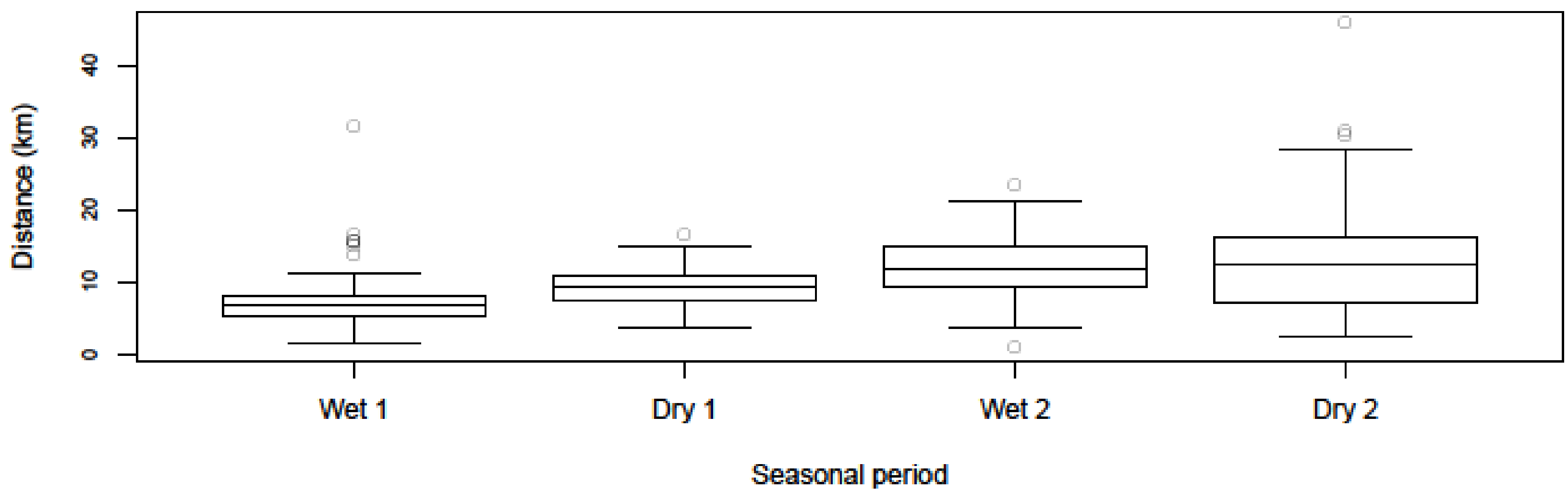


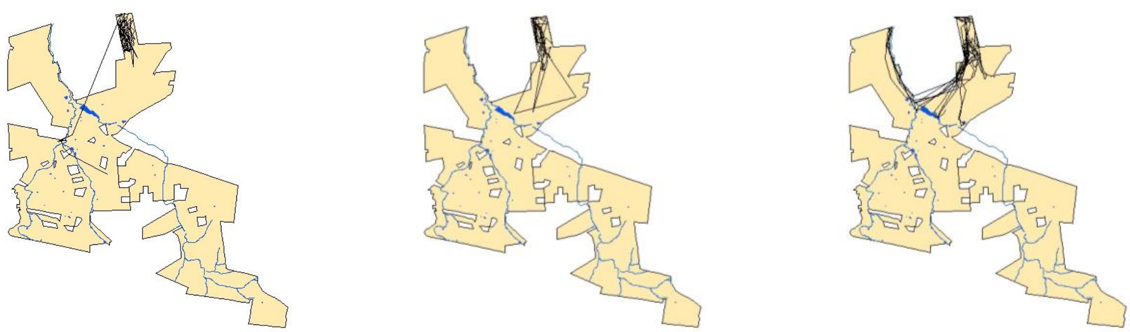
Figure 2. Daily movement distance for seasonal periods (broad scale) for an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve. Cirles represent outliers.

There is an overall increase in the size of the home range areas over the study period (Figure 4). The same pattern that was seen with the daily movement distances (Figure 1) of periods of increase, decrease and again of increase was seen for the home ranges (Figure 4).

An increase in elephant's seasonal period core and total home range was clearly seen within the first 3 seasons after release (Figure 5). However, a decrease in the core and total home range area was seen after the second wet season (Figure 5).

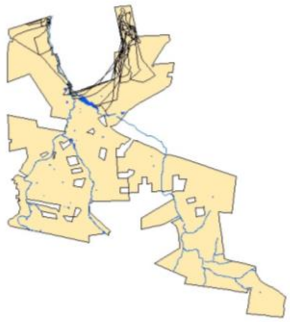
Although the elephant's 16-day period home range demonstrated large fluctuations in size (Figure 4), the elephant's 16-day period cumulative average core and total home range percentage change only showed a substantial increase at the start study period (Figure 6). The percentage change then decreased and approached zero, with the majority of percentage change remaining positive (Figure 6).

The elephant's seasonal period cumulative average core home range percentage change only showed a decrease after the second wet season, whilst the cumulative average total home range percentage change showed a trend of decreasing and approaching zero (Figure 7).

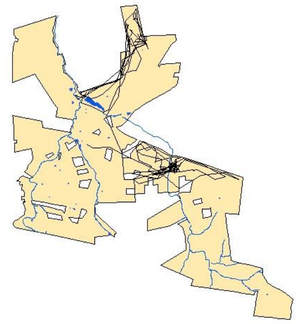


P1 (16/10/2011-31/10-2011) P6 (17/01/2012-01/02/2012) P9 (06/04/2012-21/04/2012)

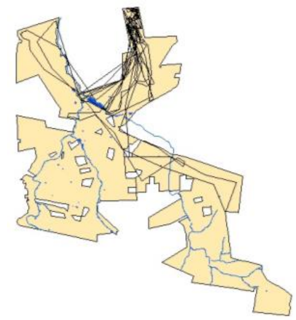
Figure 3. Core (50%) and total (95%) home ranges with lines of movement for 16-day periods (fine scale) of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve.



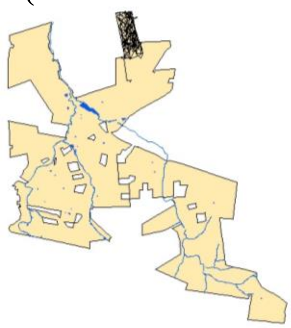
P16 (27/07/2012-11/08/2012)



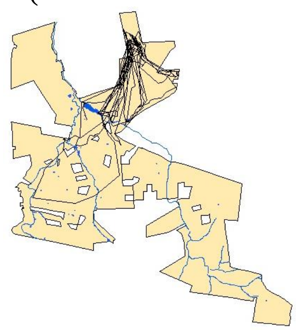
P26 (02/02/2013-17/02/2013)



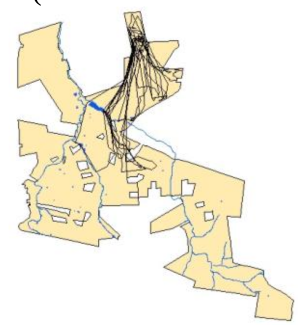
P30 (07/04/2013-22/04/2013)



P31(23/04/2013-08/05/2013)



P34 (10/06/2013-25/06/2013)



P36 (12/07/2013-27/07/2013)

Figure 3. (Continued)

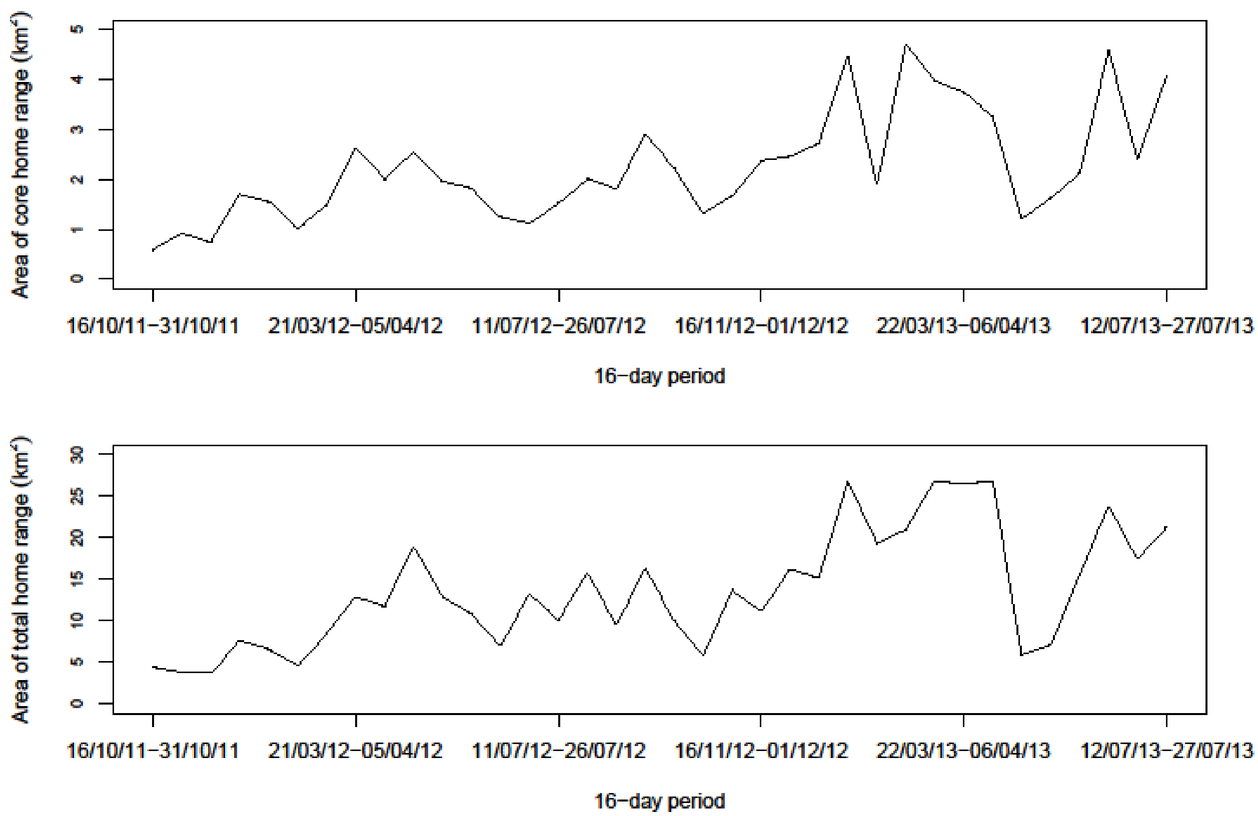


Figure 4. Area of core (50%) and total (95%) 16-day period (fine scale) home ranges of African elephant *(Loxodonta africana)* in Dinokeng Game Reserve.

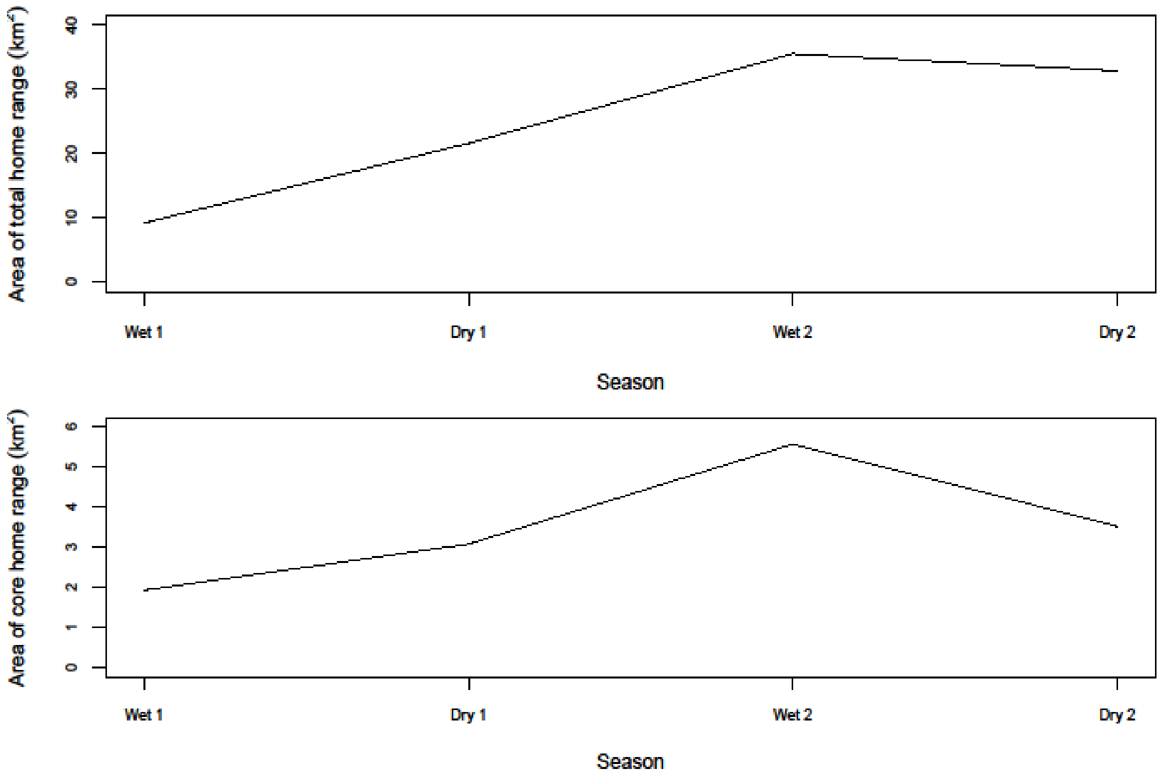


Figure 5. Area of core (50%) and total (95%) seasonal period (broad scale) home ranges of African elephant *(Loxodonta africana*) in Dinokeng Game Reserve.

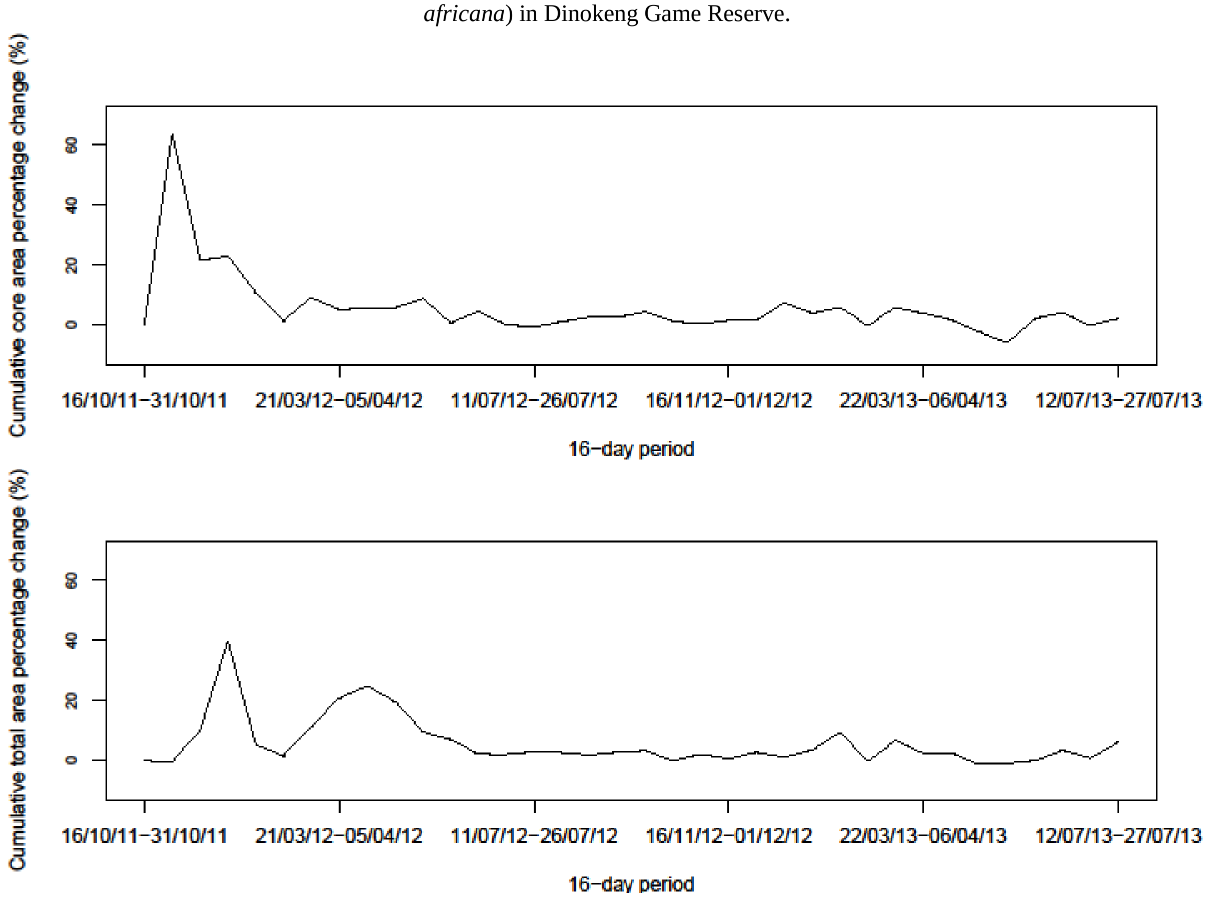


Figure 6. Percentage change of 16-day period (fine scale) cumulative average core (50%) and total (95%) home ranges of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve.

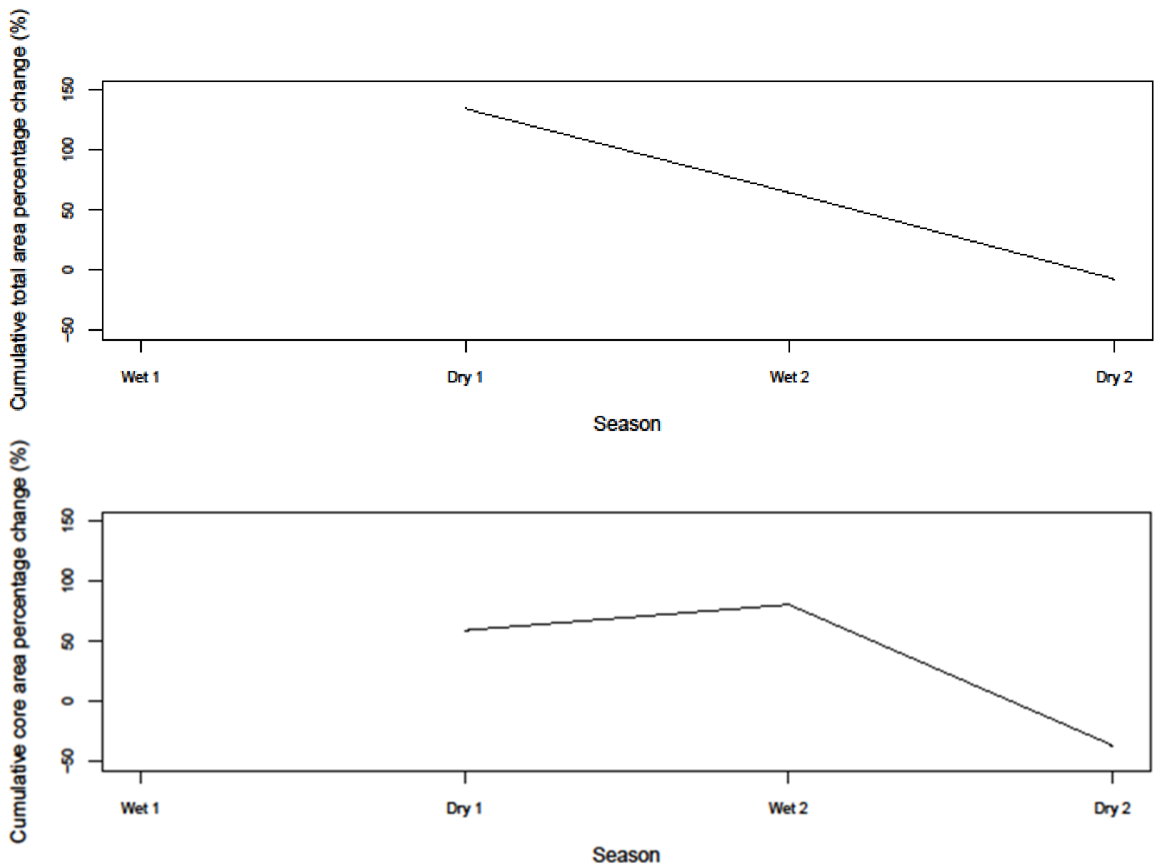


Figure 7. Percentage change of seasonal period (broad scale) cumulative average core (50%) and total (95%) home ranges of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve.

3.2 Habitat selection

For each study period, the final habitat model was an averaged model made up of different weights of the six habitat selection models (Table 2). The variables that were used in the models were tested for correlation and no strong correlation was found between variables (Table 3).

Table 3. Correlation of the explanatory variables used in the habitat model for an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve.

	Distance to water sources	**Distance to fence boundaries**	**Distance to roads**	**Distance to buildings**	**Elevation**	**NDVI**
Distance to water sources		-0.239	0.058	0.276	0.030	-0.086
Distance to fence boundaries	-0.239		0.025	0.097	-0.048	-0.076
Distance to roads	0.058	0.025		0.262	0.207	-0.080
Distance to buildings	0.276	0.097	0.262		0.100	-0.053
Elevation	0.030	-0.048	0.207	0.100		-0.131
NDVI	-0.086	-0.076	-0.080	-0.053	-0.131	

The estimates of prediction error from the 10-fold cross-validation of the six models were very low: less than 1.19% for the 16-day periods and less than 6.2% for the seasonal periods.

During the first period in the 16-day periods, the results demonstrated evidence that the elephant was using habitats closer to water sources (Figure 8). Thereafter, the evidence on the effect of distance to water sources on the elephant's habitat selection fluctuated (Figure 8). The results demonstrated evidence of the elephant using habitats closer to water sources only in the first wet season (Figure 9).

The results demonstrated evidence of the elephant using habitats closer to fence boundaries at the start of the study period; however, after P10 (22/04/2012-07/05/2012) the evidence of selection fluctuated for the rest of the study period, with no specific pattern of selection being demonstrated (Figure 10). During the first wet season, the results demonstrated evidence of selection of habitats closer to fence boundaries, yet after this the results demonstrated weaker evidence of the elephant using habitats further from fence boundaries (Figure 11).

For some of the 16-day periods, the results demonstrated evidence of the elephant using habitats close to roads, but this would be followed by inconclusive evidence of the effect of roads on habitat selection (Figure 12). During the dry seasons, the results demonstrated evidence of selection for habitats further from roads (Figure 13).

The results demonstrated evidence of the elephant using habitats further from buildings at the start of the study period; however, after P10 (22/04/2012-07/05/2012) the evidence fluctuated, with no specific pattern of selection being demonstrated (Figure 14). The results demonstrated evidence of using habitats further from buildings in the first wet season, but this evidence decreased over the time (Figure 15).

For the majority of the 16-day periods, the results demonstrated evidence of the elephant's selection for lower elevation, and this evidence increased over time (Figure 16). For the seasonal periods, all the evidence indicated that the elephant's habitat selection was for lower elevation (Figure 17).

The results demonstrated evidence of the elephant's selection for increased greenness for the majority of the 16-day periods, although there was some fluctuation in the strength of the evidence (Figure 18). During the seasonal periods, the results were demonstrating selection for increased greenness (Figure 19).

The larger confidence intervals seen in P20 (29/09/2012-14/10/2012) is as a result of missing data from October 2012 (Figure 8, Figure 10, Figure 12, Figure 14, Figure 16, Figure 18).

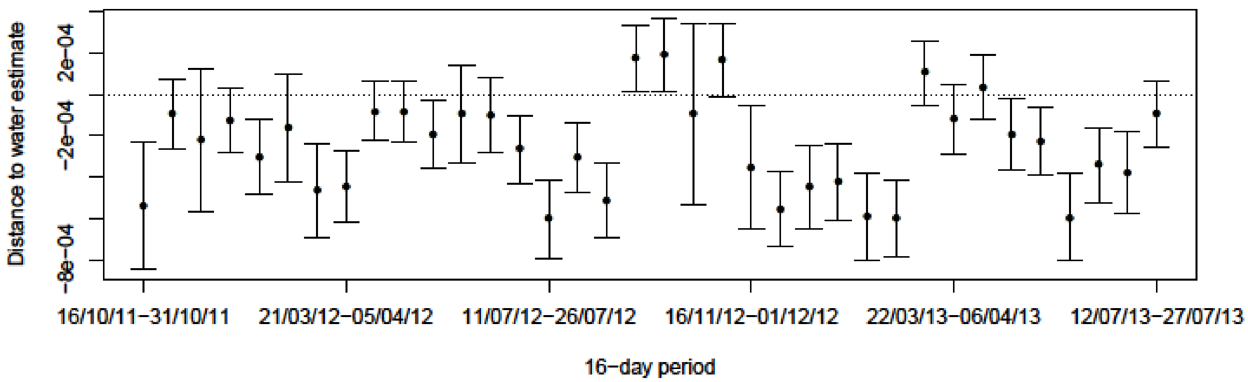


Figure 8. Regression estimates and 95% confidence intervals for selection of distance to water sources for 16-day periods (fine scale) of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve. The horizontal lines represent no selection.

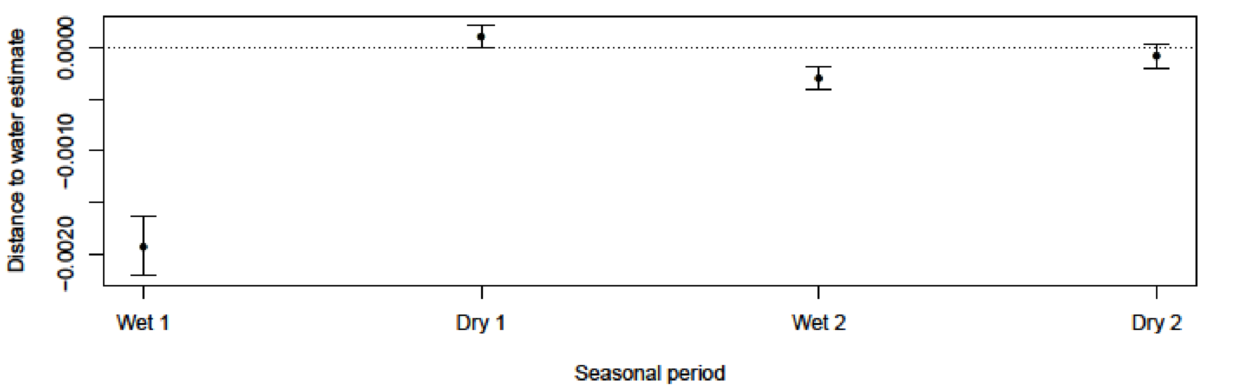


Figure 9. Regression estimates and 95% confidence intervals for selection of distance to water sources for seasonal periods (broad scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

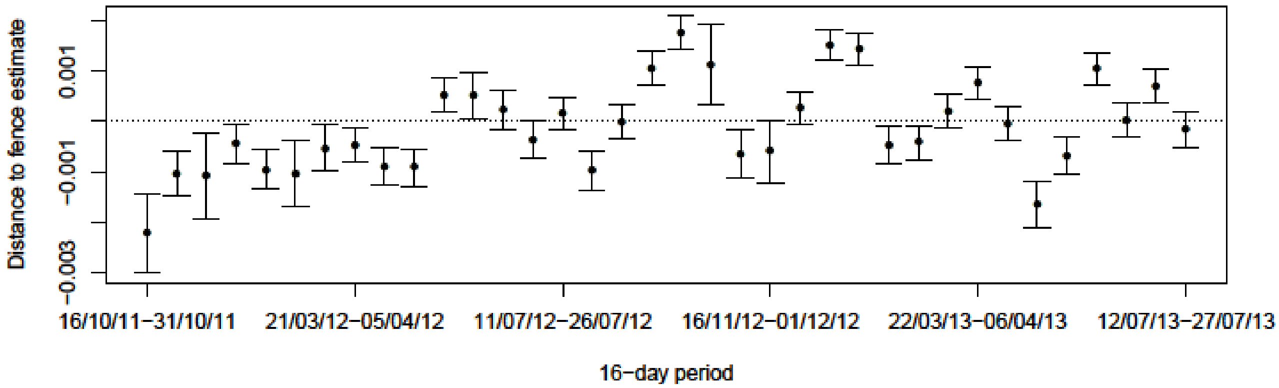


Figure 10. Regression estimates and 95% confidence intervals for selection of distance to fence boundaries for 16-day periods (fine scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

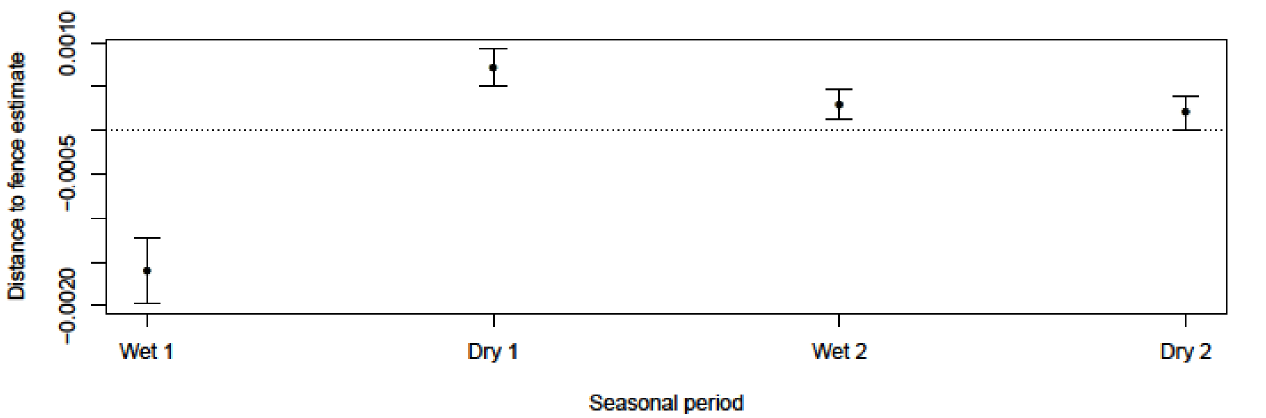


Figure 11. Regression estimates and 95% confidence intervals for selection of distance to fence boundaries for seasonal periods (broad scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

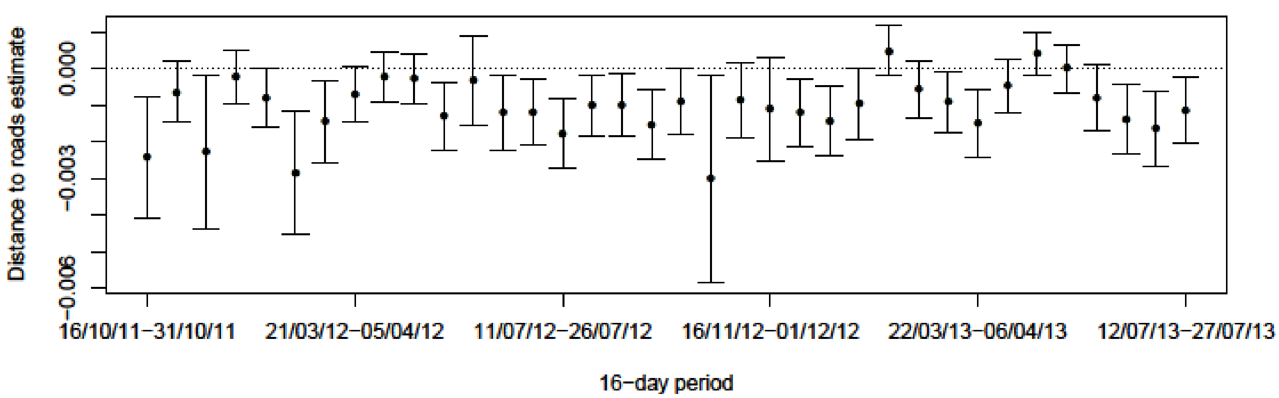


Figure 12. Regression estimates and 95% confidence intervals for selection of distance to roads for 16-day periods (fine scale) of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve. The horizontal lines represent no selection.

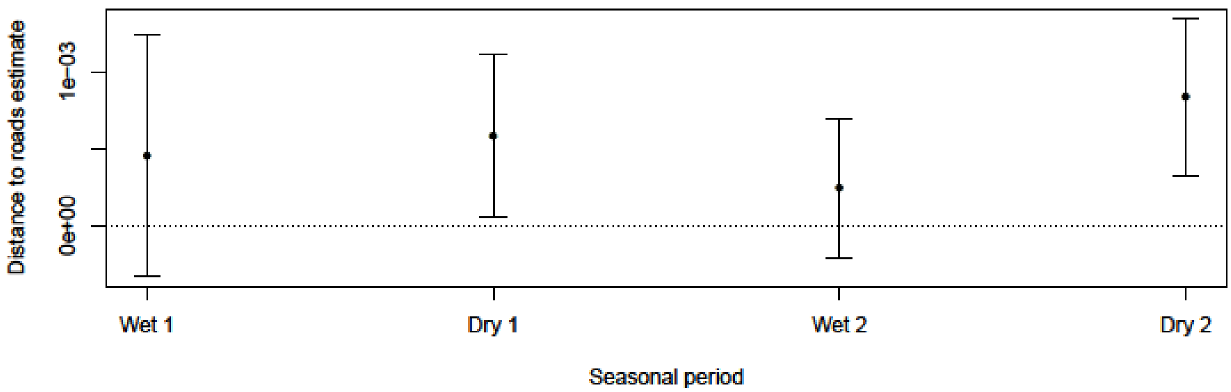


Figure 13. Regression estimates and 95% confidence intervals for selection of distance to roads for seasonal periods (broad scale) of an African elephant *(Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

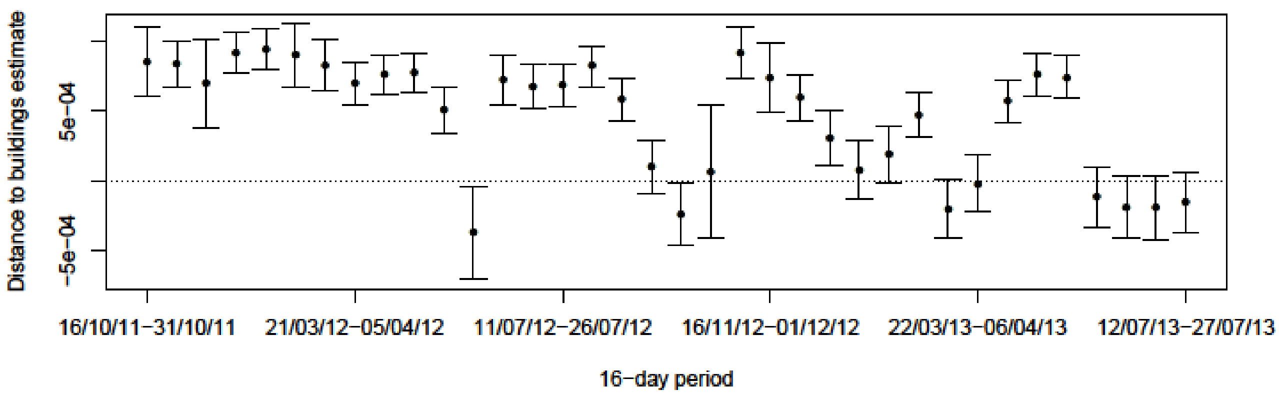


Figure 14. Regression estimates and 95% confidence intervals for selection of distance to buildings for 16-day periods (fine scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

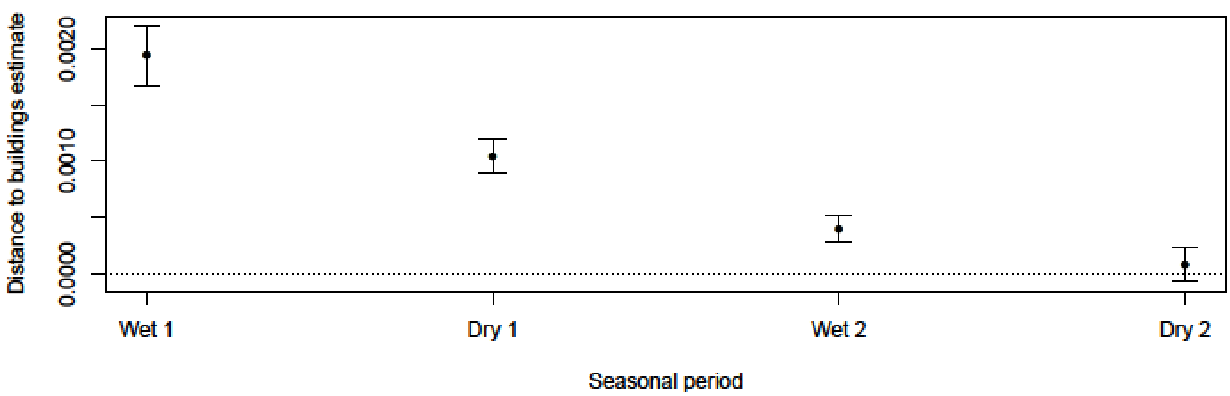


Figure 15. Regression estimates and 95% confidence intervals for selection of distance to buildings for seasonal periods (broad scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

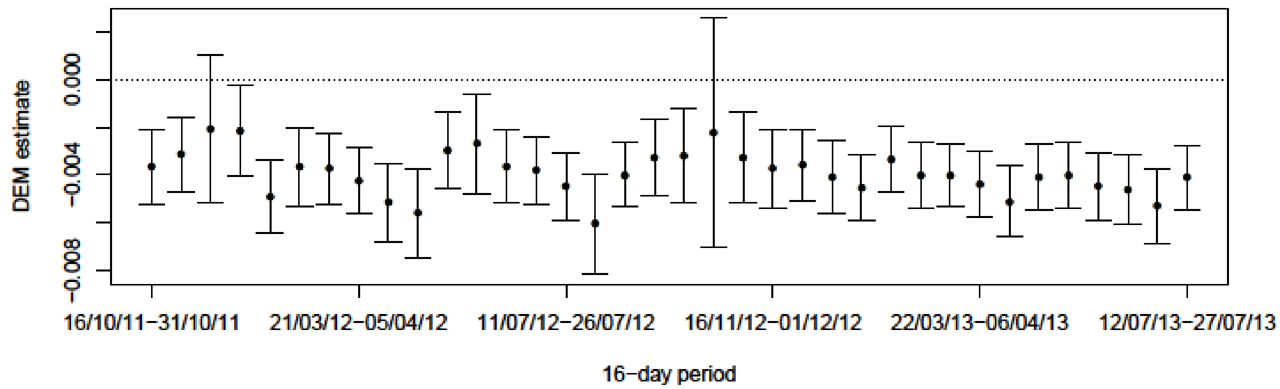


Figure 16. Regression estimates and 95% confidence intervals for selection of elevation (DEM) for 16-day periods (fine scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

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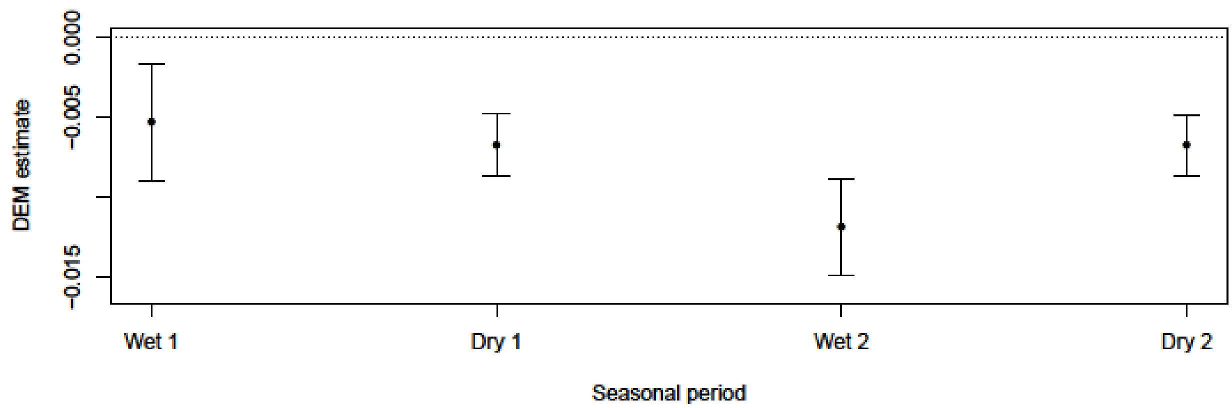

Figure 17. Regression estimates and 95% confidence intervals for selection of elevation (DEM) for seasonal periods (broad scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

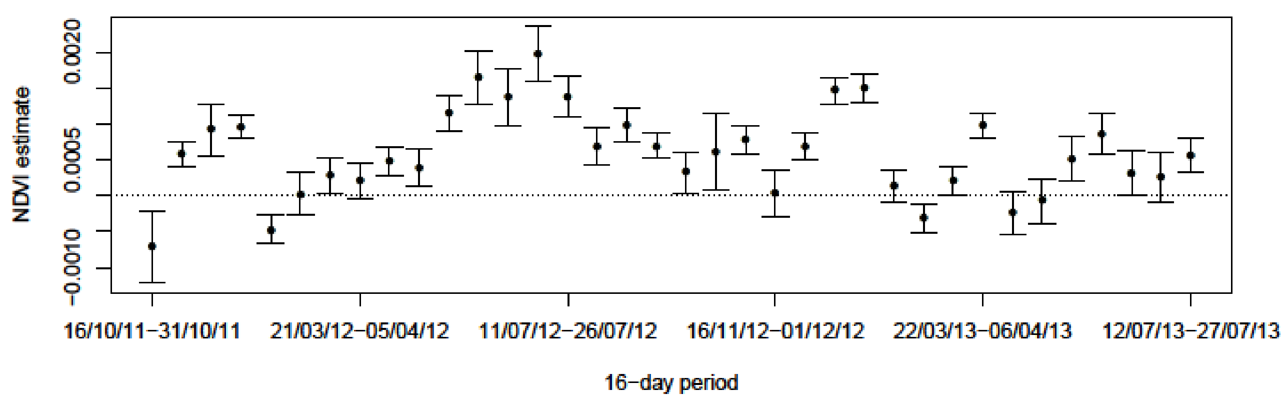

Figure 18. Regression estimates and 95% confidence intervals for selection of greenness (NDVI) for 16-day periods (fine scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

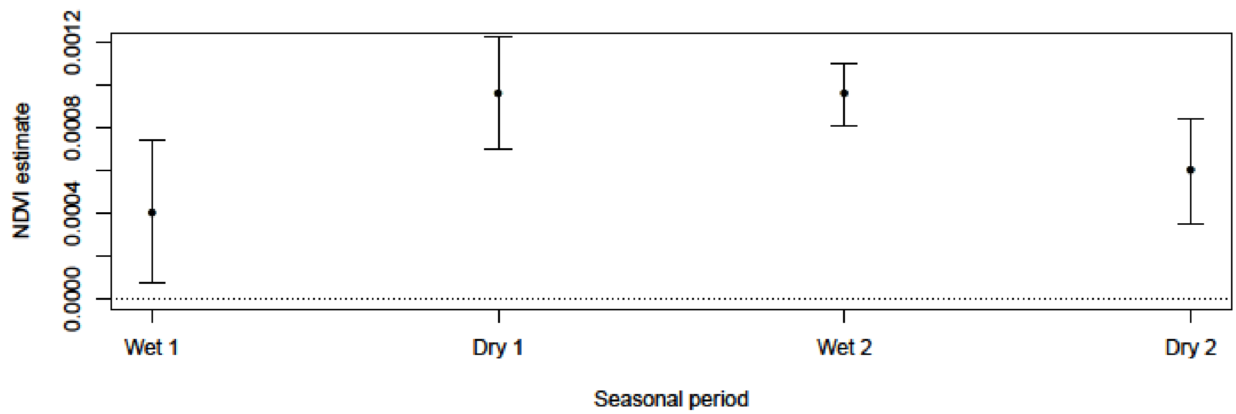

Figure 19. Regression estimates and 95% confidence intervals for selection of greenness (NDVI) for seasonal periods (broad scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve. The horizontal lines represent no selection.

4 DISCUSSION

4.1 Exploration and home range expansion

The first objective of my research was to determine whether the elephant's exploration resulted in an expansion of its home range as the elephant settled in its new environment. The expectations were that the elephant would explore until it found an area with sufficient resources, and then remain in a localised area until it started exploring again to find more resources. This behaviour was expected to continue until the elephant had settled its new environment, resulting in the expansion of its ranging limits.

The results demonstrated that the elephant's daily movement distance and home range size increased over time. Furthermore, towards the end of the study period, the percentage change of the average cumulative home range was moving towards zero.

Over the study period, there was an increase in the daily movement distance for the 16-day and seasonal periods (Figure 1, Figure 2). This was taken as an indication of increased exploration, which supports the expectation that the elephant's exploration would increase over time. At P21 (31/10/2012-15/11/2012) (Figure 3), the elephant's average daily distances had increased to 12.35 km, which is comparable to other elephants' average daily movement distances. Elephants in Rwenzori National Park in Uganda had an average speed of elephant movement was estimated at 0.5 km/h (Wyatt & Eltringham 1974), which corresponds to an average daily movement distance of 12 km.

Movement paths displayed that after release, in P1 (16/10/2011-31/10/2011), the elephant moved to the north-eastern corner of the reserve. It stayed in this area for approximately 3 months before any movement was seen out of the area. This supports the hypotheses that the elephant would remain in a localised area until it started exploring again to find more resources. However, a possible explanation for the elephant's initial movement in a north-easterly direction was that it was homing. Makalali Game Reserve, where the elephant came from, is in a north-east direction from DGR. However, the presence of the fence may have stopped the elephant from continuing back towards its source site. Homing behaviour has been seen in other translocations, such as in Kenya where some elephants moved back to their source site after a minimum of 123 days after release (Pinter-Wollman 2009).

The elephant displayed movements between new areas and its original localised range (Figure 3), which were seen in P6 (17/01/2012-01/02/2012), P9 (06/04/2012-21/04/2012), P26 (02/02/2013-17/02/2013) and P34 (10/06/2013-25/06/2013). These movements were taken as support of the hypotheses that the elephant was exploring new areas, and not just large movements in the same area or movements towards water sources, which is known to affect movement patterns (Boettiger *et al.* 2011; Roever, van Aarde & Leggett 2012). Movements seen in P6 (17/01/2012-01/02/2012) and P9 (06/04/2012-21/04/2012) seemed to have been directed towards water, but P26 (02/02/2013-17/02/2013) and P34 (10/06/2013-25/06/2013) were not. However, it is unlikely that these movements were primarily for water as the elephant would explore the surrounding area, seen in P16 (27/07/2012-11/08/2012), P30 (07/04/2013-22/04/2013) and P36 (12/07/2013-27/07/2013). There were also permanent water sources in the north-eastern corner, making it less likely that these movements were in search of water.

During P30 (07/04/2013-22/04/2013), the movements out of the home range by the collared elephant were seen towards the south-western area of DGR for the first time (Figure 3). This appears to be further support of the expectation of increased exploration by the elephant. However, these movements coincide with the time that bull elephants were released in DGR, on the 13^{th} April 2013. In the period following the release of the bulls, the collared elephant retracted its home range back to the north-eastern corner; therefore, these movements were not as a result of exploration. The retraction of the home range suggests that this corner is a secure refuge for the elephant. The daily distance moved in P31 (23/04/2013-08/05/2013) dropped to a similar range seen in P2 (01/11/2011-16/11/2011), further demonstrating that the elephant was unsettled by the new bulls. Exaggerated bunching behaviour is often an indication of stress (Dublin & Niskanen 2003); therefore, the effect of stress on elephants' behaviour after a translocation should be investigated in future.

The translocated elephant's home range size increased and decreased over time, but demonstrated an overall increase in the core and total home range at both scales of analysis, with some fluctuation in size being seen over the study period (Figure 4, Figure 5). The home range in P1(16/10/2011-31/10-2011) was very small, with a core and total range of 0.58 km^2 and 4.42 km^2, respectively. However, by the end of P36 (12/07/2013-27/07/2013), the core range increased to 4.09 km^2 and the total range increased to 21.31 km^2. The fluctuations in the size of the home range give support to the expectation that the elephant would explore, remain in a localised area and then explore again to find more resources. The overall increase in the home range size supports the expectation that the exploratory movements taking place resulted in an expansion of the home range.

The increasing and decreasing of the elephant's home range over time was most likely due to elephant habitat use not being spatially uniform (Dublin & Niskanen 2003). Similar patterns were seen in PNP, where translocated male elephants would explore and then stay in a local area for a period of time, walk round, and then again stay in a local area for a period of time (Slotow & van Dyk 2004). Therefore, depending on when the elephant was moving and staying in a local area, this is likely the cause of some of the fluctuations observed.

The elephant’s range is small compared to other small reserves. Translocated bull elephants in PNP, which is 500 km^2, had an average core range of 8.4 km^2 and total home range of 99.7 km^2 (Slotow & van Dyk 2004). At the start of the study there were 93 elephants in PNP (Slotow & van Dyk 2004). In Addo Elephant National Park, where elephants are restricted to 103 km^2, female elephants home ranges varied between 8-21 km^2 for the core range, and 36-74 km^2 for the total range (Whitehouse & Schoeman 2003). In Addo, there were 324 elephants at the start of the study (Whitehouse & Schoeman 2003). The sizes of the home ranges in DGR are smaller than both of these other reserves. Before the introduction of the bull elephants, there were no other elephants in the reserve that would have restricted home range establishment. Even so, the elephant did not explore the whole reserve when establishing its home range.

Although the home ranges are small, it is likely that there are enough resources in these areas to sustain the elephant. It has been found that smaller home ranges are associated with more resources (Grainger, van Aarde & Whyte 2005; Whitehouse & Schoeman 2003). Water is not scarce in DGR, with all locations being within 4km of either the river or a dam. Abundant water sources in PNP are assumed to be the cause of small daily movement distances and small home ranges of translocated elephants (Slotow & van Dyk 2004) , which may also be the case in DGR.

The percentage change of the cumulative average of the 16-day and seasonal periods were approaching zero (Figure 6, Figure 7), indicating that the elephant was starting to settle in its core and total home range. There was still a small amount of expansion in the total 16-day period home range, indicating that there were small amounts of exploration taking place. It was expected that the elephant would explore until it had settled in its home range, which seems to have been taking place. Therefore, after almost 2 years, the elephant had not yet completely settled in the reserve. Other species have also demonstrated long periods before settlement took place. Alpine ibex *(Capra ibex)* that were translocated to the Marmolada massif group in the Eastern Italian Alps took three years before they became socially assimilated (Scillitani *et al.* 2013). Therefore, translocation studies should be longer than one year (Pinter-Wollman 2009; Roy *et al.* 2010). (e.g. Pinter-Wollman 2009; Roy et al. 2010).

4.2 Change in use of resources and conditions

The second objective of my research was to determine how the use of resources and conditions in an elephant's environment changed from release to the end of the study period. The expectations were that after release from the boma, factors associated with human disturbances would constrain the selection of preferred resources and conditions in the initial habitat selection. Over time, I expected the effect of constraining factors in limiting the use of preferred resources and conditions to decrease. These preferred resources and conditions would include water, high vegetation cover and low slopes.

In terms of the elephant's habitat selection, there was evidence that selection shifted over time for distance to water sources, distance to fence boundaries, distance to buildings and elevation.

Only in the first wet season did the elephant show a preference of using habitats closer to water. For the 16-day periods, the elephant seemed to predominantly use habitats nearer to water. Therefore, after the first wet season, the distance to water sources was not a limiting factor in the elephant's habitat selection. In terms of water, the elephant's habitat selection was not constrained by human disturbances as expected. This is likely due to DGR having abundant water sources.

At the start of the 16-day periods and in the first wet season, the elephant seemed to be using habitats closer to fence boundaries; however thereafter there was a shift with no particular pattern of selection being seen. This corresponds to the movements seen against the fence after release from the boma (Figure 3). Therefore, this supports the expectation that there would be a shift in the factors related to human disturbances. However, the elephant did not seem to be negatively affected by the fence and avoid it, as was expected. This may have been as a result of the nearest distance to a fence being too close to pick up a particular movement pattern, or the elephant's movement was not really affected by the fence. Elephants in PNP were affected by fences, and displayed increased daily travel distances when moving in areas near fences (Vanak, Thaker & Slotow 2010). Fences seemed to have no effect on the natural behaviour of lions *(Panthera leo)*, leopards *(Panthera pardus)* and hyaenas *(Crocuta crocuta)* that were reintroduced to Addo Elephant National Park (Hayward *et al.* 2009).

The elephant did not seem to be specifically using habitats close to or far from roads. It was expected that the elephant would initially avoid roads in an attempt to avoid humans. Elephants' responses to roads vary, especially in areas where roads are near water sources (Pinter-Wollman 2009; Roever, van Aarde & Leggett 2012). Elephants in the Kruger National Park (KNP) have a concentrated vegetation impact along roads (Coetzee *et al.* 1979), indicating that some elephants show a preference to use habitats along roads . Varied responses to roads have been demonstrated in other species, such as elk (*Cervus elaphus nelsoni*) in Wisconsin, which avoided areas near roads when establishing their home range (Anderson *et al.* 2005). However, after establishment, roads within their home range were not avoided (Anderson *et al.* 2005).

The elephant was using habitats further from buildings at the start of the study period for both scales of analysis. However, a shift in DGR's elephant's preferences was seen over time as it no longer seemed to be avoiding human settlements. This supports the hypothesis that the elephant was being constrained in its initial habitat selection by avoiding human settlements. An avoidance of human settlements has been seen in elephants in Etosha National Park (Namibia), Tembe Elephant Park (South Africa) and Maputo Elephant Reserve (Mozambique), which tended to avoid human settlements, with cows remaining 5km or further away from settlements (Harris *et al.* 2008).

For the 16-day and seasonal periods, there was evidence that habitats with lower elevation were being used. For the 16-day periods, the evidence increased over time for the elephant using habitats with lower elevation. Therefore, the elephant may have been constrained in its initial habitat selection from using habitats with lower elevation, which may have been as a result of the elephant avoiding human settlements. This result is comparable to other studies where elephants have shown a preference for lower elevation. (Roever, van Aarde & Leggett 2012; Wall, Douglas-Hamilton & Vollrath 2006).

For the 16-day and seasonal periods, there was evidence that the elephant was showing a preference for habitats with higher greenness for the majority of the study period. Therefore, the elephant did not seem to be constrained in its habitat use in terms of greenness. Elephants in KNP showed a preference for intermediate or high levels of greenness at a seasonal scale (Marshal *et al.* 2011).

It has been suggested that elephants use habitats with high greenness in response to their preferred structural vegetation, such as woody vegetation, and not necessarily food availability (Young, Ferriera & van Aarde 2009). Understanding the translocated elephant's response to NDVI is limited, because the contributions of trees and grass to greenness are required to for the full interpretation of the relationship between habitat selection and NDVI (Marshal *et al.* 2011). Therefore, the results of the NDVI may be further influenced by the elephant's vegetation preference. In future studies, the influence of vegetation units on elephants' habitat selection should be investigated.

The studies that have been done on elephant translocations focus on spatial behaviour after release. Only one study (Slotow & van Dyk 2004) has focused on how the home ranges have changed during various times in the study period. Habitat selection of translocated elephants from release to settlement still requires more research. Therefore, this study provides more information on the exploration, home ranges and habitat selection of a translocated elephant as it settled into its new environment. This research will contribute towards better understanding elephant translocations, and improving management actions after the release of translocated elephants.

This study has achieved the aim of contributing to research on translocated elephants by providing information on the exploration, home ranges, settling and habitat selection of a translocated elephant. Although this does contribute towards understanding the behaviour of elephants after a translocation, the value thereof may be limited because only one female elephant was used for the analysis. Although the elephant was part of a herd of 10 elephants in DGR, its behaviour may not be a reflection of the rest of the herd at all times.

5 CONCLUSION

After a translocation to a new environment, there are various factors that affect how elephants explore and use habitats after release and as settling takes place. The elephant at DGR did not explore as expected; however, exploration slowly took place over time. The overall findings demonstrate that it may take longer than a year for an elephant to settle in its new environment. The elephant's habitat selection seemed to be constrained by human settlements in its initial habitat selection; however, it still used habitats with some preferred resources and conditions, such as habitats with low elevation and higher greenness. Over time, the elephant's habitat selection was no longer constrained by human settlements, as it demonstrated stronger evidence of selection for habitats with lower elevation. This shift was taken as an indication that the elephant was exploring, ranking habitats and settling in its new environment. Therefore, the influence of human disturbances on elephants' movement behaviour and habitat selection needs to be considered in the management of translocation programmes. In future translocation studies, the influence of vegetation and stress should be investigated, which may provide further insight into how elephants behave after a translocation.

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7 APPENDIX

Table 4. Dates of no available GPS location data for an African elephant (*Loxodonta africana)* in Dinokeng Game Reserve.

Dates
19-30 November 2011
February 2012
1-10 March 2012
1-12 June 2012
28-31 July 2012
October 2012
25 December 2012
1 February 2013

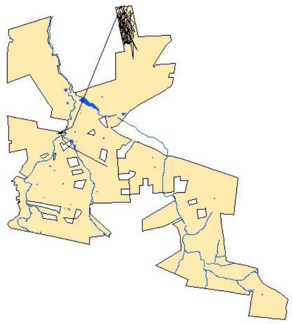
Table 5. Dates of 16-day periods used for analysis of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve.

	Date		
P1	16/10/2011	-	31/10/2011
P2	01/11/2011	-	16/11/2011
P3	17/11/2011	-	02/12/2011
P4	03/12/2011	-	18/12/2011
P5	01/01/2012	-	16/01/2012
P6	17/01/2012	-	01/02/2012
P7	05/03/2012	-	20/03/2012
P8	21/03/2012	-	05/04/2012
P9	06/04/2012	-	21/04/2012
P10	22/04/2012	-	07/05/2012
P11	08/05/2012	-	23/05/2012
P12	24/05/2012	-	08/06/2012
P13	09/06/2012	-	24/06/2012
P14	25/06/2012	-	10/07/2012
P15	11/07/2012	-	26/07/2012
P16	27/07/2012	-	11/08/2012
P17	12/08/2012	-	27/08/2012
P18	28/08/2012	-	12/09/2012
P19	13/09/2012	-	28/09/2012
P20	29/09/2012	-	14/10/2012
P21	31/10/2012	-	15/11/2012
P22	16/11/2012	-	01/12/2012
P23	02/12/2012	-	17/12/2012
P24	01/01/2013	-	16/01/2013
P25	17/01/2013	-	01/02/2013
P26	02/02/2013	-	17/02/2013
P27	18/02/2013	-	05/03/2013
P28	06/03/2013	-	21/03/2013
P29	22/03/2013	-	06/04/2013
P30	07/04/2013	-	22/04/2013
P31	23/04/2013	-	08/05/2013
P32	09/05/2013	-	24/05/2013
P33	25/05/2013	-	09/06/2013
P34	10/06/2013	-	25/06/2013
P35	26/06/2013	-	11/07/2013
P36	12/07/2013	-	27/07/2013

Table 6. Summary statistics of daily movement distance per period of African elephant *(Loxodonta africana)* in Dinokeng Game Reserve.

	Min	**Max**	**Median**	**Mean**	**St. dev.**
P1	5.256	31.598	12.137	14.101	9.499
P2	4.009	10.419	6.473	6.397	1.838
P3	1.571	6.945	5.306	4.607	2.755
P4	4.133	9.996	7.175	7.351	1.549
P5	3.972	10.245	5.826	6.521	1.676
P6	2.449	16.639	4.628	5.559	3.410
P7	3.964	11.247	6.798	7.563	2.627
P8	5.582	15.611	10.290	10.160	3.063
P9	7.190	14.527	10.947	10.671	1.988
P10	5.876	12.914	10.955	10.528	1.929
P11	5.714	16.707	9.228	9.604	2.910
P12	7.521	14.564	11.579	11.493	2.649
P13	5.246	8.842	6.795	6.828	1.154
P14	3.664	10.622	8.090	7.746	1.846
P15	4.745	12.883	8.808	8.549	2.344
P16	4.373	14.843	8.534	8.728	3.188
P17	4.680	14.401	6.301	7.771	3.106
P18	6.866	13.413	9.710	9.773	1.952
P19	7.567	11.327	9.459	9.521	0.944
P20	8.080	9.465	8.773	8.773	0.979
P21	4.506	18.135	13.199	12.350	4.673
P22	4.789	19.120	12.920	12.701	4.109
P23	3.805	14.938	12.074	11.247	3.220
P24	4.660	15.345	10.331	10.156	2.658
P25	6.734	20.226	12.930	13.205	4.087
P26	4.271	15.964	10.072	9.766	3.707
P27	6.773	23.418	11.649	12.446	4.048
P28	8.938	21.128	15.641	14.808	3.305
P29	7.963	16.865	12.580	12.184	2.503
P30	2.645	45.814	14.505	18.015	11.519
P31	4.346	10.454	6.376	6.892	2.121
P32	4.348	20.710	6.703	8.593	5.379
P33	4.628	20.269	14.318	14.095	3.963
P34	4.718	21.029	14.291	14.003	4.555
P35	3.668	18.306	11.951	11.810	4.521
P36	6.753	28.076	16.756	15.784	5.302

W1	1.571	31.598	6.798	7.365	3.677
D1	3.664	16.707	9.241	9.195	2.527
W2	0.835	23.418	11.955	11.897	3.946
D2	2.645	45.814	12.376	12.636	6.647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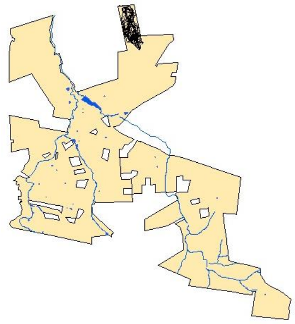
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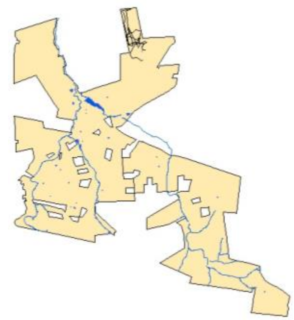
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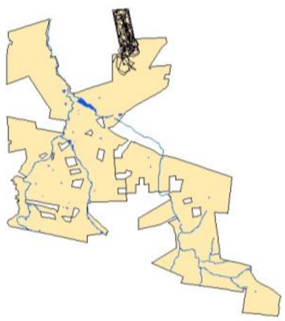
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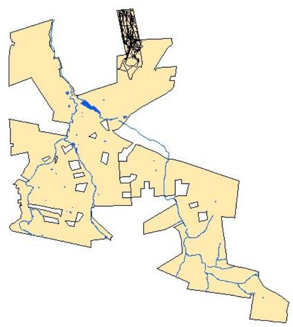
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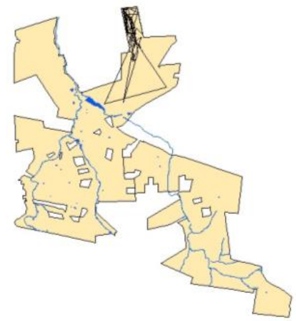
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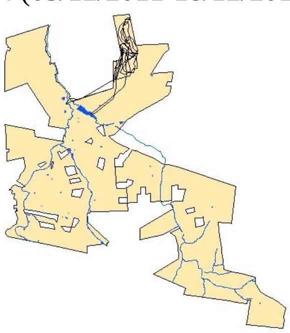
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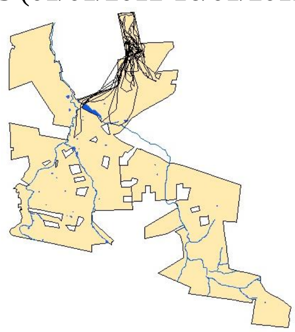
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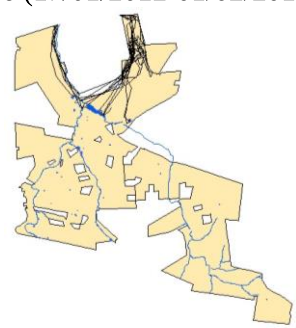
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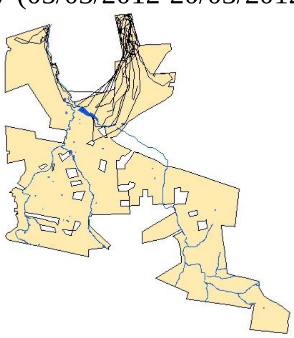
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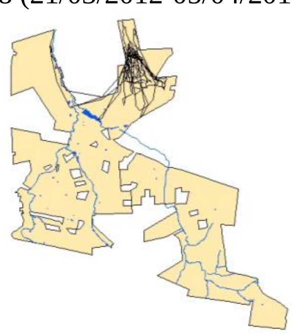
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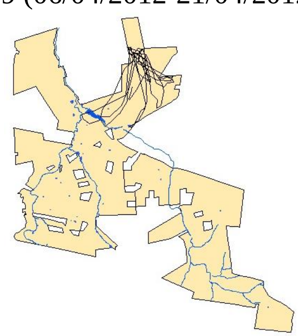
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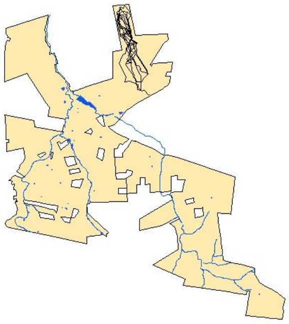

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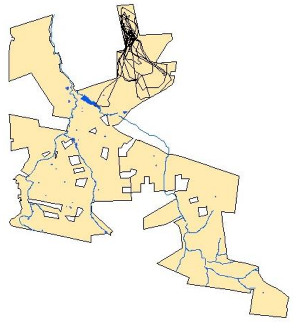

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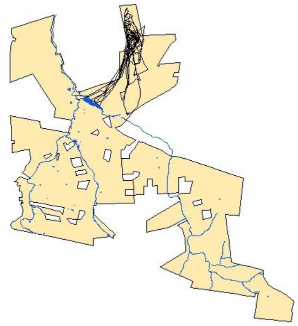

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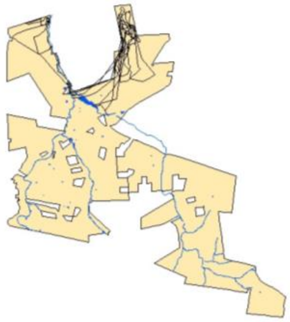

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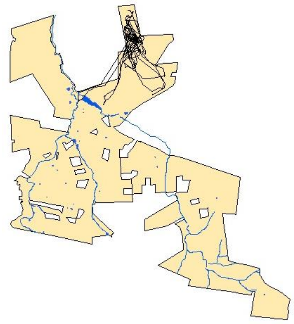

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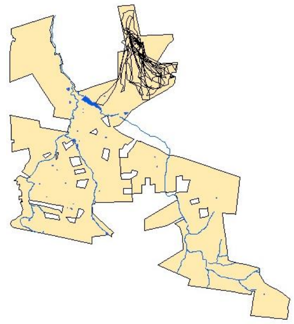

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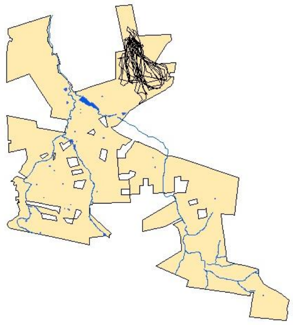

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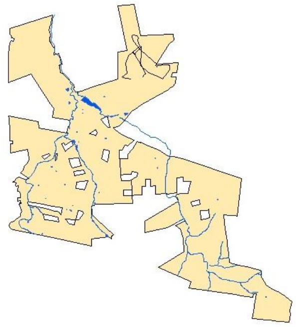

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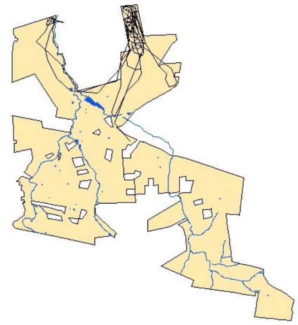

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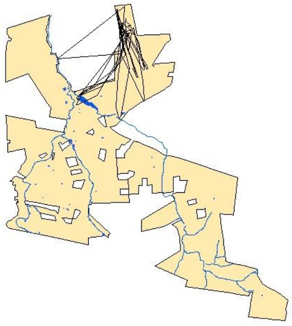

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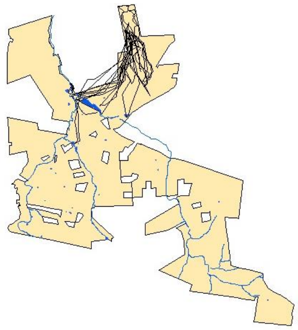

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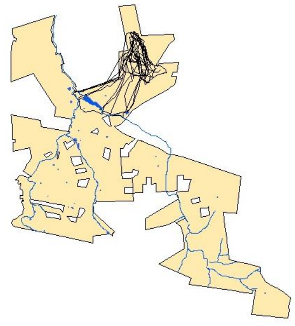

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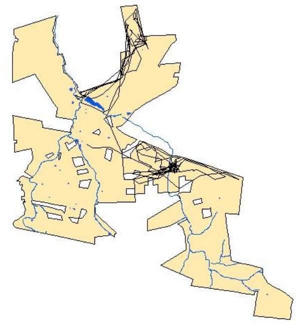
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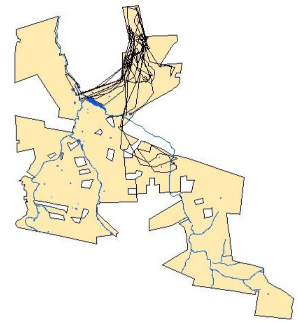
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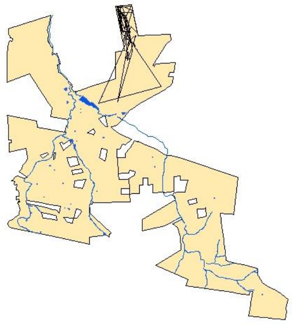
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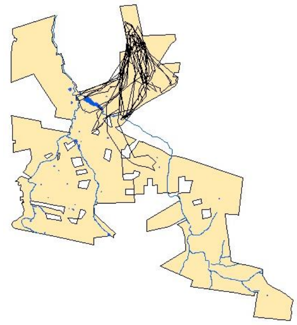
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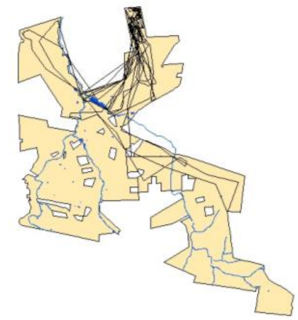
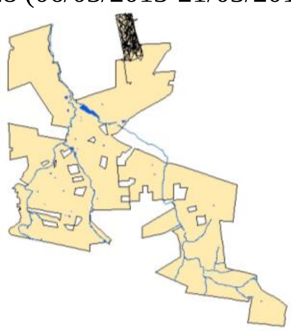
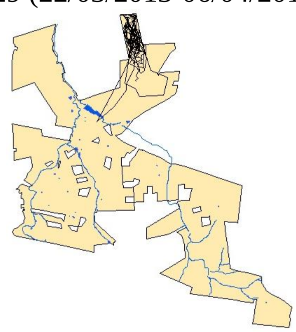
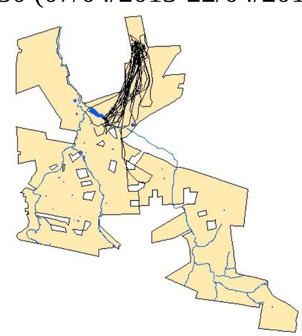
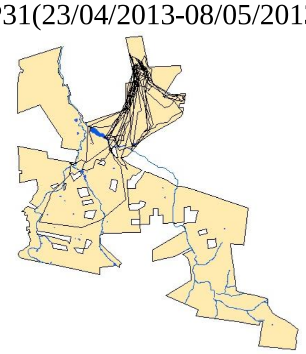
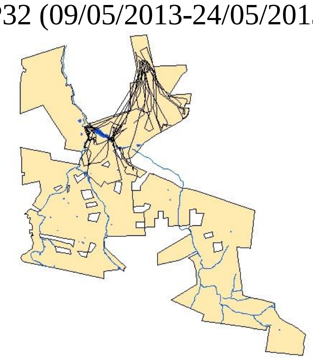

P30 (07/04/2013-22/04/2013)


P31(23/04/2013-08/05/2013)


P32 (09/05/2013-24/05/2013)


P33 (25/05/2013-09/06/2013)


P34 (10/06/2013-25/06/2013)


P35 (26/06/2013-11/07/2013)

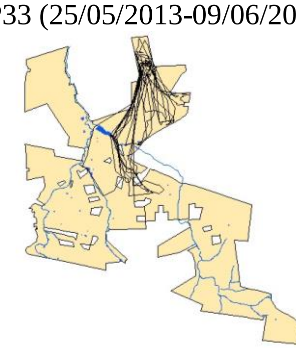

P36 (12/07/2013-27/07/2013)

Figure 20. Core (50%) and total (95%) home ranges with lines of movement for all 16-day periods (fine scale) of an African elephant (*Loxodonta africana*) in Dinokeng Game Reserve.

Table 7. Weights of each model category in the final averaged model representing the habitat selection of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve for each 16-day and seasonal period. Model categories include: landscape features (1), water and food (2), elevation, water and food (3), human factors (4), limiting factors (5) and all (6).

	Model					
	1	**2**	**3**	**4**	**5**	**6**
P1	0.000	0.000	0.000	0.000	0.023	0.977
P2	0.000	0.000	0.000	0.000	0.000	1.000
P3	0.000	0.000	0.000	0.000	0.000	1.000
P4	0.000	0.000	0.000	0.000	0.000	1.000
P5	0.000	0.000	0.000	0.000	0.000	1.000
P6	0.000	0.000	0.000	0.012	0.720	0.268
P7	0.000	0.000	0.000	0.000	0.219	0.781
P8	0.000	0.000	0.000	0.000	0.416	0.584
P9	0.000	0.000	0.000	0.000	0.000	1.000
P10	0.000	0.000	0.000	0.000	0.032	0.968
P11	0.000	0.000	0.000	0.000	0.000	1.000
P12	0.000	0.018	0.079	0.000	0.000	0.903
P13	0.000	0.000	0.000	0.000	0.000	1.000
P14	0.000	0.000	0.000	0.000	0.000	1.000
P15	0.000	0.000	0.000	0.000	0.000	1.000
P16	0.000	0.000	0.000	0.000	0.000	1.000
P17	0.000	0.000	0.000	0.000	0.000	1.000
P18	0.000	0.000	0.000	0.000	0.000	1.000
P19	0.000	0.000	0.000	0.001	0.235	0.765
P20	0.005	0.026	0.015	0.486	0.122	0.347
P21	0.000	0.000	0.000	0.000	0.000	1.000
P22	0.000	0.000	0.000	0.001	0.726	0.273
P23	0.000	0.000	0.000	0.000	0.000	1.000
P24	0.000	0.000	0.000	0.000	0.000	1.000
P25	0.000	0.000	0.000	0.000	0.000	1.000
P26	0.039	0.000	0.029	0.000	0.566	0.366
P27	0.000	0.000	0.000	0.000	0.016	0.984
P28	0.016	0.000	0.018	0.000	0.265	0.700
P29	0.000	0.000	0.000	0.000	0.000	1.000
P30	0.000	0.000	0.000	0.000	0.454	0.546
P31	0.000	0.000	0.000	0.000	0.711	0.289
P32	0.000	0.000	0.000	0.000	0.010	0.990
P33	0.000	0.000	0.000	0.000	0.000	1.000
P34	0.001	0.000	0.004	0.000	0.283	0.712
P35	0.000	0.000	0.000	0.000	0.467	0.533
P36	0.000	0.000	0.025	0.000	0.000	0.974
W1	0.000	0.000	0.000	0.000	0.000	1.000
D1	0.000	0.000	0.000	0.000	0.000	1.000

W2	0.000	0.000	0.000	0.000	0.000	1.000
D2	0.000	0.000	0.000	0.000	0.000	1.000

Table 8. Regression parameters of the averaged logistic regression model for the habitat selection of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve.

	Parameter	**(Intercept)**	**Water**	**Buildings**	**Roads**	**Fences**	**DEM**	**NDVI**
P1	Estimate	1.820	-0.001	0.001	-0.002	-0.002	-0.004	-0.001
	Std. Error	1.352	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.352	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-0.830	-0.001	0.001	-0.004	-0.003	-0.005	-0.001
	95% UCL	4.470	0.000	0.001	-0.001	-0.001	-0.002	0.000
P2	Estimate	-4.143	0.000	0.001	-0.001	-0.001	-0.003	0.001
	Std. Error	1.082	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.082	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-6.263	0.000	0.001	-0.001	-0.001	-0.005	0.000
	95% UCL	-2.023	0.000	0.001	0.000	-0.001	-0.002	0.001
P3	Estimate	-6.831	0.000	0.001	-0.002	-0.001	-0.002	0.001
	Std. Error	2.096	0.000	0.000	0.001	0.000	0.002	0.000
	Adjusted SE	2.096	0.000	0.000	0.001	0.000	0.002	0.000
	95% LCL	-10.939	-0.001	0.000	-0.004	-0.002	-0.005	0.001
	95% UCL	-2.723	0.000	0.001	0.000	0.000	0.001	0.001
P4	Estimate	-7.300	0.000	0.001	0.000	0.000	-0.002	0.001
	Std. Error	1.298	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.298	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-9.844	0.000	0.001	-0.001	-0.001	-0.004	0.001
	95% UCL	-4.756	0.000	0.001	0.000	0.000	0.000	0.001
P5	Estimate	3.665	0.000	0.001	-0.001	-0.001	-0.005	0.000
	Std. Error	1.161	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.161	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	1.389	0.000	0.001	-0.002	-0.001	-0.006	-0.001
	95% UCL	5.941	0.000	0.001	0.000	-0.001	-0.003	0.000
P6	Estimate	-1.412	0.000	0.001	-0.003	-0.001	-0.004	0.000
	Std. Error	1.161	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.161	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-3.687	0.000	0.001	-0.005	-0.002	-0.005	0.000
	95% UCL	0.864	0.000	0.001	-0.001	0.000	-0.002	0.000
P7	Estimate	-1.666	0.000	0.001	-0.001	-0.001	-0.004	0.000
	Std. Error	1.215	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.215	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-4.047	-0.001	0.001	-0.003	-0.001	-0.005	0.000
	95% UCL	0.716	0.000	0.001	0.000	0.000	-0.002	0.001
P8	Estimate	-0.163	0.000	0.001	-0.001	0.000	-0.004	0.000
	Std. Error	1.080	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.080	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-2.279	-0.001	0.001	-0.001	-0.001	-0.006	0.000
	95% UCL	1.953	0.000	0.001	0.000	0.000	-0.003	0.000

P9	Estimate	-1.146	0.000	0.001	0.000	-0.001	-0.005	0.000
	Std. Error	1.145	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.145	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-3.391	0.000	0.001	-0.001	-0.001	-0.007	0.000
	95% UCL	1.099	0.000	0.001	0.000	-0.001	-0.003	0.001
P10	Estimate	-0.034	0.000	0.001	0.000	-0.001	-0.006	0.000
	Std. Error	1.356	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.356	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-2.691	0.000	0.001	-0.001	-0.001	-0.007	0.000
	95% UCL	2.624	0.000	0.001	0.000	-0.001	-0.004	0.001
P11	Estimate	-5.838	0.000	0.001	-0.001	0.001	-0.003	0.001
	Std. Error	1.144	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.144	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-8.080	0.000	0.000	-0.002	0.000	-0.005	0.001
	95% UCL	-3.596	0.000	0.001	0.000	0.001	-0.001	0.001
P12	Estimate	-7.953	0.000	0.000	0.000	0.001	-0.003	0.002
	Std. Error	1.511	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.511	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-10.914	0.000	-0.001	-0.002	0.000	-0.005	0.001
	95% UCL	-4.992	0.000	0.000	0.001	0.001	-0.001	0.002
P13	Estimate	-5.731	0.000	0.001	-0.001	0.000	-0.004	0.001
	Std. Error	1.152	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.152	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-7.989	0.000	0.001	-0.002	0.000	-0.005	0.001
	95% UCL	-3.473	0.000	0.001	0.000	0.001	-0.002	0.002
P14	Estimate	-6.424	0.000	0.001	-0.001	0.000	-0.004	0.002
	Std. Error	1.005	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.005	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-8.394	0.000	0.001	-0.002	-0.001	-0.005	0.002
	95% UCL	-4.454	0.000	0.001	0.000	0.000	-0.002	0.002
P15	Estimate	-3.270	-0.001	0.001	-0.002	0.000	-0.004	0.001
	Std. Error	0.893	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.893	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-5.020	-0.001	0.001	-0.003	0.000	-0.006	0.001
	95% UCL	-1.519	0.000	0.001	-0.001	0.000	-0.003	0.002
P16	Estimate	0.448	0.000	0.001	-0.001	-0.001	-0.006	0.001
	Std. Error	1.244	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.244	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-1.990	0.000	0.001	-0.002	-0.001	-0.008	0.000
	95% UCL	2.887	0.000	0.001	0.000	-0.001	-0.004	0.001
P17	Estimate	-2.486	-0.001	0.001	-0.001	0.000	-0.004	0.001
	Std. Error	0.830	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.831	0.000	0.000	0.000	0.000	0.001	0.000

	95% LCL	-4.113	-0.001	0.000	-0.002	0.000	-0.005	0.001
	95% UCL	-0.858	0.000	0.001	0.000	0.000	-0.003	0.001
P18	Estimate	-3.334	0.000	0.000	-0.002	0.001	-0.003	0.001
	Std. Error	0.955	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.955	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-5.206	0.000	0.000	-0.002	0.001	-0.005	0.001
	95% UCL	-1.462	0.000	0.000	-0.001	0.001	-0.002	0.001
P19	Estimate	-2.746	0.000	0.000	-0.001	0.002	-0.003	0.000
	Std. Error	1.424	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.424	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-5.537	0.000	0.000	-0.002	0.001	-0.005	0.000
	95% UCL	0.045	0.000	0.000	0.000	0.002	-0.001	0.001
P20	Estimate	-6.197	0.000	0.000	-0.003	0.001	-0.002	0.001
	Std. Error	2.385	0.000	0.000	0.001	0.000	0.002	0.000
	Adjusted SE	2.385	0.000	0.000	0.001	0.000	0.002	0.000
	95% LCL	-10.872	-0.001	0.000	-0.006	0.000	-0.007	0.000
	95% UCL	-1.523	0.000	0.001	0.000	0.002	0.003	0.001
P21	Estimate	-6.126	0.000	0.001	-0.001	-0.001	-0.003	0.001
	Std. Error	1.358	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.358	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-8.788	0.000	0.001	-0.002	-0.001	-0.005	0.001
	95% UCL	-3.464	0.000	0.001	0.000	0.000	-0.001	0.001
P22	Estimate	-1.375	0.000	0.001	-0.001	-0.001	-0.004	0.000
	Std. Error	1.065	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.065	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-3.462	-0.001	0.000	-0.003	-0.001	-0.005	0.000
	95% UCL	0.711	0.000	0.001	0.000	0.000	-0.002	0.000
P23	Estimate	-4.370	-0.001	0.001	-0.001	0.000	-0.004	0.001
	Std. Error	1.113	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.113	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-6.551	-0.001	0.000	-0.002	0.000	-0.005	0.000
	95% UCL	-2.189	0.000	0.001	0.000	0.001	-0.002	0.001
P24	Estimate	-8.588	0.000	0.000	-0.001	0.002	-0.004	0.001
	Std. Error	1.016	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.016	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-10.580	-0.001	0.000	-0.002	0.001	-0.006	0.001
	95% UCL	-6.596	0.000	0.001	0.000	0.002	-0.003	0.002
P25	Estimate	-8.156	0.000	0.000	-0.001	0.001	-0.005	0.001
	Std. Error	0.973	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.973	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-10.063	-0.001	0.000	-0.002	0.001	-0.006	0.001
	95% UCL	-6.250	0.000	0.000	0.000	0.002	-0.003	0.002
P26	Estimate	-0.596	-0.001	0.000	0.000	0.000	-0.003	0.000

	Std. Error	0.869	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.869	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-2.299	-0.001	0.000	0.000	-0.001	-0.005	0.000
	95% UCL	1.108	0.000	0.000	0.001	0.000	-0.002	0.000
P27	Estimate	2.080	-0.001	0.000	-0.001	0.000	-0.004	0.000
	Std. Error	0.851	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.851	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	0.413	-0.001	0.000	-0.001	-0.001	-0.005	-0.001
	95% UCL	3.747	0.000	0.001	0.000	0.000	-0.003	0.000
P28	Estimate	-0.600	0.000	0.000	-0.001	0.000	-0.004	0.000
	Std. Error	0.889	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.889	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-2.342	0.000	0.000	-0.002	0.000	-0.005	0.000
	95% UCL	1.143	0.000	0.000	0.000	0.001	-0.003	0.000
P29	Estimate	-4.878	0.000	0.000	-0.001	0.001	-0.004	0.001
	Std. Error	0.935	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.935	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-6.710	0.000	0.000	-0.002	0.000	-0.006	0.001
	95% UCL	-3.045	0.000	0.000	-0.001	0.001	-0.003	0.001
P30	Estimate	1.393	0.000	0.001	0.000	0.000	-0.005	0.000
	Std. Error	1.202	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.203	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-0.964	0.000	0.000	-0.001	0.000	-0.007	-0.001
	95% UCL	3.750	0.000	0.001	0.000	0.000	-0.004	0.000
P31	Estimate	0.048	0.000	0.001	0.000	-0.002	-0.004	0.000
	Std. Error	0.921	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.921	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-1.758	0.000	0.001	0.000	-0.002	-0.005	0.000
	95% UCL	1.854	0.000	0.001	0.001	-0.001	-0.003	0.000
P32	Estimate	-2.696	0.000	0.001	0.000	-0.001	-0.004	0.001
	Std. Error	1.155	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.155	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-4.960	0.000	0.001	-0.001	-0.001	-0.005	0.000
	95% UCL	-0.431	0.000	0.001	0.001	0.000	-0.003	0.001
P33	Estimate	-2.777	-0.001	0.000	-0.001	0.001	-0.004	0.001
	Std. Error	1.014	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.014	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-4.765	-0.001	0.000	-0.002	0.001	-0.006	0.001
	95% UCL	-0.789	0.000	0.000	0.000	0.001	-0.003	0.001

P34	Estimate	0.442	0.000	0.000	-0.001	0.000	-0.005	0.000
	Std. Error	1.054	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.055	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-1.625	-0.001	0.000	-0.002	0.000	-0.006	0.000
	95% UCL	2.509	0.000	0.000	0.000	0.000	-0.003	0.001
P35	Estimate	1.196	0.000	0.000	-0.002	0.001	-0.005	0.000
	Std. Error	1.022	0.000	0.000	0.001	0.000	0.001	0.000
	Adjusted SE	1.022	0.000	0.000	0.001	0.000	0.001	0.000
	95% LCL	-0.808	-0.001	0.000	-0.003	0.000	-0.007	0.000
	95% UCL	3.199	0.000	0.000	-0.001	0.001	-0.004	0.001
P36	Estimate	-1.131	0.000	0.000	-0.001	0.000	-0.004	0.001
	Std. Error	0.828	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.828	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-2.754	0.000	0.000	-0.002	-0.001	-0.005	0.000
	95% UCL	0.491	0.000	0.000	0.000	0.000	-0.003	0.001
W1	Estimate	-1.500	0.000	0.001	0.000	0.000	-0.005	0.001
	Std. Error	1.132	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.132	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-3.719	0.000	0.001	-0.001	-0.001	-0.007	0.001
	95% UCL	0.719	0.000	0.001	0.000	0.000	-0.003	0.001
D1	Estimate	1.047	0.000	0.001	0.000	0.000	-0.009	0.002
	Std. Error	0.976	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.976	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	-0.866	0.000	0.001	-0.001	0.000	-0.010	0.001
	95% UCL	2.961	0.000	0.001	0.000	0.001	-0.007	0.002
W2	Estimate	2.611	0.000	0.000	0.000	0.000	-0.011	0.001
	Std. Error	0.861	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	0.861	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	0.924	0.000	0.000	-0.001	0.000	-0.012	0.001
	95% UCL	4.299	0.000	0.000	0.000	0.001	-0.009	0.001
D2	Estimate	6.578	0.000	0.000	0.000	0.000	-0.012	0.001
	Std. Error	1.004	0.000	0.000	0.000	0.000	0.001	0.000
	Adjusted SE	1.004	0.000	0.000	0.000	0.000	0.001	0.000
	95% LCL	4.611	0.000	0.000	-0.001	0.000	-0.014	0.001
	95% UCL	8.545	0.000	0.000	0.000	0.000	-0.011	0.001

Table 9. Values of the corrected Akaike's Information Criterion for the six model categories that were used for the averaged logistic regression model for the habitat selection of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve for each 16-day and seasonal period. Model categories include: Landscape features (1), water and food (2), elevation, water and food (3), human factors (4), limiting factors (5) and all (6).

	Model					
	1	**2**	**3**	**4**	**5**	**6**
P1	1152.378	1162.954	1150.067	1107.969	1090.913	1083.426
P2	2384.946	2349.508	2341.811	2304.285	2279.851	2242.232
P3	855.488	823.127	823.690	836.499	827.511	805.437
P4	2863.265	2728.708	2727.360	2774.672	2737.320	2604.104
P5	2680.841	2704.724	2676.155	2596.086	2562.590	2543.957
P6	1174.318	1181.510	1175.024	1127.320	1119.093	1121.070
P7	1891.246	1894.845	1882.773	1861.269	1826.125	1823.588
P8	2944.522	2960.124	2936.278	2932.691	2875.112	2874.432
P9	2995.436	3007.959	2970.959	2939.964	2881.394	2864.506
P10	2995.436	3030.338	2984.859	2939.964	2881.394	2874.595
P11	2972.930	2913.634	2905.049	2956.403	2930.252	2861.647
P12	1834.690	1772.033	1769.113	1839.848	1830.927	1764.231
P13	2163.207	2136.931	2124.952	2127.920	2113.402	2073.574
P14	2736.160	2675.231	2653.246	2715.908	2692.416	2600.060
P15	2875.597	2852.045	2824.003	2865.527	2814.409	2757.398
P16	2713.123	2755.540	2700.295	2669.765	2607.185	2591.143
P17	2909.811	2893.482	2872.196	2917.962	2873.920	2832.220
P18	2909.811	2893.482	2872.196	2917.962	2873.920	2832.220
P19	2895.935	2902.559	2894.410	2799.256	2786.957	2784.598
P20	611.770	608.464	609.596	602.582	605.354	603.255
P21	134.633	82.375	77.540	83.310	1762.565	1707.669
P22	1131.842	1141.949	1133.801	1122.090	1109.092	1111.048
P23	2968.025	2934.303	2920.217	2999.275	2926.713	2876.885
P24	2887.144	2716.852	2701.411	2858.740	2814.035	2601.763
P25	2884.189	2742.606	2716.982	2868.775	2827.740	2642.283
P26	2754.003	2767.494	2754.563	2800.590	2748.650	2749.522
P27	3159.845	3180.574	3155.538	3214.786	3139.056	3130.822
P28	3224.515	3251.183	3224.356	3239.122	3218.948	3217.007
P29	3205.306	3137.286	3105.825	3210.039	3180.332	3076.858
P30	2951.332	2991.826	2951.008	2951.138	2909.720	2909.352
P31	2528.512	2552.257	2530.309	2429.076	2400.290	2402.088
P32	2755.846	2770.486	2748.698	2709.104	2676.787	2667.654
P33	2953.225	2953.735	2926.466	2986.255	2918.708	2888.620
P34	3120.932	3158.009	3118.643	3159.406	3110.179	3108.335
P35	2881.560	2927.663	2880.349	2912.060	2855.049	2854.784
P36	3174.029	3185.034	3154.808	3185.912	3162.769	3147.495

W1	6944.003	7053.199	6910.023	6857.778	6651.656	6565.121
D1	11179.758	11067.254	10885.577	11299.712	10935.004	10624.098
W2	11880.034	11772.640	11438.053	12185.920	11745.976	11299.017
D2	10436.267	10662.832	10337.143	10733.706	10413.297	10309.500

Table 10. Estimates of prediction error percentages of each model category representing the habitat selection of an African elephant *(Loxodonta africana)* in Dinokeng Game Reserve for each 16-day and seasonal period. Model categories include: Landscape features (1), water and food (2), elevation, water and food (3), human factors (4), limiting factors (5) and all (6). The a group represents the raw cross-validation result, and the b group represents the result of the adjusted cross-validation, which is adjusted for bias by using the K-fold method and not a leave-one-out method (Canty & Ripley 2013; Davison & Hinkley 1997)

	Model											
	1a	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**
P1	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
P2	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
P3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
P4	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P5	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.010
P6	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
P7	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
P8	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P9	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P10	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P11	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P12	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
P13	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
P14	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P15	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P16	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P17	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.011
P18	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P19	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P20	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
P21	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
P22	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
P23	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P24	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P25	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P26	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P27	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
P28	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
P29	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
P30	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P31	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
P32	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
P33	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
P34	0.012	0.012	0.011	0.011	0.012	0.012	0.011	0.011	0.012	0.012	0.012	0.012
P35	0.011	0.011	0.010	0.010	0.011	0.011	0.010	0.010	0.011	0.011	0.011	0.011
P36	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012

W1	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
D1	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.056	0.056	0.056	0.056
W2	0.061	0.061	0.061	0.061	0.060	0.060	0.062	0.062	0.061	0.061	0.060	0.060
D2	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052